DEPARTMENT FOR INTERNATIONAL DEVELOPMENT
RENEWABLE NATURAL RESOURCES RESEARCH STRATEGY

FINAL TECHNICAL REPORT FOR PROJECT CODE R5179

THE USE OF SWEET POTATO TUBER AND CASSAVA ROOT MEALS FOR POULTRY PRODUCTION: ADAPTIVE RESEARCH ON CEREAL-FREE RATION DEVELOPMENT AND TRANSFER TO SMALL-SCALE FARMERS IN THE WESTERN HIGHLANDS OF CAMEROON

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2. PROJECT FUNDING AND COLLABORATION ARRANGEMENTS

Project title: The use of sweet potato tuber and cassava root meals in poultry diets: adaptive research on cereal-free ration development and transfer to small-scale farmers in the western highlands of Cameroon

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Dr R.T. Fomunyam, Chief of Mankon Research Station, P.O. Box 125, Mankon, Bamenda, North West Province, Cameroon.

International Potato Centre (CIP): (I) Headquarters, at Apartada 5969, Lima, Peru.Tel. 366920; Fax. 359982/351570. Email: 157:CG1043. (ii) Central and West Africa Regional Station, Bambui (20 km from MRS), North West Province, Cameroon.

Note:

1. This project was implemented as a collaborative project under a memorandum of understanding between NRI and IRZV. Thus, whilst the project owes much of its modest success to the funds provided by DFID, the considerable resources in terms of technical manpower and facilities devoted by the IRZV must be recognised. The contribution of CIP in producing a number of sweet potato cultivars, initially from its headquarters in Peru and subsequently from the regional station near the project site were also significant inputs into the project. The strategic research also benefited from the Carnegie Corporation in the form of a three-month Senior Research Fellowship awarded to Professor E.B. Oguntona (College of Animal Science and Livestock Production, The University of Agriculture, P.M.B 2240, Ogun State, Abeokuta, Nigeria) to participate in the NRI Phase 1 studies. It would, therefore, be appropriate to describe this project the product of an international collaborative effort.

2. LPP funded project F0004 in 1992. A sub-component project (F0060) was subsequently established in 1994 to implement field activities. The present report

incorporates, with appropriate modification, the Final Technical Report for the sub-component project submitted by IRZV in November 1996 (RNRRS Final Technical Report, The use of sweet potato tuber and cassava root meals for poultry production in Cameroon, Mankon Research Station Report No 13, August 1996).

3. ACKNOWLEDGEMENTS

This project has been made possible because of dedicated contributions from the following:

IRZV-HQ, Yaounde

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IRZV-MRS, Bamenda

Dr R.T. Fomunyam (Chief of MRS), for efficient management of field activities that made it possible to achieve a great deal of technical work within a small budget.

Dr D.K. Pone (MRS Poultry Nutritionist) and Ms E.N. Fai (MRS Laboratory Scientist) for the research effort, and

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CIP-Bambui

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IRA, Bambui

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Finally, two former NRI scientists deserve mention. First, the project was inspired by the pioneering work of Dr R.D. Cooke on root crops, which encouraged the concept note to be submitted for funding. Second, the author is indebted to Dr W.H. Parr, who in 1983 established NRI's unique environment-controlled poultry houses in Culham (subsequently reproduced in Chatham), and encouraged revisionary research on the potential for using a range of tropical feedstuffs in poultry diets. Without his vision, this project could not have been implemented.

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7. ABBREVIATIONS USED

AME	Apparent Metabolisable Energy
CAIPCIG	Cameroon Agro-industrial Promoters Common Initiative Group. Head office: Opposite WCA Nkwen, P.O. Box 5075, Bamenda.
CAS	Cassava root
CLM	Cassava leaf meal
CGIAR	Consultative Group for International Agricultural Research
CIP	International Potato Centre: Headquarters: Apartado 5969, Lima, Peru. Regional Station: Region V. Afrique Centrale et de Ouest, B.P. 279, Bambui Bamenda, Cameroon
CMFFPB	Cameroon Mutual Fund of Farmers, Peasants and Breeders. BP. 572,
Bamenda,	Mezam Division, North West Province.
CP	Crude protein
CR	Cassava red
CSC	Cottonseed cake
CTCRI	Central Tuber Crops Research Institute, Thiruvananthapurum, Kerala, India
CW	Cassava white
CWA	Catholic Women's Association, Bamenda, Cameroon
CWF	Christian Women's Fellowship, Bamenda, Cameroon
EFU	Efficiency of food utilisation (ration of weight gain: food intake)
FCR	Feed conversion ratio (ratio of food intake: weight gain)
FM	The Family Movement, Bamenda, Cameroon
FSH	Ferrous sulphate heptahydrate
IITA	International Institute for Tropical Agriculture, Ibadan, Nigeria
IRA	Institute for Research in Agricultural Development, Cameroon
IRZV	Institut de Recherces Zootechniques et Veterinaires (Institute of Animal and Veterinary Research), Cameroon
LPP	Livestock Production Programme
MHAZ	Mid and High Altitude Zone
MRS	Mankon Research Station
NRI	Natural Resources Institute, United Kingdom,
NGO	Non-governmental organisation
ODA	Overseas Development Administration, United Kingdom
OUAT	Orissa University of Agriculture and Technology, Bhubaneswar, Orissa, India.
PKC	Palm kernel cake (traditionally-processed)
PPS	Palm pit sediment (traditionally-processed)
PRTC	Presbetarian Rural Training Centre, PO Box 72, Mfonta, Near Bamenda, Cameroon.
RCS	Research Continuity Scheme (of ODA)
RRA	Rapid rural appraisal
SDP	Societe Des Provenderies du Cameroun, Bafoussam, Cameroon
SP	Sweet potato tuber
SPLM	Sweet potato leaf meal
SSA	Sub-Saharan Africa
SSF	Solid-state fermentation
TDF	Total dietary fibre
TRS	TRS Dito Sama Crypto Peerless electric food processor
WPK	Whole palm kernels

8. EXECUTIVE SUMMARY

8.1. Project Concept

1. Maize is a basic staple for millions of humans throughout the developing world, particularly in the countries of sub-Saharan Africa. There is, however, competition for maize from the human food and the livestock feed sectors, which raises the price of the cereal and makes it difficult for the poorest and most vulnerable people to consume. This developmental problem is of particular concern in relation to intensive poultry production systems, in which the ration may comprise maize at up to 70 per cent. It is, therefore, necessary to develop poultry rations devoid of maize and promote their widespread adoption in developing countries.

2. Between 1980 and 1990, NRI conducted considerable ODA-funded strategic research in its environment-controlled poultry houses to evaluate a range of unconventional tropical feeds (mainly, root crops and oilseed processing by-products) for nutritive value, and to improve these raw materials by appropriate processing for use in practical poultry rations. Although research on poultry feeds then assumed a low priority, in 1992, ODA introduced the Research Continuity Scheme (RCS) with the specific objective of promoting the uptake of its research-generated technologies by small-scale, resource-poor farmers. The RCS permitted adaptive research projects that were based on technologies generated in previous research to be considered by the Research Programmes.

3. With this background, in 1992 the Livestock Production Programme (LPP) funded a project (F0004) that had three objectives: (a) to demonstrate that low-in-maize or maize-free poultry rations can be developed using sweet potato tuber (SP) and cassava root (CAS) which would be more profitably used for poultry production than maize-based rations; (b) to adapt this concept to the resources and constraints small-scale farmers in a developing country in order to ensure a high adoption rate by this group; and (c) to develop mechanisms for transferring the poultry ration technology to the target beneficiary group.

8.2. Collaboration with the International Potato Centre

4. The International Potato Centre (CIP) has been developing and promoting new genotypes of sweet potatoes that substantially out-yield the traditional cultivars on farmers fields. With greater appreciation of the need for integrated production to consumption projects in agriculture, and the declining market for SP as it becomes increasingly regarded as a 'poor man's crop', CIP has started to examine post-harvest utilisation aspects, and of particular relevance, is seeking alternative uses for the tubers. CIP, therefore, agreed to provide much-needed support to this project, both from its Headquarters in Lima, and from its regional station near Bamenda, in Cameroon.

8.3. Selection of field location

8.3.1. *Country selection*

5. Several countries were considered for identification of a suitable site in which to conduct the field work. This included Peru, Indonesia, India, Nigeria and Uganda. However, Cameroon was selected because of the considerable importance of SP, CAS and maize in its smallholder farming systems and in the livelihood strategies of the poorest people. The cost-structure in the animal feed and livestock product sectors were also particularly conducive to implementing the project concept, the country being an importer of maize for the poultry industry, with poultry products also being regularly imported despite high import taxes.

8.3.2. *Prefeasibility study to select field site*

6. In 1994, a rapid rural appraisal (RRA) was conducted jointly by staff of NRI and IRZV in the mid to high altitude zone (MHAZ) of Cameroon, the zone with the highest national production of maize, SP and CAS (Appendix 16.3, Table 2). The RRA study examined the farming systems of the region in terms of crop rotations and labour availability in different seasons, the energy requirements of drying these commodities for preservation after harvest, and the utilisation prospects for the commodities based on human dietary preferences and the demand for poultry products. The results showed convincingly that the project was highly appropriate for the MHAZ around Bamenda town, for three main reasons: SP and CAS were under-utilised and there was spare capacity to increase production, especially of SP; poultry products were costly in relation to other livestock products; and imported maize was being used in commercial poultry feeds even though the root crops were cheaper on a dry matter basis. Thus, the western highlands was selected as the project field site.

7. In order to benefit from the greater knowledge of field conditions by researchers at the Mankon Research Station (MRS), the management of field activities was devolved to the IRZV under a memorandum of understanding between NRI and IRZV. For this LPP funds were channelled through an Extra-Mural Contract (F0060). Project F0060 was managed by Dr Banser (Director of IRZV), who reported to the Project Manager of F0004.

8.4. Project Strategy

8. The project strategy was to conduct a combination of strategic and adaptive research on selected feed raw materials of relevance for the development of practical poultry rations in the project area, and then to develop and test rations in the project field site. Research was conducted in the environment-controlled poultry houses of NRI to establish feed potential, in on-station poultry feeding trials at MRS to pre-test dietary options, and finally, in on-farm poultry feeding trials under farmer control, the three components being implemented in an iterative manner to maximise the chances of developing maize-free, SP- and CAS-based poultry rations that would be adopted by farmers. Since NRI had no previous research experience on the processing and nutritional characteristics of SP (previous research on root crops being on CAS and yams) strategic research was required on this commodity initially to enable the selection of the field site and the planning of field activities.

9. To ensure that NRI experiments and field activities remained integrated, good communications were maintained using postal and courier services, and telecommunication facilities. Additionally, visits were made at yearly intervals to the project site by the Project Manager of F0004, for detailed discussions and rescheduling of activities in light of project developments.

8.5. Research activities at NRI

8.5.1. *NRI Phase 1 studies (strategic research)*

10. Root crops need to be converted to dried small particles sizes before these may be included in poultry rations. In Phase 1, the objective was to determine whether the variety of sweet potato and the conditions of chipping, drying and grinding the tubers were important factors that needed to be considered in relation to the planning of field work. In Experiment 1, tubers from eight cultivars of sweet potato were obtained from breeding trials in CIP (Peru). The tubers were chipped in peeled or unpeeled states, and then oven-dried at 40^{o}C or 80^{o}C, or dried in a solar simulator at a mean temperature of about 33^{o}C. The dried samples were assessed for nutritional value by proximate analysis, starch and characteristics, trypsin inhibitor activity, and *in vitro* digestibility using the method of total dietary fibre (TDF). It was found that peeled samples were generally of slightly higher digestibility, but more importantly, both variety of SP and processing conditions had

significant effects on nutritive value. It was, however, not clear whether this effect was temperature- or humidity-related, and further, there was uncertainty on how TDF values related to actual feeding value for poultry. In view of the importance of these findings for the selection of appropriate climatic and weather conditions for field work, a second experiment was, therefore, conducted using two commercial varieties of SP, which were chipped, oven-dried at 40, 60 or 80^{o}C, and then ground and fed to broiler chicks in nutritionally-balanced diets. The results from this study confirmed not only that variety and humidity were significant factors affecting the feeding value of SP, a significant interaction between the two suggested that the processing method may need to be altered according to the variety available.

11. Previous NRI research had similarly shown that CAS varieties may differ in cyanide content, and also that the rate at which cassava root chips were dried affects the cyanide content, and hence, its feeding value for poultry. The significance of NRI Phase 1 findings on both root crops for the planning of field work were three-fold: (a) the benefits of peeling tubers and roots on nutritive value differed for different varieties but on the whole were not great, whereas peeling represented a major cost in time and labour for the production of poultry feed; project work was, therefore, planned to be conducted with unpeeled SP and CAS; (b) there was a clear need to evaluate local varieties of root crops in the project site in on-station poultry feeding trials before any on-farm trials were conducted; (c) in view of the significant variety *x* processing method interaction but lack of time to develop appropriate processing methods for different field varieties of SP, it was decided to avoid humid drying conditions altogether, all tuber processing work in the project field site was, therefore, conducted in the dry season. The limited amount of work that could be done in the short dry season in the project field site (December to March) increased the duration of the sub-component project (F0060), and hence the parent project, both of which required extensions beyond the original projection dates.

8.5.2. *NRI Phase 2 (Part 1 and Part 2) studies (adaptive research)*

8.5.2.1. *Assessment of the nutritive value of project field site feeds*

12. The NRI Phase 2 experiments involved selected feed development research to determine the optimal tuber and root variety, feed presentation method, and other ration characteristics for field testing. This adaptive research was prioritised to determine the benefits of technologies identified to be feasible on small farms. An aspect of SP and CAS processing for poultry feeds that holds considerable promise for use on small farms is their development into grits that can be consumed by chickens without grinding. This would save on the cost of feed production and prevent dustiness which reduces poultry performance and causes problems in the handling of these feeds. Thus, the benefits of using SP and CAS grits instead of the ground materials was examined by producing shreds using the J3 plate of the TRS electric food processor (TRS) and crumbling the dried shreds into small particles that young could consume. This experiment also evaluated the varieties of SP and CAS from the project field site to determine best varieties for use. Other feed technologies identified as having potential for adoption by the target beneficiaries were the use of feed mixtures of SP and CAS with agricultural processing by-products available in the project area, and the use of fresh SP and CAS that were solid-state fermented prior to sun-drying in an attempt to improve feeding value. For the feed mixtures, SP and CAS were mixed with palm pit sediment (PPS), whole palm kernels (WPK), traditionally-processed palm kernel cake (PKC) and cassava leaves (CLM) and sweet potato vines and leaves (SPLM).

13. Small quantities of these test raw materials and mixes were prepared in field site and air-freighted to NRI for assessment of nutritional value under controlled-environment conditions. The results of these '*look-see*' experiments formed the basis for selecting the dietary formulations for pre-testing in on-station poultry feeding trials, and thence, in on-farm trials. However, not all the findings from these trials could be incorporated into the design of the first on-farm trials, for two reasons: (a) the timing the feed preparation work in MRS, the NRI feeding trials, and the on-station and on-farm

poultry feeding trials could not logistically be matched to permit this (Appendix 16.4); and (b) it was considered appropriate to first develop some basic rations and to try and improve these by introducing minor changes. The NRI Phase 2 experiments are, therefore, reported in two parts, separated by the ration design considerations applied in the first on-farm feeding trials.

14. The first Part 1 feeding trial showed that diets in which SP and CAS grits were used compared favourably with maize controls in growth performance of broiler chicks, particularly in relation to results obtained previously with mash feeds. The effect of grit presentation was primarily to enable high food intakes. However, with SP, there was a lowering in digestibility as some of the grits passed through the gastro-intestinal tract undigested. Nonetheless, since other characteristics such as reduced dustiness and feed spillage were also lower with grits, it appeared that overall grits were preferable. As a result, more extensive gritting trials were undertaken in MRS to determine the optimal grit dimensions, (paragraphs 35 and 37). Of the three varieties of SP and two varieties of CAS tested, sweet potato 1112 and cassava White were selected for field work because of their superior feeding values. The second series of Part 1 feeding trials showed that WPK and PPS were good poultry feeds and could be included in rations for resource-poor farmers because of their widespread availability in the rural areas. Accordingly, the first on-farm feeding trials utilised WPK and PPS with SP and CAS. However, despite the fact that PKC proved to be as good a feed ingredient as WPK it was excluded from field trials due to (a) its lesser availability and (b) concerns of environmental sustainability arising from the large quantities of firewood used in the oil milling process that generates this material as a by-product.

15. In the first Part 2 feeding trial, chicks fed diets containing 48-hour fermented SP and CAS performed as well as the maize-fed controls; however, for CAS it appeared that a longer fermentation period of 72 hours might be detrimental to feeding value. In the second Part 2 feeding trial, broiler chicks were fed SP and CAS with their respective leaf meals at 3, 6 and 12 per cent dietary inclusion rates. This trial showed that whereas SPLM had little potential for use, diets with CLM at up to 12 per cent inclusion rate had dry matter retentions similar to the maize controls. Overall, when food intakes were taken into consideration results indicated CLM use may be optimal at 6 per cent dietary inclusion rate. CLM also proved to be an excellent source of carcass pigmentation, so that it was considered suitable for the dual purpose of supplying protein and egg yolk pigmentation in laying hen rations. As a result of these Part 2 studies, broiler and layer rations were developed for testing in on-station and on-farm poultry feeding trials conducted during 1997-1998.

8.5.2.2. *Feed composition chart for project field site region*

16. The nutritional analysis of feeds in the NRI Phase 2 studies was elaborated following the less than ideal results obtained in the first on-station poultry feeding trials (paragraph 23-24) to lead to the construction of a feed composition chart for the project field site area. All the diets and excreta from the NRI feeding trials were subject to gross energy determination from which the apparent Metabolisable energy values of the test materials were estimated. In addition to the feed raw materials referred to in paragraphs 12-15 and 22, other readily available feeds considered to be complementary to SP and CAS in ration formulation were obtained (fishmeal, wheat feed, meat meal, brewers dried grains, blood meal, bone meal, cottonseed cake, rice bran with and without chaff, oyster shells, palm oil, commercially-processed palm kernel meal, and soyabean meal) and analysed. The inclusion of an additional column in this chart for the prices of feeds (Appendix 16.5) permitted the least-cost ration formulations required for the project.

8.6. Research activities in Cameroon

17. The field work had ten inter-linking aspects. These were (a) a study to characterise the poultry production systems and feed resources in the western highlands; (b) selection of farm types for project technologies; (c) selection of participants for on-farm testing and demonstration feeding

trials; (d) identification and processing of feeds for nutritional analysis at NRI (paragraphs 12-16) which then formed the basis for ration development; (e) testing dietary options in on-station poultry feeding trials before the on-farm trials; (f) implementing the farmer-managed on-farm poultry feeding trials by securing farmer participation; (g) holding group discussions with project participants after on-farm trials to examine farmer responses; (h) conducting SP and CAS gritting trials; (I) planning activities for the improvement of project-developed technologies; and (j) developing pathways for diffusion of project-generated technologies to maximise project impact.

8.6.1. *Poultry farm characterisation study*

18. The objective of this study was to determine the type of poultry production systems prevailing in the region in terms of the resources, constraints and objectives of farmers, and the feed resources available to them. This information was required for (a) identifying the types of small-scale poultry production systems in which the project concept would make the greatest developmental impact; (b) determining the poultry ration technology that would have widespread applicability, and thus, will be adopted by largest numbers of resource-poor farmers; and (c) the selection of demonstration farms for the project. The report is reproduced, with minor modifications, in Appendix 16.3.

19. There are two types of small-scale poultry production systems in the region: the traditional backyard scavenging chicken, and the modern poultry sector that uses hybrid birds in confinement. The latter are more productive but require large quantities of feed. They are found in peri-urban areas as a purely income generating enterprise and in rural areas as a sub-system within a mixed farming system. Roughly a third of these producers considered poultry litter to be a major reason for their involvement in poultry rearing due to the high soil leaching of nutrients in the long rainy season. The poultry housing were of deep-litter and slatted-floor systems. The costs of feeds (60-64 per cent of variable costs) and of day-old chicks (25 per cent) are found to be the major issues for any strategy to assist this sector. Few producers knew how to mix their own feeds using on-farm resources, and therefore relied on commercial feeds. Fifty per cent of broiler producers, 11 per cent of egg producers, and 20 per cent of mixed broiler and layer farms were female-owned.

8.6.2. *Selection of farm types for design of project technologies*

20. Researchers agreed that there was little scope for intensifying the traditional backyard poultry system, so that the project focused on the modern sector. The target poultry producer was defined in order that the ration technology could be designed to maximise the chances of adoption. These were small-scale resource poor farmers operating within mixed farming systems and poultry producers in peri-urban areas. In either category, the farm type selected were those keeping a maximum of 500 broilers or 250 layers per production cycle in deep-litter or slatted-floor housing. Caged-hen production systems were, therefore, excluded from consideration.

8.6.3. *Selection of participants for on-farm feeding trials*

21. In addition to selecting some resource-poor male and female farmers, it was also decided to select some individuals and institutions who could promote the technologies developed in the project. The farmers selected for demonstration of the project concept were: one male farmer who was also a driver, one male farmer who mixed feeds and sold it to small-scale livestock producers from an animal feed shop, one female farmer, a women group producer, a non-governmental organisation (NGO) involved in training extension workers, and a respected village leader who guides local farming activities.

8.6.4. *Identification and processing of feeds for nutritional analyses at NRI*

22. The following feeds and feed mixtures were prepared and sent to NRI for nutritional analysis: maize; three varieties of SP; two varieties of CAS; SP and CAS mixed with PPS, WPK, or PKC at concentrations up to 25 per cent; SP mixed with SPLM, and CAS mixed with CLM, at concentrations up to 50 percent leaf meals; solid-state fermented SP and CAS; and a range of local agricultural by-products and slaughter house wastes. SP 1112 and CAS White proved to be the best varieties nutritionally for use as poultry feeds.

8.6.5. *On-station poultry feeding trials*

8.6.5.1. *First on-station feeding trials*

23. The object of the first on-station poultry feeding trials was to determine the potential maize replacement value of the varieties of sweet potato and cassava available in the project site. For this nutritionally-balanced rations were needed but this was not perfectly achieved because lack of time led to excessive reliance being placed on '*book values*' of the composition of local feeds. Notwithstanding, the results of the feeding trials confirmed that the basic project proposition of replacing maize with sweet potato tubers and cassava roots in chicken diets was both technically-feasible and financially-viable. Weight gain per FCFA expended on broiler feeds was 3.53 g in a SP+cottonseed cake-based ration compared with 2.72 for a standard maize-based ration. For laying hens, three varieties of SP gave the same egg production rates as a maize-based control diet whilst two varieties of CAS gave even higher production rates than the controls; the financial impact was also evident in the fact that egg production in relation to cost of the feed consumed was more favourable for each of the test diets than it was for the maize-based control diet.

24. In view of the proven inadequacy of '*book values*' of composition of feeds for project work, all potential test feeds in the project field site area were sampled and sent to NRI for nutritional analysis (see paragraphs 12-16). The analyses included the determination of the amino acid composition of all feeds and apparent Metabolisable energy values of all major feeds and feed mixtures. A feed composition chart that enabled least-cost poultry ration formulation was thereby constructed (Appendix 16.5). This chart formed the basis of the development of rations in subsequent feeding trials in the project.

8.6.5.2. *Second on-station feeding trials*

25. The second on-station poultry trials tested the tentative diets formulated for meeting the resources and constraints of small-scale, resource-poor poultry producers. These diets (Tables 19 and 20) were not of ideal nutrient specifications for chicken performance but were designed to be socio-economically optimal. The plane of nutrition and ingredients used in the ration were adjusted to the level that would facilitate adoption. The results of the broiler trial showed considerable promise in that cereal-free SP- and CAS-based rations produced average savings of around 25 and 45 per cent, respectively, on the cost of feed used per kg broiler liveweight gain compared with the commercial control ration, although the broiler growth rates were lower as would be expected for nutrient-submaximal diets. The layer trial was conducted with old hens that were at a moderate rate of production and were housed in wire cages to keep costs down, notwithstanding the fact that caged systems were excluded from considerations of the target beneficiaries (paragraph 20). The results showed that the cassava-based diet produced a similar rate of egg production as the commercial control diet but SP-based diet produced fewer eggs; however, due to the higher food intake associated with the commercial diet, the cost of feed used to produce a tray of 30 eggs were 951, 650 and 1306 FCFA for the cereal-free SP-based, low-in-cereal CAS-based, and commercial rations, respectively; the corresponding profit margins being 399, 700 and 44 FCFA.

26. Thus, both the broiler and layer rations developed showed considerable promise for field application, and it was decided to test these rations unchanged on farmers' premises for the on-farm trials.

8.6.6. *First on-farm poultry feeding trials*

8.6.6.1. *Broiler meat production trials.*

27. The on-farm broiler trials confirmed the results in the on-station pretesting stage on each of the six demonstration farms, the average 8-week liveweights for the SP-based, CAS-based and commercial rations being 1.6, 1.8 and 2.1 kg, respectively, and the corresponding cost of feed used per kg liveweight gain figures being 382, 292, and 533 FCFA. Thus, the cereal-free SP-and CAS-based rations produced average savings of 25 and 46 per cent over the commercial diet in the cost of feed for producing poultry meat. It is reasonable to conclude that the project has achieved a sustainable, non-cereal, intermediate-intensity poultry production system that is appropriate both to the needs of resource-poor farmers and achieves efficient resource management from the point of view of the country.

8.6.6.2. *Egg production trials*

28. The results of the layer trial conducted with newly laying hens in deep litter and raised slatted bamboo floor systems were, however, not encouraging, and differed from the findings from the on-station ration pre-testing stage. The production rate obtained with cereal-free SP- and low-in-cereal CAS-based rations were around 50 and 57 per cent of that obtained with the commercial ration, and the profitability expressed in terms of the weight of eggs laid per 1000 FCFA spent on feed were also lower, although in terms of the number of eggs it was more encouraging.

29. The researchers are considering the reasons for these poor results with laying hens. The differences obtained in the on-station and on-farm situations might have been due to the different age of hens or housing systems used. It is also possible that laying hens, especially those at an age that is capable at producing at a high rate (of around 90 per cent production), should not be fed nutritionally submaximal diets for attaining high profitability; whereas such diets might be highly appropriate later in the egg production cycle when hen-day production has fallen to around 50 per cent.

30. It was also found that replacing maize with tubers and roots resulted in paler than acceptable yolks, and the diets need to be supplemented with a pigment source to make these marketable.

8.6.7. *Group discussions with participating farmers after first on-farm trials*

31. At the end of the first on-farm trials, the results of the project were discussed with participating farmers and selected economic operators. Farmers acknowledged that it was cheaper to produce chicken meat and eggs using SP- and CAS-based rations compared with a maize-based ration. However, there were some concerns about the small size of the chickens fed with SP-based diets. Farmers were keen that the growth rate achieved with this group of broilers should be increased even at a higher cost of production in terms of feed quality. The precise conditions under which the laying hen rations might be used also required clarification.

8.6.8. *Ration development during 1997-1998*

32. The research conducted during 1997-1998 attempted to make improvements to the basic broiler and layer ration technology developed. In view of the uncertainty arising from the first on-

farm feeding trials (particularly from the laying hen trial), and the responses of the participating farmers to the results obtained, a project extension has been established to investigate the prospects of improving the basic SP- and CAS-based broiler and layer rations developed thus far in terms of productivity and profitability of production. Apart from the issues outlined in paragraphs 28-32, the technologies identified in the NRI Phase 2 third and fourth feeding trials will also be tested, namely the use of 48-hour solid-state fermented SP and CAS instead of unfermented material, and the use of CLM to supply protein, but more importantly for layers, pigmentation for yolk colour. Based on these trials root crops-based rations will be developed that are socio-economically optimal in the region of the project field site.

8.6.8.1 *Broiler feeding trial*

33. Broiler rations based on CAS and SP were developed that were optimal to the Bamenda region, and these were tested with and without SSF. Although growth rate with CAS and SP were again lower than with the best commercial diet, by 8 weeks performance with the CAS-based diets were a respectable (in terms of marketability) 1.6 to 1.7 kg range. Fermentation did not produce a major beneficial effect on broiler performance and again the 500 g SP/kg diets were slowest to grow and had the poorest EFU. The benefits of the tubers and roots-based rations were however clear when examining the all-important parameters of feed cost/kg liveweight gain and feed cash outlay per day. All the rations were more profitable than the commercial rations, and excepting the 500 g SP/kg diets by a considerable amount. For example, the Diet considered optimal for the Bamenda region) containing about 500 g CAS/kg cost only 284 FCFA/kg liveweight gain compared to 562 for the commercial diet. For all the tubers and roots-based diet, the cash outlay per day on feed was roughly one-third that of the commercial diet. Thus, the results show that cereal-free practical tubers and roots-based broiler rations appropriate to the circumstances of resource poor farmers can be developed.

8.6.8.2. *Laying hen feeding trial*

34. For laying hens, however, limited improvements were possible. SSF appeared to make the diets slightly better, particularly for cassava root. However, overall these sub-optimal diets are not likely to produce high rates of egg production. It may be that their use is more appropriate when egg production has fallen to around 50 per cent in the flock, since it is dictated by their low ability to consume the feed, as was indicated from the earlier on-station caged feeding trials. Overall, under certain circumstances the use of cereal-free tubers and roots-based laying hen rations can be very profitable, although not as profitable as broiler rations.

8.6.8.3. *Replacement pullet feeding trials*

35. Only the first phase of the laying hen replacement trials with SP- and CAS-based diets has been completed. The delay was caused by complicated institutional changes at IRZV during the year. The full results from this experiment are expected from IRAD by October 1998, based on which a separate report will be submitted.

8.6.9. *Tuber and root gritting trials*

36. Following the preliminary NRI Phase 2 gritting trial (paragraphs 14), the TRS was used to produce grits of various dimensions in order to examine the optimal size of SP and CAS grits suitable for young and adult chickens. These trials indicated that a machine should produce grits 40-60 per cent of which were of 4 mmx3 mmx2 mm dimensions, with the remainder being smaller. These specifications would be optimal in the project area because this size increased food intakes in chicks

and were practical by virtue of the fact that the fresh material could be sun-dried within a day in the weather conditions prevailing in the western highlands of Cameroon. It was agreed that a manual gritting machine/implement was required for on-farm use. Research was needed to determine whether this machine should have two inter-changeable blades, one for SP and the other for CAS. The gritting machine should be designed to minimise physical effort and maximise safety (in terms of the position of various handles, bars and pedals), and must be developed with the participation of women who are eventually expected to operate it.

37. Since the development of a suitable gritter required considerable additional research and funds, it was agreed that the present project should continue with mash feeds, that is SP and CAS should be shredded using the J3 blade of the TRS.

38. Although it had been intended to develop a manual gritting implement/machine in accordance with paragraphs 35-36, the technical difficulties were too great to surmount. It was, therefore, decided to produce two machines, one to chip the SP and CAS tubers and roots, and the other (named 'Pioneer gritter' to grit the sun-dried chips. Photographs of the machines are shown in Appendix 16.10.

8.7. Project outputs

39. The project outputs are (a) cereal-free SP- and CAS- broiler rations that are more profitable for small-scale farmers for whom an intermediate-intensity production system is appropriate; (b) a technology of chipping and sun-drying SP followed by gritting, which prevents the 25-40 per cent rotting losses that normally affects the produce; (c) methods of utilising other local agricultural by-products and wastes to add value to traditional agro-processing activities and to ameliorate environmental pollution; and (d) a feed composition chart for the project site region to assist future feed developmental research and extension work; (e) a manual tuber and root chipping machine; (f) a manual dried tuber and root gritting machine; and (g) institution building.

40. Of these outputs, the Director of IRZV singled out institution development as being of greatest benefit to Cameroon, specifically acknowledging the transfer of knowledge that took place during the course of project implementation. The IRZV benefited from the approach adopted in assessing the regions farming systems and feed resources, and in particular, from the training given to staff in the use of a feed formulation software package installed on MRS computer which can now be used for least-cost ration formulation. With this facility and the feed composition chart (paragraph 16) IRZV, local agricultural extension agencies, and other research organisations of the region can continue with other feed developmental research, and more importantly, advise farmers directly on the use of feed resources to assist poultry producers.

8.8. Contribution of outputs to development

41. The competition for maize between human food and livestock feed sectors is a major developmental issue globally but for developing countries in particular because these are generally dependent on imports of this cereal. This project has developed cereal-free broiler chicken rations that have been demonstrated to be more profitable than the normally used maize-based rations in intensive poultry production system..

42. The outputs of the project contributes to poverty alleviation among the poorer sectors of the population by providing them with cheaper and more affordable poultry rations that reduce their dependence on commercial feeds. More poorer people will take up poultry rearing as an income generating activity since the rations designed are only suitable for this group. If the rations are adopted on a large scale it will also make it easier for poor people to consume more cereals the price of which will be reduced as a consequence of its replacement by SP and CAS. The price of poultry

meat and eggs will also be reduced making it accessible to lower income groups to improve their nutrition and health.

43. The project has also demonstrated that it is possible to improve livestock production and productivity to generate income for resource-poor farmers and other low income groups in an environmentally-conscious manner such as minimising the use of fossil fuel in poultry feed processing and preventing pollution (as with PPS). The approach, based as it was on optimising the use of local feed resources including traditional rural agroprocessing by-products and waste, itself makes a contribution as a way forward for livestock developmental projects.

44. A novel research methodology was also established for the development of poultry rations for small-scale producers through an iterative process of strategic and adaptive research by conducting feeding trials in controlled-environment conditions to establish feed potential; on-station feeding trials under researcher control for pre-testing of tentative rations, and finally, on-farm trials under farmer control to test the applicability of the rations developed. This approach could be applied in other concepts such as in agroforestry/livestock projects where tree leaves are considered as poultry feeds.

45. The project has also highlighted the need for crop and livestock research to be developed in parallel. There is a need for greater emphasis on the utilisation characteristics of new cultivars for use as animal feeds before promoting new varieties of tubers and roots in developing countries.

8.9 Project follow-up activities

8.9.1. *Dissemination of project findings*

46. Only limited dissemination has thus far been undertaken since the project is incomplete and due to lack of funds. A poster promoting the use of SP in poultry feeds has been developed (Paragraph 334, Poster 1), and the NGO and 'Animal feed shop owner' project participants were given ration advice (Appendix 16.9) A scientific paper describing the processing and nutritional characteristics of two varieties of SP for poultry has been published (Panigrahi *et al*, 1996a), and a review paper on the use of cassava root for poultry production was presented at an International conference held in India (Panigrahi, 1996).

47. Further selected dissemination activities should be conducted through (a) publications and reports; (b) holding a regional workshop in West Africa; (c) designing appropriate leaflets and posters for display in the buildings of national agricultural research stations, extension agencies and other suitable establishments; (d) assisting small-scale animal feed producers directly with ration formulation advice; and (e) assisting local NGOs with advice on ration formulation and other feed production techniques.

8.9.2. *Agricultural project*

48. To ensure that the benefits of the research-generated technology is carried through into the field, sustainable systems of production and utilisation of cereal-free poultry rations are required. These will involve an economic stakeholder system of integration comprising the processing of roots and tubers into grits and their marketing directly to poultry producers or through animal feed manufacturers. The private sector has an important role to play. A distinction should, however, be made between large-scale and small-scale feed millers in terms of the ration characteristics that would be applicable for each. Large-scale producers are considerably more restricted in the rations and production methods they can use than small-scale millers who in turn are more restricted than resource-poor farmers mixing their own feeds. Thus, each category requires a different type of assistance in agricultural projects. For example, one of the on-farm project participants was given

rations that utilised materials such as brewery dried grains which are available only intermittently (Appendix 16.9). Similarly, large-scale animal feed compounders need to be assisted with appropriate technology to convert tubers and roots to suit their production systems.

49. To maximise the benefits of the project-developed technologies to the poorest farmers and other low income groups an approach is needed that brings together farmer groups and local NGOs in an agricultural project as four stakeholders: those cultivating tubers and roots, those processing the tubers and roots, those engaged in animal feed production, and those rearing chickens. Following the development of a suitable manual gritting machine (Appendix 16.10) - it was decided that an agricultural project proposal will be developed for submission to aid agencies for funding.

50. The project also highlighted the need for research institutes involved in animal production (such as NRI and IRAD) to engage in on-going collaborative research with crop research institutes such as CIP and IITA in developing varieties of sweet potato and cassava suited for development as poultry feeds. A chart of the type of research data on utilisation characteristics required is shown in Appendix 16.8. Such data requires consideration along with agronomic data before new varieties are introduced in developing countries.

9. PROJECT CONCEPT

9.1. Competition for cereals between humans and livestock

51. In 1981, about 600 million tons of cereals representing some 40 per cent of the world harvest was fed to livestock. Thus, globally there is competition between food and feed use of cereals which may affect cereal prices (Sarma, 1986; FAO, 1983). Twenty-two per cent of cereal use as animal feed, or 130 million tons, are used in developing countries, which represents 15 per cent of the total staple food consumption in grain equivalent terms (von Braun and Kennedy, 1987), with Africa accounting for only 3 per cent of this total. Whilst, the current patterns of food versus feed competition in developing countries, therefore, does not appear to be a major developmental issue, the use of cereals for feed increased at 8 per cent a year for the 10 years up to the late 1980s compared with only 1 per cent in developed countries. Besides, the increase in world population is also increasing the demand for grain food to increase consumption by humans and as animal feeds. there is more pressure on the use of raw materials, conventional and unconventional

52. The income elasticity of the demand for livestock products averages about 1.0 for Asia and the Far East while that for cereals for direct human consumption averages about 0.2. The supply and demand of cereals during the course of economic development and its impact on prices has been proposed by Mellor and Johnstone (1987) to be triphasic, the second phase growth of demand causing the upward trend in the real price of food unless there is rapid growth in imports of cereals. Initially livestock are fed mainly waste and by-products, the supply of which is inelastic with respect to livestock production. As demand for livestock products grows with economic development (in countries with a significant non-agricultural sector) cereals usable for direct human consumption are fed increasingly to livestock. Given the diminishing returns to limited land area plus the great difficulty and lack of experience with increasing the yield per unit of land by more than 2 per cent a year, this phase sees rising real prices and rising imports of cereals. Even for countries with substantial areas of unexploited land, expansion of output in pace with demand is likely to be difficult because of deficiencies in their physical and institutional infra-structure. Cameroon and Zimbabwe are in this category because of their higher than average incomes in Africa, and due to the fact that the contribution of agriculture to Gross Domestic Product is only moderate at 32 and 21 per cent, respectively (Jahnke, 1982).

53. The nature of competition between food and feed utilisation of basic staples may result in an adverse effect on food consumption of the poor, especially in countries whose growth pattern is combined with a skewed income distribution (von Braun and Kennedy, 1987). Derived income elasticity for feed due to increased demand for livestock products may be higher in the middle to upper income groups than the income elasticity for direct cereal consumption among the poor whose budget share for cereals is particularly high. Rising incomes in such a pattern could then produce an upward pressure on cereal prices depending on whether the country increased cereal imports and on the local market infrastructure. These higher prices would largely affect the poor who tend to be more price-responsive in demand for basic food.

54. To relieve the competition for cereals between the human food and livestock feed sectors it is necessary to develop practical cereal-free animal feeding systems. In developing countries this applies mostly to poultry production and increasingly so since the demand for poultry meat and eggs has risen considerably at the cost of red meat production world wide. Poultry rations generally comprise maize at 50-60 per cent.

9.2. Demand for poultry products in sub-Saharan Africa

55. In recent decades, the demand for livestock products has grown steadily in the countries of sub-Saharan Africa (SSA) but this has not been matched by increased production. Thus, existing trends in per capita income and population growth rates in SSA forecast a meat deficit by the year 2000 that will be three and half times as large as it was in 1990 (Sarma and Young, 1985). The predicted deficit may be higher still as concerns mount on the sustainability of rangeland productivity for future beef production. It is, therefore, clear that greater attention will need to be devoted to meeting some of the meat deficit from poultry production in the high potential agro-ecological zones. Indeed, the use of non-ruminant animals as a source of food is increasing throughout SSA.

56. The livestock production projected for 2025 will, however, require substantial quantities of feed (Winrock, 1992). At present most poultry and pigs are farmyard scavengers that are fed little grain, but in the future a large proportion will be raised on concentrate feeds in small-scale intensive systems on crop-livestock farms or commercially in confined operations. For poultry and pigs feed grain requirements are expected to increase 10-fold by 2025, and oilseed meal requirements even more. Research is needed on novel strategies and technologies for increasing the production of coarse grains, root crops and oilseeds to provide feed for white meat production. The sub-humid zone farming systems of SSA is in early stages of evolution and farmers still have inadequately-developed skills in the use of new technology. This remains a major barrier to raising the productivity of the livestock sector. Adaptive research is needed at gradual intensification using methods that will be easy for farmers to adopt.

9.3. Small-scale poultry production

57. There is a particular need for assisting those small-scale poultry producers in developing countries who are sufficiently progressive and able to keep hybrid birds in confinement, as different to those who restrict themselves to the backyard system using indigenous chickens. Small-scale poultry producers may be defined as those keeping a maximum of 500 broilers per production cycle or a maximum of 500 egg layers at any point in time. Since commercial feed costs represent 60-70 per cent of the cost of poultry production, resource-poor producers generally try and reduce their feed costs by diluting commercial feeds with on-farm feed resources. This has adverse effects on nutritional balance of the ration, and hence, production, and results in non-optimal utilisation of both types of feed. There is, therefore, a demand for developing unconventional mixed feeds and supplements to reduce the dependence of small-scale poultry producer on commercial feeds. Another consideration is that these producers can only afford basic housing and veterinary care under which commercial feeds do not yield the same productivity as that achieved by local large-scale poultry producers with better housing and husbandry provisions. Consequently, the small-scale producer is disadvantaged and unable to compete with the large-scale producer in the market for poultry products.

9.4. NRI's poultry programme

58. Between 1980 and 1990, NRI conducted considerable DFID-funded strategic research in its environment-controlled poultry houses to evaluate a range of tropical feeds (mainly, root crops and oilseed processing by-products) for nutritive value. NRI oriented its poultry programme specifically to meeting the needs of small-scale poultry producers in the rural areas, small towns and the peri-urban areas of the major cities in developing countries. This group has access to a limited number of feeds, which may, however, be abundant in relation to local prospects for utilisation. Many of these rural feeds are termed unconventional by virtue of their nutritional peculiarities, e.g. lack of uniformity, consistency of availability and nutritive value and (some contain anti-nutritional or toxic factors).This means that these feeds are not generally used by large-scale feed millers. NRI's approach was to test these feeds at very high inclusion rates in nutritionally-balanced diets; for

example, cassava root (CAS) was tested at up to 60 per cent, cottonseed meal at 40 per cent, and palm kernel meal at up to 70 per cent of the ration. Where toxicological factors were present, simple means of detoxification appropriate at the small-scale level were developed in order that farmers could still feed the raw materials to their chickens.

59. This research provided valuable data on the potential of different feeds and was disseminated through publications. However, dissemination by itself produced little impact in the field, since the group for which the research is appropriate is unable to decipher the literature and use the information in practical feeding systems. Small-scale poultry producers require ration formulae that they can use. This presents a challenge to the poultry nutritionist who needs to develop rations that maximise the use of local feed resources. To induce small-scale poultry producers to confidently adopt a ration, it needs to reduce their cash outlay on feeds and generate higher profits from the sale of the poultry meat and eggs than that achieved by commercial poultry feeds sold in the area; this objective necessitates a study of those commercial feeds. In short, it is necessary to undertake poultry ration developmental research and diffusion activities.

10. PROJECT PURPOSE

10.1. Concept note submitted to LPP

60. NRI had its first opportunity for this type of adaptive research in 1992 when DFID introduced the 'Research Continuity Scheme' (which was later termed Adaptive Research Initiative) in a shift of emphasis of its Renewable Natural Resources Research Strategy. The purpose of the scheme was to enable technologies generated in its strategic research programmes to be adapted to the resources and constraints of resource-poor farmers in developing countries in order to improve prospects for the uptake of those technologies. NRI's previous research on root crops provided an ideal subject on which to submit a concept note for funding under this Scheme.

61. The original concept note approved by DFID is reproduced in Appendix 1. The project objective was to demonstrate the technical feasibility of incorporating the tropical root commodities SP and CAS in poultry diets to replace maize. Such an objective may be met by working directly with feed millers, as is the case in the DFID-TC funded project T0404 in Ghana (1995-1998). If these projects are designed to ensure sustainability, they should contribute to agricultural development. However, the prospects of the benefits of the technology reaching the resource-poor farmer cultivating the root crops or rearing livestock may be limited depending on what proportion of the gains the miller passes down the production to consumption system chain. The present project, therefore, undertook to develop poultry rations and technology transfer mechanisms specifically for peasant poultry producers (some of whom grow their own root crops), with a view to reducing their dependence on commercial mixed feeds. The development of sustainable rations for these beneficiaries is a complex task, necessitating an approach that involves a study of the resources, constraints and objectives of the producers, and local agricultural systems where the project is located.

10.2. Intended beneficiaries and other benefits of project

62. The major intended beneficiaries of the project were: root crop farmers who would find a better market for their produce; small-scale poultry producers rearing poultry within a mixed farming systems and in peri-urban areas who would benefit from cheaper poultry feeds; urban and rural consumers of eggs and chicken meat who would find these products cheaper because of increased availability and lower cost of production; and urban and rural consumers of maize, which would become cheaper and more abundantly-available as its use for livestock feeding is reduced. The project would also improve the efficiency of food and feed resource management by appropriate tuber and root processing, (particularly for SP which is highly vulnerable to rotting during storage)

and use if other local agricultural byproducts and waste. Finally, where appropriate the foreign exchange reserves of a country would improve from reduced imports of animal feeds and poultry products.

11. PROJECT ACTIVITIES

11.1. Establishment of collaborative arrangements with the International Potato Centre

63. The International Potato Centre (CIP) (HQ in Lima, Peru) has been developing and promoting new genotypes of sweet potatoes that substantially out-yield the traditional cultivars on farmers fields. With greater appreciation of the need for integrated production-consumption projects and the declining market for sweet potato tuber (SP) as it becomes increasingly regarded as a 'poor man's crop', CIP was examining post-harvest utilisation aspects and of particular relevance, was seeking alternative uses for the tubers, (e.g. for bread making or for replacing the maize content of traditional dishes, such as 'ugali' in Kenya). The nutritional value of these varieties of SP for poultry were, however, unknown as CIP lacked technical expertise and facilities to conduct research on livestock production. CIP does not have the mandate for conducting research on animal feeds.

64. CIP agreed to provide much-needed support to this project, both from its Headquarters in Lima and from its regional stations in Cameroon and Kenya. This support demonstrates their endorsement of the project initiative. Since high yielding varieties have been gradually replacing the traditional varieties of sweet potato in developing countries, it was decided to focus effort, as far as possible, on cultivars that CIP had recently introduced in the field, or those on the verge of being promoted.

11.2. Selection of project's field location

11.2.1. *Country selection*

65. The identification of a suitable project site in which to conduct the field work was a crucial component of the project. In the preliminary assessment, the importance of maize as a basic staple in the countries of SSA narrowed down the choice of region to West and Central Africa. Although national SP and CAS production records easily led to Cameroon being specified for field activities in the concept note (Appendix 1) DFID had not identified it as a high-priority country for the LPP research programme. It was, therefore, necessary to consider alternatives for the field activities.

11.2.1.1. *Peru and Indonesia*

66. Peru was considered because of the importance of sweet potato in its agriculture, and due to the fact that CIP has its Headquarters there. This would enable cultivars with high potential for application to be taken directly from the germplasm maintained at CIP, rather than having to develop the technology with varieties available in the field. The approach has merits and should be given serious consideration. However, the high cost of conducting the field work in this country was an important factor against its selection, a factor that also ruled out Indonesia. Further, once preliminary NRI Phase 1 experiments (paragraphs 97-107) showed that the project should be conducted in a country with a distinct dry season it was considered that the choice of countries with year-round high humidity should be deferred because in these places the appropriate technology would be to use costly oven-drying methods for processing CAS and SP. It was first necessary to prove the technology in countries where the use of cheap sun-drying technology is feasible.

11.2.1.2. *India*

67. The Project Manager visited India in December 1993, to assess the programme and facilities of the Central Tuber Crops Research Institute (CTCRI), Thiruvananthapurum, Kerala. Although Kerala and adjoining Tamil Nadu are the major cassava producing States of India, sweet potato is cultivated largely in the eastern states of Orissa, Bihar and West Bengal. CTCRI has, therefore, established a regional station in Bhubaneswar, Orissa. Sweet potato is a major crop cultivated by the low-income tribal groups in Orissa, but the urban market for it is now in decline due to changing consumer tastes. There is much interest in finding alternative uses for the tubers because the government places a great deal of emphasis on the upliftment of the tribal people to bring them into the mainstream of national life by feasible forces of integration. Providing a market for their crop will assist these people in maintaining their incomes. Orissa University of Agriculture and Technology (OUAT) has excellent animal and laboratory facilities and was keen to participate in this project. It has close links with the Central Poultry Breeding Farms in Bhubaneswar. Similarly, CTCRI has close links with Kerala's agricultural university and the nearby Madras Veterinary College, the latter having an excellent record on poultry feed developmental research. Climatically, the country is ideally-suited for the project concept in that sun-drying technology is feasible. However, the distance between the major sweet potato and cassava growing regions is considerable, and would have required separate collaborative arrangements with local institutions. This would have increased the cost of the project and posed considerable logistical problems in the management of activities.

11.2.1.3. *Nigeria*

68. The Project Manager visited the Abeokuta University of Agriculture (AUA), in February 1994 and discussed the proposed work. The University is near one of the Consultative Group of International Agricultural Research Centres, the International Institute for Tropical Agriculture (IITA), Ibadan, which has an extensive programme on cassava development. This makes AUA well-suited for a collaborative project. The region is also the most important cassava producing regions of Nigeria, with production being very elastic with respect to price and there being spare capacity to increase production. CAS can be harvested throughout the year but due to a lack of demand, the roots are often left in the field for up to one year. There is, therefore, considerable interest in promoting the use of root crops in poultry diets, a subject on which the university had a research programme. The project could, therefore, have been implemented at AUA. However, the political environment in Nigeria was not conducive to collaboration on DFID-funded projects.

11.2.1.4. *Kenya, Uganda and Tanzania*

69. The Project Manager visited Kenya in March 1994 and held discussions with Dr E. Carey of CIP's Regional Station in Nairobi. Joint visits were made to various organisations, such as the University of Nairobi, International Livestock Centre for Africa and the Kenya Agricultural Research Institute's Root Crops Programme to assess the possibility of implementing the project's field work in Kenya. A local feed miller was also visited to determine the scope for developing commercial feeds for peri-urban poultry production. The responses from all potential participants were encouraging. The feed miller complained about the high cost and quality of maize, which was largely imported from USA, and thus remained in transit or storage for up to three months with consequent quality problems. The cost of this cereal had increased considerably in recent years, and was mainly responsible for the high cost of eggs and poultry meat in the urban areas. However, whilst Kenya had significant areas where CAS and SP were cultivated by farmers, the quantities produced were low and the price structure relative to maize not particularly favourable. Kenya was, therefore, not considered a high priority country for the project concept.

70. On the other hand, SP and CAS are major commodities in Uganda and the crops are highly important in the livelihood strategies of smallholder farmers. The country was, however, only just beginning to re-establish its agricultural systems after many years of neglect so that it was decided not to implement the project in this country at that time. It should be noted that Uganda remains an important country for a similar future poultry feed developmental project. A project focused on CAS should also similarly be considered for Tanzania, which has a high production of this root crop.

11.2.1.5. *Cameroon*

71. Cameroon lies between 2&11^{0}N and 9&16^{0}E. It is shaped as a triangle and situated between Nigeria to the west, Chad and Central African Republic to the east and the Congo, Gabon and Equatorial Guinea to the south (Map 1). The apex is situated on Lake Chad. It is described as bilingual (ignoring 200 local dialects!) with Anglophones living in the Southwest region (occupying approximately 20 per cent of the land area), and Francophones in the rest of the country. The agro-ecological zones ranges from semi-arid desert in the north to dense equatorial forest in the south. Annual rainfall ranges from 500 mm in the North through 1200 mm at Ngoundere in Adamoua province to over 3000 mm in the south, which falls in two seasons. A visit by another NRI scientist in 1993 showed that Cameroon was blessed effectively with self-sufficiency in food production, which included a wide variety of fruits, vegetables, staples, fish and meat. Cameroon has cocoa, coffee and cotton in quantities suitable for export. Cameroon also has oil reserves, adequate road and communication systems and, therefore, is relatively well-developed and has considerable potential for further development (Silverside, 1993). However, since 1991 Cameroon was in financial crisis. France had been reluctant to allow the FCFA to float from its parity of 50:1 with the French Franc. There was a community linked to the FCFA which had more stable economies. In the early 1990s the government was bankrupt and had not paid a large proportion of its civil servants for periods of up to 18 months. Cameroon was, therefore, deep in recession, consumption being limited to necessities. The population generally had enough to eat, although the protein intake was variable, and the average citizen had difficulty in meeting medical bills and school fees for their children. Hotels, roads and passenger seats on commercial aircraft were almost empty. Services however, remained intact. Airlines operated, telephones functioned and there was water and relatively reliable electricity.

72. Cameroon imported substantial quantities of poultry products, which in 1986 amounted to 31 per cent of total domestic consumption despite high import taxes of 1000 FCFA/kg. Between 1977 and 1986, total poultry imports increased at an annual rate of 85.2 per cent from 81 tons to 6,647 tons (Nogu Ngoupayou and Emmanuel, 1989). This also indicated that there was sufficient effective demand for the potential outputs of the present project. With the 50 per cent devaluation of the FCFA in 1991, feed mills in Cameroon that had hitherto depended on imported on imported feed stuff to prepare chicken feed, also operated at 50 per cent capacity. Even so, feedstuff costs had risen by 30-60 per cent and finished feeds by 76.6 per cent, forcing most poultry producers to go out of business. Cameroon had also been a significant importer of maize during the late 1980s and early 1990s (Appendix 3, Table 26). However, it was considered that the devaluation of currency should improve the financial and economic viability of the project by stimulating domestic production of commodities in which the country had comparative advantage, and by making maize imports more costly. The channelling of root crops, specifically SP and CAS into poultry feeds to replace maize was, therefore, a logical development in such circumstances.

73. Following communications with the Minister of Scientific and Technical Research, in October 1993, the Director of the Institute of Animal and Veterinary Research (IRZV), which has the national mandate for research on Animal Production and Health in Cameroon, expressed interest in collaborating with NRI on this project, and recommended the western highlands as being the appropriate project location for implementation of the field work.

11.2.2. *Prefeasibility study to select field site in Cameroon*

11.2.2.1. *Rapid rural appraisal of farming in the western highlands*

74. The country was visited by the Project Manager in February 1994, and a rapid rural appraisal (RRA) conducted with IRZV staff in the mid to high altitude zone (MHAZ) (Map 2) to examine its suitability for project implementation. An important consideration was that the Bamenda region was Anglophone, so that there would be no language barriers to overcome for effective collaboration. The RRA examined the farming systems of the region in terms of crop rotations and labour availability in different seasons, local root crop cultivation and marketing methods and poultry production systems, the fuel energy resources suitable and available for the processing and marketing SP, CAS and maize, and the demand for maize and poultry products. There was stiff competition for maize between the human and animal feed sectors, with feed millers frequently buying the standing crop from farmers before harvest. However, cassava and sweet potato were of considerable importance to the livelihood strategies of small farmers and to the wider economy. The cost-structure and organisation of the local animal feed and livestock product sectors were also particularly attractive for the project concept. Chicken was the most expensive meat in the market (Appendix 16.3, Table 40) despite the availability of under-utilised feed resources.

75. Agriculturally, the MHAZ was the most productive zone of Cameroon (Appendix 16.3, Table 20), the production of maize, SP and CAS representing 68, 25 and 59 percent of the country's total production. Cassava was harvested all year round while sweet potato was harvested twice - as the wet season and dry season crops. These roots and tubers can be mixed cropped and intercropped with maize, and therefore would not raise the demand for land by a significant amount if the project led to an increased demand for SP and CAS. And since most of the root crops were harvested in the off season (the dry season) there would also not be much competition for labour and time for the smallholder farmer. Sweet potato in particular appeared to be under-utilised and there was spare capacity to increase further production.

76. For CAS various traditional methods of processing have been developed to make it more palatable, as for example in the fermented products '*garri*' and '*fufu*'. Garri had a high urban demand because of its grainy texture. However, it absorbs water and becomes quite sticky, so that it is not as palatable as maize, and makes one bloated; whereas maize is grainy and does not make one feel bloated. SP is more palatable than CAS, especially when roasted (a high cost processing) but it too is less palatable than maize and makes one bloated quickly. Because of these food palatability characteristics it was not considered surprising that the population preferred maize; significantly, even many hotel waiters referred to sweet potato as 'dog food' because it was produced in much larger quantities than could be consumed.

77. The method and cost of drying and storing the maize relative to SP and CAS were also important project considerations. The IRZV experimental station at Bambui had a special hut with hollow tin rolls under the floor into which logs were inserted. The maize on cobs were piled on a raffia-bamboo platform inside the building and the logs were set alight to heat up the room above in order to dry the maize. This form of drying maize is needed during the wet season crop in August when the first crop if maize is harvested and needs to be marketed. It is a high-cost method of drying, using firewood as fuel, with resulting environmental problems. Since most of the SP and CAS for this project was to be harvested between December and March (the dry season), these commodities can be processed into poultry feeds using solar energy: not only would this reduce the cost of drying the energy component of poultry feed the processing would be more environmentally-friendly than using maize. Thus, because of abundant production and low-cost processing, incorporation into poultry diets was economically feasible so that the farmer could once again produce poultry meat and eggs at a profit and stimulate poultry production. The use of the tuber and roots would, therefore, reduce the competition for maize between the human food and animal feed sectors.

78. The region also had several high-protein feed resources, including fishmeal, cottonseed cake (CSC), palm kernel meal, blood meal, brewery dried grains. CSC, in particular, was under-utilised and, therefore, cheap and NRI studies had shown it to have good potential as a complementary feed for SP and CAS in poultry rations. Of particular interest was the widespread use of traditional palm fruit processing in rural areas for cooking oil, a process that generates a number of by-products, such as palm pit sediment (PPS), whole palm kernel (WPK), and palm kernel cake (PKC). These materials were considered to have good potential for use in peasant poultry production systems (see Section 11.5.5.). For the approach adopted in this adaptive project to be harmony with the farming systems of the region it needed to maximise the use of these local feed resources.

79. CIP's West and Central Africa station was in Bambui, within the premises of the Institute of Agronomic Research (IRA), while new offices were opened by IITA near Yaounde for cassava development. The results of the strategic research conducted at NRI on SP (see paragraphs 97-102) and CAS (Panigrahi *et al.* 1992a; Panigrahi, 1996) were discussed with IRZV, CIP and IRA researchers. Local researchers supported the project concept as fitting well into the national priorities and developmental plans for agriculture. IRZV had carried out much research on the use of root crops in livestock diets, although the concept of cereal-free rations was new. Poultry production based on commercial feeds was in decline during the recession, for which the only viable option was to reduce feed costs to produce eggs and poultry meat cheaper. However, this needed to be achieved by enabling the poor (especially women farmers and unemployed youth) to engage in profitable poultry rearing. A new orientation to get farmers back to keeping chickens and staying in business was required that was based on making chicken feed available and affordable by resource-poor farmers. Researchers agreed that small-scale farmers needed technologies to become as independent of feed millers and institutional support as possible; but progressive, rather than retrogressive, in chicken production.

11.2.2.2. *Local institutions and facilities*

80. IRZV had 12 regional stations in Cameroon of which two were in the MHAZ. One was the Mankon Research Station (MRS) near Bamenda, and the other was the IRA in Bambui. The two centres were situated 5 hours drive from Yaounde, and were 30 km apart. The stations had facilities for all classes of livestock, including poultry, rabbits, pigs, sheep, goats cattle and horses. There was over 140 ha of land available and a number of large production sheds. The poultry houses were adequate for conducting feeding trials, but some upgrading of equipment was necessary to enable statistically-valid feeding trials to be conducted. Other facilities included an animal feedmill and hatchery (unused) and an experimental abattoir for pigs, poultry, rabbit and smallstock. At MRS, there were laboratories for analytical chemistry, biochemistry, mineral analysis, histology, a grinding room for animal feed preparation, chromatography and distillation unit. However, as recurrent costs had been cut, few of the major analytical equipment (such as the amino acid analyser) were in good working order. It was also noteworthy that MRS had previously implemented an aid-funded project in which a diesel-powered cassava grater was developed; this was still in good working order.

81. The RRA study also identified support institutions which could facilitate project implementation. A local engineering firm, CAIPCIG, was visited and discussions held on the design of a manual machine to slice or grit SP and CAS into particles sufficiently small for practical sun-drying, the fundamental technology on which the project concept was predicated. CAIPCIG had worked for aid agencies for many years in developing farm implements, and had well-trained engineers to develop the machine. Their resources for research was, however, limited so that much project funds would have had to be diverted for their services. The Presbyterian Rural Training Centre (PRTC) were also involved in producing farming household implements, such as hoes, seeders, and cassava graters for garri production Of particular interest was that their main activity was to train extension workers in advising smallholder farmers. PRTC had in the past also been involved in animal feed production and its sale to local farmers but which was discontinued when

demand fell. The NGO was, therefore, keen to participate in the proposed project. PRTC also had significant financial resources to devote to project activities.

11.2.2.3. *Implication of rapid rural appraisal findings for management of field work*

82. The findings of the RRA summarised above led to the selection of this site for the project. However, the study had also made it clear that the project design needed to pay close attention to the characteristics of the mixed farming and backyard poultry systems operating in the MHAZ (including the social and environmental considerations) as well as organisational and managerial aspects of project implementation. For this, a poultry farm characterisation study was initially required to assess the resources and constraints of resource-poor poultry producers such that poultry rations could then be designed to meet their circumstances. A study of the detail required could only be conducted by the IRZV researchers based in the project area. MRS scientists were well-placed for this work because of their superior knowledge of the local environment, institutions and social customs, and the fact that one of the scientists (Dr Pone) had already previously studied small-scale poultry production systems in the area.

83. It was also clear that the limited funding available from LPP would make the project difficult to implement unless the management of field activities was devolved to the IRZV, and IRZV devoted a great deal of its own resources in a collaborative project. A memorandum of understanding was, therefore, signed by NRI and IRZV (Appendix 16.2). The LPP funds for local expenditures were then channelled separately through a sub-component project (F0060) of Project F0004, established as an Extra-Mural Contract. Project F0060 was managed by Dr Banser (Director of IRZV) who reported to the Project Manager of F0004, who in turn reported to the LPP Manager.

11.3. Project Strategy

11.3.1. *Outline of approach*

84. The basic project strategy was to conduct strategic research on feed selected feed raw materials of relevance to field activities in the environment- controlled poultry houses of NRI, and on-station and on-farm feeding trials in Cameroon in an iterative manner to maximise the chances of developing maize-free, SP and CAS-based poultry rations that will be adopted by farmers. The strategy is a modification of the farming system adaptive research and extension (FSAR/E) methodology, as discussed by Collinson (1987). The approach is based on the need to obtain precise measurements of responses to experimental factors/stimuli in conventional technical research, for which treatments need to be isolated as effectively as possible from uncontrolled sources of variation. These measured responses are then used as indicators of potential improvements in farm system productivity. A conflict naturally arises between precision in the quantification of treatment responses and exposure to these wider sources of variation. In adaptive research, the control of these sources of variation is therefore gradually relaxed as monitoring and measurement of the variations and their effects on response becomes increasingly important down the FSAR/E sequence. Accordingly, the poultry feeding trials were planned to take place in three stages (a) in the facilities of NRI (full environment and researcher-controlled), (b) on-station trials at MRS (open-house caged-system without temperature and humidity controls and but with researcher control), and (c) on-farm trials (in farmer's premises under farmer control).

85. To ensure that NRI experiments and field activities remained integrated, good communications were maintained during the project using postal and courier services and telephone and telefax facilities, depending on the urgency and importance of particular project documents. Additionally, visits, at yearly intervals, were made by the Project Manager to the field site, for detailed discussions and the rescheduling of activities as these proved necessary.

11.3.2. *Nutritional requirements of hybrid chickens*

86. It is essential to know the nutritional requirements of different classes of poultry before considering how to develop rations. Detailed nutritional considerations are not given here as these may be found in any standard text books on the subject (for example, see Parr *et al*, 1988). For the small-scale rural poultry sector, it is sufficient to consider the following nutrients for broilers chicks and laying hen rations: Crude protein, metablisable energy, calicum, proporus, salt, lysine and mettium + capture.

87. In Table 1, a range is given for figures of nutrient requirements because, strictly, requirements are be based on productivity expectations. In addition, a vitamin-mineral package is provided at dietary fixed inclusion rate to meet all the essential micro-nutrient requirements of chickens. For egg production, a particular concern may be egg yolk quality. If the acceptability of yolk colour is poor, the ration will require a natural pigment source or, if this is not available, a commercial product. Finally, drugs may be added to feeds to counter diseases such as coccidiosis.

Table 1. Major nutrient requirements of different classes of chickens (% unless otherwise stated)

	Broilers[1]	**Layers chick (0-8 weeks)**	**Layer rearer (8-16 weeks)**	**Laying hen (17 weeks+)**
Crude protein	19-24	18-21	14-16	16-19
Metabolisable energy (ME) (MJ/kg)	12.00-13.20	10.8-12.0	10.8-12.00	11.0-11.5
Calcium	1.0-1.2	1.0-1.2	1.0-1.2	1.0-1.2
Phosphorus	0.60-0.75	0.65-0.70	0.65-0.76	0.65-0.73
Salt	0.4-0.5	0.4-0.5	0.4-0.5	0.4-0.5
Lysine	1.15-1.35	1.15-1.25	0.9-1.15	0.85-1.0
Methionine+cystine	0.80-92	0.80-0.91	0.75-0.90	0.75-0.90

Note: 1. Broiler starter require higher crude protein (23-24 %) and lower ME than broiler finisher rations.

11.3.3. *The technique of poultry ration formulation*

88. It is appropriate to give a brief account of what is involved in least-cost poultry ration development. A good deal of information is needed before it is possible to determine poultry ration formulae. It is necessary to obtain the nutritional composition of all the raw materials available, which should be analysed. A 'second-best' alternative is to guess at the nutritional composition of these feeds by reference to standard text books, that is use '*book values*' of composition (see Appendix 16.3, Table XIII of Parr *et al.*, 1988). However, this approach is not recommended because there is normally considerable variability in the composition of some raw materials, in particular, oilseed cakes, cereal brans, meat and bone meal and fishmeal.

89. The basic technique of ration formulation is based on assessing the dietary nutrient requirements of chickens of different types (e.g. broilers for meat production, layers for egg production, breeders for reproduction, etc.) under different production systems, and then finding the correct mix of the raw materials available to achieve these specifications. However, economic benefits will only be realised by incorporating in this analysis, the prices of all the feeds that are available, so that the blend of different raw materials to provide the nutrients required by the animal at the lowest cost can be determined (so called least-cost ration formulation). It should be noted that prices vary in different seasons and from year to year so that least-cost diet formulation to be conducted periodically. Poultry producers, therefore, require on-going support in this aspect.

90. Another factor that the nutritionist needs to consider is whether any of the raw materials available has toxic or anti-nutritional principles that limit their dietary inclusion rates. Furthermore, for poultry rations in particular, a commercial micro-nutrient (vitamins and minerals) premix need to be added to the ration at fixed (low) dietary inclusion rates (up to 5 per cent), although, frequently it is given in the drinking water supply with drugs (as in Cameroon). For examples of vitamin and mineral requirements of different livestock, see Appendix 1, Table VII of Parr *et al.*, 1988.

11.3.4. *Adapting rations to the resources and constraints of the target user*

91. It was mentioned above that nutrient requirements of poultry depends on productivity expectations. Crucially, it is essential to know what type of livestock production system is operational for which rations are required. For chickens the basic question concerns whether farmers keep free-range (backyard-type) indigenous chicken (which have low growth rates and egg production) and for which supplementary feeds are being considered, or those rearing high-yielding hybrid chickens under more intensive conditions. For the latter, the plane of nutrition needs to be adjusted in accordance with the resources, constraints and objectives of farmers. For poultry production the value of the poultry excreta (litter) generated needs to be considered in developing the feeding system, as this represents a major co-product of the poultry sub-system within some mixed farming systems in sub-humid agro-ecological zones.

92. In essence, for small-scale peasant poultry production ration developmental research is needed which utilises high levels of local feedstuffs not directly in the human food chain, and for which processing costs can be minimised by reducing the use of wood- and fossil fuel energy resources. Such poultry rations stand the best chance of being adopted on a large scale by resource-poor farmers; however, the variability in quality, the seasonality and multiplicity of feedstuffs, and fluctuating prices poses a considerable challenge for finding the optimal ration mix. The approach adopted needs to be one of optimisation and optionisation, whereby farmers can switch between one optimal ration formula to another depending on the availability and prices of feeds.

11.3.5. *Maintaining the quality of poultry feeds*

93. The quality of poultry rations depends on the technology used in processing the individual feed raw materials, the form of presentation in terms of particle sizes, and associative effects related to these factors. To ensure high quality, careful management of the collection, processing, drying and storage of ingredients is essential. In practice, the procedure needs to balance the temptation to keep costs low by considering the time, energy (fuel-type) and space use, and maintaining a nutritional quality. For example, high temperature processing of high-in-protein feeds (such as blood meal) will reduce the protein digestibility. Other aspects of quality influencing the nutritionist, the feed miller, the poultry husbandry person, and affecting the chicken in terms of productivity concern the bulkiness, dustiness, consistency of feed particle sizes and the presence of anti-nutritional factors.

94. The user of a ration formula needs to pay attention to the quality of raw materials used. At the small-scale where unconventional feeds are used more care is generally needed. These apply to some ingredients in particular, such as bone meal (for which one needs to ensure that it is not contaminated with hooves and horns), blood meal (for which the temperature of boiling needs to be kept low), and brewers dried grains (which needs to be collected fast off the production process, drained quickly, and dried within 3-4 days).

95. Once a ration is suggested the user must recognise its specificity in terms of the ingredients it contains. Rations are so-designed that one cannot leave out any ingredient or include more or ess of it. Slight changes to the 'wrong' ingredient in terms of quantity could markedly affect the nutrient balance and result in poor poultry performance. If sudden problems in the availability of a particular

feed ingredient are encountered, it is necessary for the user to move on to a different ration formula altogether.

11.3.6. *Mixing poultry rations on a small-scale*

96. It is essential to get a very good blend when preparing poultry feeds. An attempt should be made to obtain a homogenous mixture even if very basic 'bucket' or 'floor & shovel' methods of mixing are employed. This can be achieved by adopting a step-by-step approach. Ingredients that are included in the ration in the smallest quantity (e.g. blood meal, fishmeal, bone meal, oyster shells, salt, etc.) must first be accurately weighed and hand-mixed in a bucket, ensuring that there is no loss by wind blowing any feed particles away. Other ingredients should then be added to this and the blending continued. This mixture should then be transferred to a larger drum, or better still, a cement mixer, if this is available. The mixture is, therefore, gradually bulked-up. The largest ingredient (SP or CAS) should be added last of all, and it is at this stage that floor mixing may be employed. Absence of colour patches or streaks in the mixture is used at each stage as a guide to how well the ration is being blended. In this regard, the white colour of CAS and SP is particularly helpful.

97. The temptation to produce a very large batch of a ration that would last for long periods must be avoided, particularly when the ration contains ingredients with high fat content. Mixing small quantities every 3-4 weeks using fresh feeds is suggested. This will increase production cost for a commercial miller because of extra labour requirements but it should be more appropriate for the small farmer who has limited storage space and cash for procuring large quantities of feed. Small batches of 25 kg are also easier to blend on a regular basis.

11.4. Research activities at NRI

98. NRI had not previously conducted research on the processing and use of SP in poultry diets, the previous work programme being concentrated on CAS. Thus, some strategic research on this commodity was necessary in controlled laboratory conditions before the field work could be planned. All technical considerations stem from the need to process tubers and roots in order to dry, preserve and convert it into particles sufficiently small that these can be consumed by chickens. The relevance factors concerning tubers and roots are: (a) basic nutritional composition of as determined by proximate composition and amino acid profile (assumed to be variety and cultivar-dependent); (b) the Metabolisable energy value as assessed by the digestibility of starch, which may be related to the amylose to amylopectin ratio, and free sugar content (these are assumed to be dependent on variety and method of processing); (c) the anti-nutritional and toxic components (trypsin inhibitor activity in SP and cyanide in CAS, both being variety and processing method dependent); (d) whether the commodities should be peeled or left unpeeled; and (e) the form in which it is presented to poultry, for example given as mash, grits or pellets, and whether digestibility increasing enzyme supplements are added. It should be noted that poultry require small particles for ingestion, but grinding tubers and roots increases the cost of producing poultry feeds and produces dustiness which reduces feed intake, poses feed handling difficulties, increases losses during transport and storage and from increased feed spillage behaviour by poultry. Further, the sun-drying profiles of different varieties of SP and CAS chips and grits of different dimensions, need to be determined as these will affect the practicality and cost of processing, and thus the viability of the concept of converting the commodities to poultry feeds.

11.4.1. *NRI Phase 1 strategic research*

99. Two hypotheses concerning sweet potato were of importance to the design of field work: first, that cultivars varied in nutritive value for poultry, with the implication that certain varieties were more suited for use than others; and second, that the nutritive value of different cultivars could be affected differently by the processing method employed (because of differences in starch, amylase, anti-nutritional factors, and peel thickness), thereby influencing the feed technology that should be adopted. In the NRI Phase 1 studies, the objective was to determine whether the variety of SP and the conditions of chipping, drying and grinding the tubers were important factors that needed to be considered for effective planning of the field work. Thus, the research was designed to identify (a) cultivars with greater potential for development as poultry feed, and (b) the most appropriate method for processing different cultivars.

100. An experiment was conducted to determine the effects of different processing methods on the chemical composition and nutritional value of different sweet potato cultivars. Since high-yielding varieties are gradually replacing the traditional varieties of sweet potato in developing countries, it was decided to concentrate project effort on cultivars that have recently been established in the field or those on the verge of being promoted in developing countries. Accordingly, the assistance of CIP (Peru) was sought for a supply of tubers. Eight varieties of SP were cultivated at CIP (Peru) during the winter of 1992-93, harvested between March and May and air-freighted to NRI. The cultivars are shown in Table 2.

101. The processing study was designed to investigate the effect of different drying conditions on peeled or unpeeled, sliced tubers. The experiment comprised a factorial arrangement, with sliced tubers from 8 cultivars, peeled or unpeeled, being dried as follows: artificial sun-drying (X); slow oven-drying (Y), and rapid oven-drying (Z). The tubers were processed into 4 mm oblong shaped chips using the C3 plate of the TRS food processor. The drying conditions were selected to examine the effects of different drying rate and humidity conditions (correlated factors), with the drying rate from artificial sun drying being intermediate to those in the two oven drying cases. Environmental humidity was an important factor to consider for the field work: if found to influence nutritive value it could, for example, determine the season in which field trials were conducted. Tubers were sliced

longitudinally (oblong shape) at a thickness of 4 mm. Thermometers will be placed in the samples to monitor temperature changes during drying. For artificial sun drying (X) the temperature of samples ranged between 33 and 35°C, whereas the oven drying methods produced temperatures of 40°C (Y) and 80°C (Z). It was considered that at higher processing temperatures starch gelatinisation might occur to improve starch digestibility, while trypsin inhibitors might be inactivated to reduce anti-nutritional activity. The peels from each cultivar were also collected and oven-dried at 40°C for 24 hours. The drying samples were weighed periodically, and moisture determination on sub-samples was carried out at the beginning and end in a force-draught oven set at 105°C for 3 hours. Drying rates and other technical characteristics were determined.

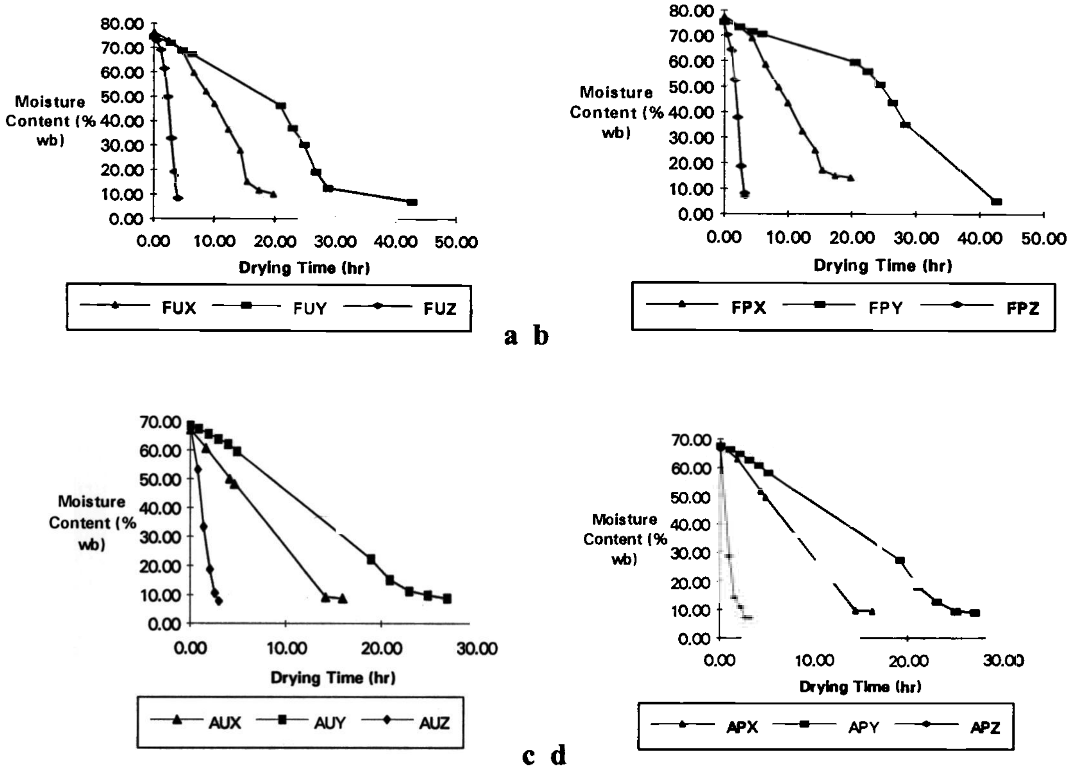
Table 2. Cultivars of sweet potato used in the NRI studies.

NRI Code.	CIP Accession No.	Cultivar Name
A	440031	Jewel
B	187003.1	ST 87.070
C	193001.1	AVRDC 3.005
D	193002.1	AVRDC 5.018
E	490082.1	CHGU 12.001
F	490074.1	CHGU 1.0003
G	490141.1	JPK9 12.011
H	490142.1	RURB 15.004

102. Forty-eight tuber samples (and 8 peelings) were produced and drying curves obtained for each treatment. Some examples of drying curves are shown in Figure 1(a-d). As would be expected, the high dry matter tubers dried quicker, and the drying curves followed the same pattern for all varieties. The artificial solar drying method allowed quicker drying than the 40°C oven drying method due to the high humidity in the latter, 80°C oven drying producing the quickest drying by far.

103. From the drying curves the dry matter content of fresh tubers were determined (Table 3). The dried samples were assessed for nutritional value using proximate composition trypsin inhibitor activity and *in vitro* digestibility using the method of total dietary fibre (TDF) (Tables 4 and 5), and changes in carbohydrate composition in terms of total and reducing sugars and total starch contents (Table 6),. TDF is an *in vitro* enzymatic procedure that gives a measure of the solubility of a feed following sequential treatment with alpha-amylase, amyloglucosidase and protease. Thus, it is likely to reflect whole-gut digestibility more closely than the other methods. The TDF figures showed significant effects of cultivar ($P<0.0001$), drying method ($P=0.0040$), and peeling ($P<0.0001$). Cultivar D was the most digestible and cultivar F, the least. Slow rates of tuber drying under humid conditions (drying condition Y) also appear to have resulted in higher TDF value meals and, as expected, peeled samples yielded lower TDF values than unpeeled, on average. However, TDF values also show an interaction ($P=0.0009$) between cultivar and peeling, a finding of significance for field work, since peeling involves much labour and, hence, cost. It would appear that SP with more digestible peels should be selected for poultry feeds so that the peeling stage may be avoided. There were also indications of an interaction ($P=0.0790$) between cultivar and drying method which, if confirmed, will also influence the field work. TDF appears not to be related to dry matter content of SP, variety CHGU 1.0003 (NRI code F) having the lowest dry matter and the highest TDF value while AVRDC 5.018 (NRI code D) having a moderate dry matter content but the lowest TDF value.

Figure 1 a-d. Examples of drying curves for sweet potato chips for determining processing characteristics, moisture content expressed on a wet basis (wb).



Legends: first letter- sweet potato variety (see Table 2), second letter - unpeeled (U) or peeled (P); third letter - dried by artificial solar 34°C (X), oven at 40°C (Y) or oven at 80°C (Z)

Table 3. Dry matter content of the CIP cultivars determined during the drying trials.

Sweet potato variety	Peeling	Dry matter (DM) content of fresh tuber (%) determined during drying trials			Mean DM (%)
		Artificial solar 34°C drying (X)	40°C oven drying (Y)	80°C oven drying (Z)	
A	Unpeeled	31.79	31.71	31.41	31.64
A	Peeled	32.85	32.36	33.34	32.85
B	Unpeeled	36.04	34.92	35.06	35.34
B	Peeled	35.88	38.05	34.15	36.03
C	Unpeeled	38.45	37.94	37.35	37.91
C	Peeled	38.20	37.68	37.75	37.88
D	Unpeeled	32.78	32.24	30.69	31.90
D	Peeled	32.55	33.53	34.10	33.39
E	Unpeeled	35.84	34.5	34.19	34.84
E	Peeled	36.81	34.66	34.32	35.26
F	Unpeeled	22.52	25.4	24.68	24.20
F	Peeled	23.53	24.74	25.00	24.42
G	Unpeeled	38.10	36.75	38.22	37.69
G	Peeled	39.73	39.09	39.78	39.53
H	Unpeeled	35.90	33.48	34.17	34.52
H	Peeled	33.81	37.27	37.56	36.21

Table 4. Nutritional value of sweet potato tubers from CIP after drying (g/kg dry matter).

Treatments[1]	Drying time (hrs)	Moisture	Crude fat	Crude protein	Crude fibre	ADF[2]	Ash	TDF[3]	TIA[4]
AUX	12.78	85.9	12.5	59.8	34.2	61.3	34.6	13.46	1.95
AUY	21.31	87.0	-	57.2	37.7	71.6	37.2	15.57	2.12
AUZ	2.07	77.2	-	60.1	37.3	68.5	33.2	14.53	2.11
BUX	12.93	94.5	-	68.2	28.2	44.1	26.2	10.95	4.53
BUY	22.02	88.2	10.7	66.7	27.3	49.6	26.3	11.84	4.64
BUZ	1.57	62.1	-	67.7	25.5	41.3	27.3	10.02	4.68
CUX	12.75	92.4	6.67	50.5	31.4	60.1	36.0	13.94	4.09
CUY	19.29	96.9	-	50.8	32.9	65.5	37.8	14.76	3.43
CUZ	2.04	69.6	-	51.5	29.2	55.0	35.0	13.26	4.04
DUX	16.41	88.2	-	63.7	32.6	49.7	33.0	9.58	6.34
DUY	26.41	88.1	-	62.6	30.4	48.5	30.0	11.68	5.72
DUZ	1.67	69.9	-	65.8	29.0	43.3	34.9	10.19	5.98
EUX	7.88	85.9	-	26.0	32.7	63.0	34.5	11.73	1.62
EUY	28.79	111.5	10.4	30.6	30.6	69.1	36.6	12.02	1.88
EUZ	2.62	97.5	-	27.3	33.1	52.2	32.7	12.79	1.53
FUX	15.3	98.3	21.9	24.9	46.8	75.2	45.8	16.62	1.94
FUY	28.18	71.9	-	33.4	46.1	80.0	48.1	15.57	2.41
FUZ	3.33	82.2	19.7	32.7	47.8	81.8	49.7	16.03	1.81
GUX	10.15	100.2	-	42.5	30.2	48.2	32.4	11.14	5.29
GUY	32.57	80.9	-	45.9	29.6	58.4	37.1	12.24	5.27
GUZ	2.12	47.5	-	49.1	30.4	50.1	35.6	10.74	6.39
HUX	9.54	76.4	-	28.0	30.7	55.9	40.5	10.86	3.27
HUY	37.73	114.2	8.5	31.3	31.1	63.1	43.0	11.89	3.69
HUZ	3.18	102.7	-	31.2	31.9	67.4	44.6	12.20	3.25
APX	13.13	93.8	-	54.9	30.1	43.6	27.8	12.15	2.43
APY	22.27	89.3	-	58.8	30.4	55.6	27.1	13.39	2.26
APZ	1.52	65.5	11.2	57.5	28.1	46.6	26.4	12.17	2.35
BPX	14.19	81.8	-	64.8	23.2	31.7	19.5	9.5	4.41
BPY	26.41	96.8	10.0	66.5	23.6	36.8	21.4	10.71	4.60
BPZ	2.12	66.2	-	74.5	24.6	32.6	22.5	9.88	5.40
CPX	13.06	94.1	-	48.4	26.2	36.6	27.6	10.4	3.60
CPY	19.9	84.1	-	49.9	24.6	40.1	27.2	11.01	3.24
CPZ	2.35	75.8	-	48.1	25.3	35.4	28.3	10.25	3.45
DPX	15.0	88.2	-	61.7	23.8	30.7	25.3	7.5	5.74
DPY	25.2	87.3	-	58.1	24.7	32.9	25.0	8.32	5.04
DPZ	3.64	69.9	-	53.0	22.3	29.1	24.8	7.46	5.24
EPX	11.29	82.5	-	27.1	25.2	42.5	26.7	10.15	2.37
EPY	24.24	53.2	-	27.7	27.4	49.4	27.5	10.74	2.21
EPZ	2.27	88.1	-	27.6	30.1	46.5	28.6	11.26	1.92
FPX	17.31	141.2	-	35.3	43.7	64.7	38.3	14.41	3.00
FPY	33.77	50.8	17.2	31.1	38.1	58.2	34.1	13.08	1.98
FPZ	2.62	71.4	-	31.6	43.5	61.6	37.9	13.3	1.63
GPX	8.48	74.9	-	45.6	25.7	35.3	22.7	8.52	5.80
GPY	29.39	52.9	-	45.4	25.9	36.5	24.3	9.26	5.34
GPZ	2.58	22.2	-	46.4	25.6	36.8	22.9	9.5	5.66
HPX	13.71	155.4	-	34.1	27.7	45.1	34.6	11.39	4.39
HPY	28.11	53.5	-	31.0	25.2	57.7	31.7	12.17	3.13
HPZ	2.12	39.0	-	31.7	27.4	48.4	32.1	10.55	4.13
A-PEEL	-	72.5	-	78.4	93.5	264.4	105.6	38.31	1.02
B-PEEL	-	70.3	-	85.7	97.8	259.4	117.4	36.82	1.88
C-PEEL	-	71.2	-	55.3	83.2	226.3	100.9	32.74	1.14
D-PEEL	-	74.7	-	84.0	96.6	221.8	85.8	34.69	2.07
E-PEEL	-	68.5	-	40.9	97.6	271.2	130.6	37.99	1.44
F-PEEL	-	61.9	-	52.6	112.0	339.6	183.5	45.92	1.24
G-PEEL	-	64.1	-	54.4	99.7	272.1	156.9	42.55	1.65
F-PEEL	-	68.0	-	42.9	80.6	227.4	131.4	35.66	1.56

Notes: 1. In treatment codes, first letter denotes the cultivar (A-H), the second whether peeled (P) or unpeeled (U), and the third the drying method (X = artificial solar; Y = 40°C oven; Z = 80°C oven). 2. ADF = Acid detergent fibre. 3. TDF = Total dietary fibre. 4. TIA = Trypsin inhibitor activity (mg trypsin inhibited per g dry matter.

Table 5. The main effects on the total dietary fibre (TDF) values for processed sweet potato tubers.

Level	SEM	Count	TDF (%)	Significance (P=<)
Grand mean	0.073	48	11.72	
Cultivar	0.206	6		0.0001
A			13.55	
B			10.48	
C			12.27	
D			9.42	
E			11.45	
F			14.83	
G			10.23	
H			11.51	
Drying	0.126	16		0.0040
X			11.51	
Y			12.14	
Z			11.51	
Peeling	0.102	24		0.0001
U			12.73	
P			10.71	

Note: SEM=pooled standard error of means.

Table 6. Starch and sugar content of sweet potato tubers from CIP after drying.

Treatments[1]	Reducing sugars content (g/kg)	Total sugars content (g/kg)	Starch content (g/kg)
AUX	70.58	216.44	514.65
AUY	77.24	229.76	505.94
AUZ	74.72	234.16	493.66
BUX	29.23	95.84	620.25
BUY	43.23	139.06	586.14
BUZ	31.22	115.09	565.06
CUX	41.10	158.86	504.04
CUY	56.44	165.20	475.08
CUZ	46.58	160.46	472.70
DUX	28.77	133.30	502.08
DUY	35.87	144.72	462.62
DUZ	37.19	152.00	477.40
EUX	40.95	121.76	506.14
EUY	53.52	141.86	570.82
EUZ	48.96	134.31	657.64
FUX	135.48	282.90	480.25
FUY	127.16	246.49	456.36
FUZ	123.30	249.36	473.20
GUX	16.26	102.58	645.22
GUY	33.60	152.34	581.32
GUZ	20.99	119.77	640.52
HUX	20.52	122.71	579.46
HUY	37.68	132.03	622.42
HUZ	27.87	153.58	626.41
APX	65.65	231.38	490.72
APY	71.0	229.44	471.43
APZ	68.02	223.74	500.14
BPX	29.25	139.12	524.22
BPY	45.54	162.48	541.08
BPZ	27.00	113.76	598.12
CPX	25.60	148.82	525.05
CPY	40.97	166.98	517.86
CPZ	29.40	138.56	565.12
DPX	32.76	161.10	544.20
DPY	37.60	190.28	576.33
DPZ	33.16	142.05	519.14
EPX	39.56	124.59	656.88
EPY	57.14	149.87	538.16
EPZ	45.30	135.37	677.84
FPX	127.54	268.64	477.80
FPY	154.95	251.69	402.59
FPZ	124.68	234.03	434.78
GPX	16.74	137.01	615.22
GPY	27.09	151.44	568.04
GPZ	14.38	111.06	590.56
HPX	16.14	146.08	637.37
HPY	30.76	134.58	581.53
HPZ	13.60	133.53	588.21
A-peel	86.26	193.68	251.14
B-peel	74.06	154.38	287.68
C-peel	75.14	179.19	310.90
D-peel	79.18	183.30	287.52
E-peel	85.98	182.04	288.80
F-peel	91.38	196.08	170.12
G-peel	78.11	199.19	244.79
F-peel	82.23	196.88	295.08

Notes: 1. For treatment codes, see Table 4

104. The benefits of peeling tubers and roots on nutritive value differed for different varieties but on the whole were not great, whereas peeling represented a major cost in time and labour for the production of poultry feed. A decision was taken at this point to conduct all future project work with unpeeled SP and CAS. Although the results showed that both variety of SP and processing conditions had significant effects on the nutritive value of SP, as assessed by TDF and starch and sugar contents it was not clear whether the effect of processing was temperature or humidity-related. Further, since no systematic study is reported on the usefulness of these techniques for predicting the nutritive value of sweet potato for poultry there was uncertainty on how TDF related to feeding value to poultry.

105. For amino acid composition, only the artificial solar dried unpeeled tubers samples were analysed as it was clear that this was the technology to be adopted in the field work. The amino acid composition of the 8 cultivars varied, as shown in Table 7. As expected, the crude protein content of the eight cultivars varied greatly. However, lysine content also varied on a g/16 g nitrogen basis, from 3.95 for variety B to 6.60 to varieties E and H.

106. A second experiment was required to confirm the findings of a varietyxprocessing interaction by feeding dried SP to chickens. This research needed to be focused at identification of cultivars with greater potential for development as a poultry feed. From the results of the NRI Phase 1 research the three that would have best served the objectives of the project were (NRI Code/CIP Code/ Cultivar Name): D/193002.1/AVRDC 5.018, E/490082.1/CHGU 12.001, and F/490074.1/CHGU 1.0003. However, lack of project time to grow sufficient quantities of the tubers at CIP (Peru) and the need to proceed with the project work led to these studies being shelved. It is expected that a future collaborative programme of research with examine these varieties in greater detail.

107. Instead of these varieties it was decided to continue project work with two commercial varieties of SP (Bosbok and Carmel) obtained from UK markets. Unpeeled tubers were chipped into 4 mm oblong shapes and oven-dried at 40, 60 or 80^{o}C to examine effects on nutritive value. The dried ground chips were substituted for maize at 500 g/kg diet and fed to day-old, Ross-1 broiler chicks. Compared with Carmel, Bosbok had a slightly lower crude protein content (90 v 138 g/kg DM) and trypsin inhibitor activity (TIA) (3 versus 5 mg of trypsin inhibited per g flour). Processing did not significantly affect TIA, but the lysine and cystine contents were lowered, and the starch content raised, as the drying temperature increased. However, whereas this was reflected in increased reducing sugars in Carmel, there was no such trend in Bosbok. See Panigrahi *et al.* 1996a.

108. The results of *in vitro* pancreatin digestibility and TDF assays (not shown in Table 8) showed variety and processing temperature to be significant factors influencing the nutritive value of SP, with a varietyxdrying temperature interaction also being indicated. The interaction was also observed for weight gain, dry matter intake, water:food intake ratios, excreta water content, presence of bile in excreta (Table 8) and liver weights. The best growth was obtained with Bosbok dried at 60^{o}C, for which liveweights at 21 days were 11 per cent lower than for the maize controls (not shown in Table).

109. A correlation study was incorporated in the design of this experiment in order to determine the predictive power of TDF. There was poor correlation between TDF and growth performance, indicating that *in vitro* techniques, which are not able to take account of voluntary food intakes on diets of different texture or toxins, cannot replace whole animal feeding studies in the screening of SP for high feeding value in chicks. For details of the findings from this experiment, see Panigrahi *et al* (1996a).

Table 7. Amino acid composition of eight cultivars of artificial solar dried, unpeeled sweet potato chips.

Samples	AUX	BUX	CUX	DUX	EUX	FUX	GUX	HUX
Nitrogen (N) (%)	0.96	1.09	0.81	1.02	0.42	0.40	0.68	0.45
Amino acids (g/16 g N)								
Aspartic acid	17.35	24.14	15.18	21.74	9.35	11.81	15.42	9.35
Threonine	4.29	4.15	5.11	4.81	4.88	4.72	4.80	4.88
		4.85	5.60	5.51	5.68	5.82	5.53	5.68
		11.31	13.04	11.21	13.06	14.40	11.25	13.06
Glycine	3.69	3.34	4.42	4.07	4.63	5.09	4.31	4.63
Alanine	4.54	4.41	5.78	5.32	4.72	5.45	5.12	4.72
Valine	5.33	5.42	6.27	5.94	5.44	6.08	5.87	5.44
						4.33	4.48	3.98
						6.85	6.23	5.92
						4.28	3.75	3.46
	4.60	5.16	5.71	5.53	5.44	5.65	5.50	5.44
	4.48	2.51	2.50	2.44	2.65	3.11	2.68	2.65
	8.21	6.93	5.63	5.05	7.75	6.24	4.71	7.75
				4.33	6.30	4.20	3.92	6.30
				4.72	6.60	6.26	5.04	6.60
				2.07	2.64	2.89	2.45	2.59
	2.52	2.35	3.64	2.97	4.14	3.44	3.52	3.87
	5.98	6.82	5.05	6.37	2.60	2.49	4.25	2.80
Amino acids (g/100 g sample DM)								
Aspartic acid	1.04	1.65	0.77	1.38	0.24	0.29	0.66	0.26
Threonine	0.26	0.28	0.26	0.31	0.13	0.12	0.20	0.14
Serine								
Glutamic acid								
Glycine								

Table 8. Performance of chicks during 0-14 days on Carmel and Bosbok SP (Least Squares Means).

	Maize Control	Sweet potato variety						Pooled SEM[1]	Significance (P=or<)			
		Bosbok			Carmel				Diet	Var	Temp	Var*Temp
Drying temperature		40°C	60°C	80°C	40°C	60°C	80°C					
***Growth parameters*:**												
Weight gain (g)	381^{a}	307^{c}	332^{bd}	322^{bc}	302^{d}	293de	281^{e}	2.32	0.0001	0.0001	0.2482	0.0213
Dry matter (DM) intake (g)	418^{a}	371^{cd}	402^{ab}	388^{bc}	378^{cd}	365de	352^{e}	2.44	0.0001	0.0006	0.1124	0.0047
Organic matter intake (g)	387^{a}	345^{cd}	372^{ab}	361^{bc}	347^{cd}	335de	321^{e}	2.24	0.0001	0.0001	0.1167	0.0038
EDMU[2]	0.911^{a}	0.828^{b}	0.827^{b}	0.832^{b}	0.798^{b}	0.802^{b}	0.798^{b}	0.005	0.0001	0.0177	0.9804	0.8852
Efficiency of organic matter utilisation	0.985^{a}	0.891^{b}	0.894^{b}	0.893^{b}	0.870^{b}	0.874^{b}	0.875^{b}	0.005	0.0001	0.1393	0.9415	0.9900
***Nutrient retention*:**												
Dry matter retention (%)	0.599^{ab}	0.606^{b}	0.610^{b}	0.608^{b}	0.592^{ab}	0.591^{ab}	0.587^{a}	0.002	0.0928	0.0026	0.9192	0.8715
Organic matter retention (%)	0.635^{a}	0.642^{a}	0.648^{a}	0.648^{a}	0.642^{a}	0.643^{a}	0.636^{a}	0.002	0.7376	0.2666	0.8298	0.7531
N[3] retention (%)	0.545^{a}	0.552^{a}	0.623^{bc}	0.571^{a}	0.631^{bc}	0.669^{c}	0.647^{c}	0.008	0.0016	0.0016	0.0441	0.6264
AME[4] of DM (MJ/kg DM)	12.79^{c}	12.12^{b}	12.02^{b}	11.97^{b}	11.87^{ab}	11.64^{a}	11.61^{a}	0.04	0.0001	0.0017	0.2011	0.8287
AME of organic matter (MJ/kg DM)	13.83^{a}	13.03^{b}	13.00^{b}	12.86^{b}	12.94^{b}	12.68^{b}	12.72^{b}	0.05	0.0001	0.0694	0.2901	0.6249
AMEn of DM (MJ/kg DM)	11.90^{a}	11.31^{c}	11.11^{bc}	11.11^{bc}	10.87^{ab}	10.62^{a}	10.60^{a}	0.039	0.0001	0.0001	0.0608	0.9548
N retained:GE metabolised (g/MJ)	2.02^{ab}	1.93^{a}	2.20^{b}	2.11^{ab}	2.43^{c}	2.56^{c}	2.53^{c}	0.024	0.0001	0.0001	0.0148	0.5387
***Other symptoms*:**												
Water:food intake (ml/g)	3.04^{a}	3.59^{b}	3.73^{bc}	3.77^{c}	4.36^{d}	4.49^{d}	4.82^{e}	0.021	0.0001	0.0001	0.0001	0.0240
Water:DM intake (ml/g)	3.42^{a}	4.02^{b}	4.16^{b}	4.20^{b}	4.88^{c}	4.98^{c}	5.31^{d}	0.023	0.0001	0.0001	0.0003	0.0590
Excreta water content (%)	67.0^{a}	75.2^{b}	78.7^{c}	77.6^{bc}	83.7^{d}	84.1^{d}	84.6^{d}	0.36	0.0001	0.0001	0.0013	0.0144
Pasty vents-day 6[5]	19^{a}	19^{a}	56^{bc}	63^{cd}	30^{ab}	87^{d}	74^{cd}	3.7	0.0002	0.0703	0.0002	0.6125
Pasty vents-day 6[6]	0.55^{a}	0.55^{a}	1.41^{ab}	1.18^{ab}	0.81^{a}	2.90^{c}	1.92^{bc}	0.139	0.0025	0.0224	0.0042	0.3245
Bile in excreta-day 10[6]	0.95^{ac}	0.70^{abc}	0.09^{a}	0.39^{ab}	3.19^{e}	1.85^{d}	1.33^{cd}	0.088	0.0001	0.0001	0.0001	0.0038

Notes: Least squares means adjusted for Block and Tier effects only. Key: 1 - SEM=Pooled standard error of means. 2 - EDMU = efficiency of dry matter utilisation: gain:food; 3 - N=nitrogen; 4 - AME = apparent metabolisable energy; AMEn= nitrogen corrected AME; 5 - % of chicks affected; 6 - scored on a 1-3 scoring system. Values in the same horizontal line with different superscripts are significantly different (P<0.05).

11.4.2. *Implications of NRI Phase 1 research findings for planning of field work*

110. Previous NRI research had similarly shown that different varieties of CAS vary in cyanide content, and that the rate at which cassava root chips are dried affect the cyanide content, and hence,its feeding value for poultry (Panigrahi *et al.*, 1992). The significance of these NRI strategic research findings on both root crops for the planning of field work was four-fold: (a) for SP, it strongly suggested that the field activities should initially be conducted in a country with a distinct dry season, confirming the western highlands of Cameroon as the ideal site; (b) the benefits of peeling roots and tubers on nutritive value were small, at least for some varieties, but peeling by hand involved considerable which would increase the cost of feed production - it was therefore decided to conduct all subsequent project work with unpeeled SP and CAS; (c) there was a clear need to evaluate local varieties of root crops in the project site area by conducting poultry feeding trials and select the optimum variety for on-farm trials; and (d) it was neccessary to complete the tuber processing in the dry season, the period associated with low humidity. This raised the question of the storability of sun-dried SP and CAS for use in the remainder of the year. In the selected project site, the dry season was short so that only limited amount of root processing work could be done. This, in turn, affected the cost and length of the project above those specified in the original Concept Note (Appendix 16.1).

11.4.3. *NRI Phase 2 adaptive research*

111. The NRI Phase 2 experiments involved selected feed development research to determine the optimal root and tuber processing methods and the ration characteristics suitable for field testing on-station and on-farm. Forty-six, 5-6 kg samples of SP and CAS feed and feed mixtures with other agricultural wastes in the project field site were prepared by the MRS team during 1995 and air-freighted to NRI for assessment of their feeding value to chicks. These studies need to be conducted under tightly controlled experimental conditions. Details of when the samples were prepared and used in NRI experiments are shown in Appendix 16.4. The samples were sub-sampled for proximate and amino acid composition and stored at 5°C. When the composition was known short broiler (*'look-see'*) trials were conducted in environment-controlled poultry houses to determine their feed potential. Since these trials were conducted using caged chicks, excreta could be collected for gross energy determination and nitrogen retention. From the balance studies, the apparent metabolisable energy (AME) value of the test feed ingredients were revised (Appendix 16.5).

112. It should be stated that for logistical reasons these feeding trials could only use a small number of chicks (12 chicks per treatment) and be conducted over only a two-week feeding period, Thus, the results could only be used as a guide for developing the field activities. However, despite ther '*look-see*' nature the results provided a good indication of feed potential and eliminate technologies that appeared to have little potential for application. A preliminary screening of this nature is essential if only to prevent high-cost large-scale field trials with inappropriate technology from being conducted. In this project, the findings formed the basis for selecting the precise dietary formulations for pre-testing in on-station poultry feeding trials, and thence, in on-farm trials. It should also be noted that not all the findings from these NRI '*look-see*' trials could be incorporated in the first on-farm trials, for two reasons: (a) logistically, the timing of feed preparation work in MRS, the NRI Phase 2 feeding trials, and the on-station and on-farm poultry feeding trials could not be aligned as originally, the field activities were scheduled to take place over only a 2 year period; and (b) due to uncertainties concerning the nutritional values of most of the feed raw materials available it was decided to develop rations step by step by developing some basic rations and gradually improving these by introducing small changes at a time.

113. The '*look-see*' studies examined the benefits of using (a) grits produced from the fresh SP and CAS to enable high food intakes by chicks and reduce dustiness in feeds; (b) fresh SP and CAS that are solid-state fermented (SSF) prior to sun-drying in an attempt to improve feeding value, and (c) feed mixtures of SP and CAS with local agricultural processing by-products available in the project

field site area (the materials were palm pit sediment (PPS), whole palm kernels (WPK), palm kernel cake (PKC), cassava leaf meal (CKM) and sweet potato leaf and vine meal (SPLM).

11.4.3.1. *Part 1. Studies completed before the planning stage of the first on-farm feeding trials*

114. In Trial 1, SP and CAS shreds were prepared in MRS after the fresh materials using the J3 plate (Appendix 16.7) of the Crypto Peerless Dito Sama TRS electric food processor (TRS) and sun-dried. The shreds measured 2 mm diameter by 10 mm length for SP and 2.5 mm by 14 mm for CAS. These were then crumbed in to grits in a 5 kg Hobart mixer followed by hand crumbling. The grits were fed to 6-day-old broiler chicks. Younger chicks were not used due to uncertainty on whether day-olds can cope with grits well. The results showed that gritting SP and CAS made a marked improvement in the performance of broiler chicks overall, primarily by improving feed intakes (Table 9a). However, it was quite clear from looking at the excreta that the grits being poorly digested by the chicks. On the other hand, the performances of chicks fed the CAS grits were excellent. Based on these preliminary trials, more extensive gritting trials were planned in MRS to determine the optimal grit size produced directly from the TRS machine (see Sction 11.5.10). As for varietal differences, the results provided early evidence which was later confirmed in first on-station feeding trials (see section 11.5.7) that for CAS, the White variety was superior in feeding value to Red, and for SP, 1112 was superior to both TIB1 and TIB2.

115. Following the results of Trial 1, it was necessary to test how chicks coped with ground SP shreds, and also whether day-old chicks could utilise these feeds. Thus, in Trial 2, the SP-PPS and CAS-PPS feeds were tested after grinding all the samples. Due to the limitation of facilities, not all of the treatments prepared at MRS could be tesed in this experiment and it was decided to omit the ones with 15 per cent PPS inclusion. Table 9.6 shows that there was a much better utilisation of the SP-based diets in terms of dry matter retention in this experiment as compared with Trial 1, indicating that grinding improved the digestibility of the grits. However, food intake was now much lower than that of controls, probably because of the powdery nature of the diets. Food intake was also lower for the CAS-based diets. It was, however, clear that PPS had made a significant contribution to the nutrient content of diets as an energy source, replacing some of the maize oil that was added to the other diets to maintain the energy level. PPS did not reduce performance, but the 20% inclusion rate with cassava appeared to give the best results.

116. Overall, the results showed that the technology of PPS dried on to sun-dried tuber and root grits is beneficial and practical for use at the small farm level. It can be seen to be serving four purposes: providing nutrients to the diet, improving the dustiness of root crop-based feeds, preventing the wastage of a resource, and solving a local pollution problem arising from the pit sediment being normally allowed to run out and contaminate soil and ground water. The decision was taken to promote its use in the first on-farm trials. However, an appropriate level of treatment first needed to be tested in on-station trials feeding first (see paragraph 198, Table 19).

117. In Trial 3, it was decided to test the use of ground SP-based feeds on day 4 of age instead of in day-old chicks to food intakes relative to maize contrls. The results were most encouraging, with the higher levels of WPK inclusion rate in particular giving high food intakes and weight gains (Table 6). Finely ground WPK appeared to assist the chicks in consume the SP meal by improving diet texture. The decsion was taken to incorporate WPK as a dietary ingredient in the planning of the on-farm trials.

Table 9. Results of NRI broiler chick feeding trials, using chicks of different ages.

Treatments	Weight gain	Food intake	Gain:food ratio	Dry matter Retention
(a)**Trial 1- May 1995 (6-21 d of age):**				
Maize control	644	1047	0.62	0.67
SPTIB1, J3 sun-dried grits crumbed	571	1053	0.54	0.59
SPTIB2, J3 sun-dried grits crumbed	564	1055	0.54	0.61
SP1112, J3 sun-dried grits crumbed	589	1100	0.55	0.62
CASRed, J3 sun-dried grits crumbed	621	1045	0.60	0.70
CASWht, J3 sun-dried grits crumbed	649	1043	0.62	0.71
(b)**Trial 2 - July 1995 (0-13 d of age):**				
Maize control	371	446	0.83	0.67
SPTIB1-5%PPS	357	426	0.84	0.68
SPTIB1-10%PPS	321	389	0.83	0.69
SPTIB1-20%PPS	345	416	0.83	0.69
SPTIB1-25%PPS	348	422	0.82	0.70
CASWht-5%PPS	365	407	0.90	0.74
CASWht-10%PPS	378	417	0.91	0.74
CASWht-20%PPS	388	430	0.90	0.73
CASWht-25%PPS	368	416	0.88	0.73
(c)**Trial 3 - July 1995 (4-18 d of age):**				
Maize control	563	772	0.73	0.63
SPTIB1-5%WPK	547	766	0.71	0.59
SPTIB1-10%WPK	556	769	0.72	0.62
SPTIB1-15%WPK	525	745	0.70	0.61
SPTIB1-20%WPK	560	782	0.72	0.62
SPTIB1-25%WPK*	583	804	0.72	0.62

Notes: PPS - palm pit sediment; WPK - whole palm kernels. SPT1B, SPTIB2 and SP1112 - sweet potato varieties TIB1, TIB2 and 1112, respectively; CASRed and CASWht - cassava varieties Red and White respectively. J3 refers to TRS plate used to produce shreds. Feed mixes were included in balanced diets at 40% in Trial 1 and at 42.5% in Trials 2 and 3. * Additional energy given to this ration compared with others.

118. In Trial 4, detailed observations were made on the utilisation of CAS with WPK or PKC by day-old chicks. Food intakes and weight gains were recorded on a daily basis to detect whether chicks had difficulty in consuming these materials when combined in a ration. The objective was to test the suggestion of the results of Trial 3 that WPK (and possibly PKC) could cause positive associative effects to promote the intake of CAS meal by day-old chicks. In this trial, the samples were ground in a hammer mill through a 6 mm screen so as to obtain a range of particle sizes, ranging from finely ground to about 3 mmx3 mmx3 mm bits (most were less than 1.5 mm). The samples were incorporated in the diet at 46.5 per cent, the composition of some are shown in (Table 10).

Table 10. Composition of selected diets in NRI Phase 2 Trial 4 to test various cassava and whole palm kernels (WPK)- or cassava and traditionally-processed palm kernel cake (PKC)-based diets.

Diets:	Control-maize	CAS-25% PKC	CAS-25%WPK
Ingredients:			
CASWht-25%WPK	0	0	46.5
CASWht-25%PKC	0	46.5	0
Maize	60	0	7.81
Maize gluten feed	11.82	9.32	6.42
Fishmeal	9.79	8.23	12.07
Soyabean meal	16.54	30	24.6
Maize oil	0.06	4.1	1.56
Dicalcium phosphate	0.07	0.78	0
Limestone	0.62	0.19	0.28
Salt	0.13	0.17	0.1
Lysine-HCl	0.32	0.04	0
Methionine	0.15	0.17	0.16
Premix	0.5	0.5	0.5
Total	100	100	100

Note: PKC - palm kernel cake produced by traditional boiling method. AME value used for diet formulation (MJ/kg DM): CASWht-25%PKC 14.25; CASWht-25%WPK 14.55. Calculated analysis of diets: crude protein 21.75 %; AME 12.3 MJ/kg.

119. The results are presented in Table 11. It was observed that chicks found the ration highly palatable and enthusiastically consumed the cassava particles right from day 1. This resulted in a high food consumption, which in some treatments were similar to that in the controls (maize diet). Although food intakes then became lower, this might have been due to the higher digestibility of these diets compared with that of the controls, as is indicated from the figures for dry matter retentions. The first days food intake showed that food intakes increased with an increase in the PKC (and concomitant decrease in CAS) up to 20 per cent PKC but at 25 per cent PKC there was a decrease. With WPK, the food intake increased with greater replacement of CAS. It was pleasantly surprising to note that by the 12th day, there were no differences among treatments in weight gain. Over 0-12 days, there were no significant differences between the weight gain of chicks fed the test diets and those fed maize, due to the higher dry matter retention and efficiency of food utilisation in the former groups. The results again showed that both PKC and WPK have good potential for use in poultry diets.

Table 11. Results of broiler feeding trials in NRI Phase 2 Trial 4 conducted in September 1995 to test various cassava and whole palm kernels (WPK)- or cassava and palm kernel cake (PKC)-based diets.

		Food intake of chicks (g/d)				Total	
Period of trial (days)	**1**	**2**	**3**	**4-6**	**7-10**	**11_12**	**0-12**
Treatments:							
Maize- control	11.6	13.2	17.7	28.5	42.9	60.5	420.7
CASWht-5%PKC	10.9	11.2	15.4	24.0	40.0	60.6	390.7
CASWht-10%PKC	11.8	12.3	16.2	25.6	39.4	58.4	391.7
CASWht-20%PKC	12.0	12.3	17.2	25.2	40.2	59.2	396.6
CASWht-25%PKC	11.3	11.8	16.5	24.3	39.6	59.2	389.3
CASWht-5%WPK	11.6	11.5	15.9	24.7	40.9	61.1	398.9
CASWht-10%WPK	12.3	11.5	16.8	24.5	40.2	59.7	394.5
CASWht-20%WPK	11.9	12.5	16.1	24.6	40.8	62.2	402.1
CASWht-25%WPK	11.3	11.7	16.2	25.2	41.2	62.5	404.4

		Weight gain of chicks (g/d)					Total
Period of trial (days)	**1**	**2**	**3**	**4_6**	**7_10**	**11_12**	**0-12**
Treatments:							
Maize- control	14.1	15.1	14.4	22.3	32.3	42.9	325.4
CASWht-5%PKC	12.1	13.0	12.7	20.6	32.8	48.1	328.6
CASWht-10%PKC	13.3	14.3	15.0	21.7	31.5	45.1	323.7
CASWht-20%PKC	13.5	14.5	14.1	21.8	32.7	46.3	331.9
CASWht-25%PKC	11.7	13.3	14.6	20.2	32.3	46.1	322.0
CASWht-5%WPK	13.2	13.7	14.2	21.5	34.3	48.3	341.2
CASWht-10%WPK	12.8	13.0	14.9	21.5	33.2	46.5	332.0
CASWht-20%WPK	13.4	14.5	12.8	21.2	33.4	50.2	339.6
CASWht-25%WPK	12.7	13.7	14.3	21.0	33.9	49.4	339.1

	Efficiency of food utilisation (gain/food)				Water:food intake (mls/g)	Excreta moisture (%)	Dry matter retention
Period of trial (days)	**0-6**	**7-10**	**11-12**	**0-12**	**0-7**		**8-11**
Treatments:							
Maize- control	0.862	0.753	0.707	0.773	2.11	58.4	0.66
CASWht-5%PKC	0.912	0.829	0.795	0.841	2.36	66.0	0.73
CASWht-10%PKC	0.916	0.798	0.772	0.826	2.24	62.6	0.71
CASWht-20%PKC	0.919	0.818	0.782	0.837	2.24	56.8	0.68
CASWht-25%PKC	0.891	0.818	0.779	0.827	2.25	59.1	0.68
CASWht-5%WPK	0.935	0.848	0.791	0.855	2.34	67.8	0.72
CASWht-10%WPK	0.920	0.831	0.778	0.841	2.36	63.8	0.71
CASWht-20%WPK	0.912	0.825	0.808	0.845	2.25	62.7	0.69
CASWht-25%WPK	0.903	0.830	0.790	0.838	2.17	61.1	0.69

11.4.3.2. *Implications of NRI Phase 2, Part 1 research findings for planning of field work*

120. These studies identified PPS and WPK as two feed ingredients that had potential for on-farm application as part of poultry feeds for small-scale rural farmers. Whilst the use of PKC was promising, the quantities available is low since only a few farmers practice this method of oil extraction (paragraph 142). The use of PKC was also considered to be too much trouble for project researchers in terms of the volumes of materials that would have been needed and the quantity of fuelwood that would have been used to generate the required amounts. Even more importantly, despite the high nutritive value of PKC it was considered that the high cost of wood fuel used in this oil extraction process renders this technology economically and environmentally unsustainable. It was, therefore, decided not to promote its use through this project. The NRI Phase 2 Part 1 studies, therefore, selected the use of WPK, PPS along with CAS and SP as the most important on-farm feed resource to form the basis of ration development. Thus, for the first on-farm broiler trials it was planned to test three treatments (Tables 19 and 20) as follows:

Diet A.	SP at 50 %, WPK at 15 % dietary inclusion (plus balancer)
Diet B.	CAS at 50 %, PPS at 5 %, WPK at 10 % dietary inclusion (plus balancer)
Diet C.	Best commercial diet

11.4.3.3. *Part 2. Studies completed after finalising the rations for the first on-farm feeding trials*

121. Since the powdery nature of SP and CAS meals produced dustiness, which causes a lowering in food intake to reduce poultry performance (as observed in the NRI Phase 2 Trials 1-4) feed technologies to overcome this dustiness are needed which would be appropriate for adoption by resource-poor poultry producers. The tuber and root gritting technology was simultaneously researched and developed (Section 11.5.10) represents a major attempt to address this issue. The use of PPS dried on-to tubers and root grits should also improve teed texture due to its high oil content. Solid-state fermentation of CAS may also improve nutritional characteristics, as evidence by human food products such as 'garri' and 'fufu' in West Africa, both products representing major improvements in the palatability of CAS. It is possible that SSF improves feed texture by allowing the release of microbial enzymes which act to change starch characteristics. If ammonium salts are added during the fermentation process, there may also be an increase in the protein content of CAS. Since the use of SSF represented a simple-to-use, low-cost feed technology, it was decided to test its benefits on SP and CAS for poultry feeding. In Trial 5, SSF of SP and CAS was conducted on freshly produced shreds from the J3 plate of TRS. The shreds were placed in PVC bags and the mouths sealed with ropes. After 24, 48 and 72 hours of fermentation the grits were sun-dried.

122. A 14-day broiler chick feeding trial was conducted using 5-day-old chicks to determine the effects of feeding chicks with SP and CAS prepared using the SSF technology. These materials were ground and included in balanced diets at the 40 per cent inclusion rate. The results are shown in Table 12.

123. The growth performance of chicks improved by the use of SP and CAS produced by SSF. However, with CAS there was a deciline in dry matter retention and food intake was also reduced with the 72 hours of fermentation.This sample had a 20 per cent moisture content and had become quite mouldy, which might explain the poorer performance obtained with this treatment. With SP, 48 hours fermentation resulted in weight gains similar to those in the maize-control group. The effect appears to be due to an improvement in food intake due perhaps to an improved feed texture caused by SSF, possibly by reducing dustiness and increasing density. Because SP is lower in nutritive value compared with CAS and maize, the results of this '*look-see*' experiment indicates that SSF technology might offer the prospect of feeding SP to obtain growth rates comparable with maize at the small farmer level because of the simplicity of the technique. It was essential to repeat this experiment on a larger scale in an on-station feeding trial.

Table 12. Results of broiler chick feeding trial (Trial 5) with solid-state fermented grits from sweet potato tubers and cassava roots (5-19 days of age), conducted in April 1996.

	Weight gain (g)	Food intake (g)	Efficiency (gain/feed)	Dry matter retention
Maize controls	501	717	0.70	0.73
SP-24 hr fermented	490	703	0.70	0.66
SP-48 hr fermented	503	723	0.70	0.67
SP-72 hr fermented	508	736	0.69	0.66
CAS-24 hr fermented	458	628	0.73	0.78
CAS-48 hr fermented	504	695	0.72	0.76
CAS-72 hr fermented	481	684	0.70	0.75

124. In Trial 6, the effect of feed mixtures of SP with sweet potato leaf and vine meal (SPLM) and CAS with cassava leaf meal (CLM) were tested.The SP-SPLM and CAS-CLM were prepared in MRS (as described in paragraph 150-151) and fed to 2-day old broiler chicks. The raw materials were incorporated into nutritionally-balanced diets such that the leaf meal content of the diets were 3, 6 and 12 per cent. The results are shown in Table 10. With the SPLM the growth performance was poor and its use in poultry diets is, therefore, not recommended. For CLM, however, the responses obtained at 3 and 6 per cent dietary concentrations were good. Since 2-day-old chicks are not expected to be able to consume as much cassava as maize due to the powdery texture of the former, the significant findings were that at 6 per cent CLM dietary inclusion rate, food intake was not lower than at 3 per cent CLM level, that both diets had similar efficiencies as the controls, and that their dry matter retentions were similar to controls. Thus, a 6 per cent inclusion rate was considered to be optimal in terms of growth performance that took into account food intakes. Another very significant finding was the fact that the CLM produced yellow carcasses, and, therefore, should be an important source of yolk colour pigment for laying hen diets if it is included in the ration at 3-5 per cent inclusion rate. It is known that poultry production systems in countries of the Far East use cassava leaves as feeds, so that it would be appropriate to test these in laying hen diets in particular.

Table 13. Results of broiler chick feeding trial (Trial 6) with sweet potato with its leaf and vine meal and cassava roots with its leaf meal (0-12 days of age), conducted in April 1996.

Dietary inclusion rate of test materials (%)	Weight gain (g)	Food intake (g)	Efficiency (gain/feed)	Dry matter retention
Maize (controls)	340	453	0.75	0.70
4.6 % SP-3 % SPLM	334	445	0.75	0.69
9.2 % SP-6 % SPLM	305	420	0.72	0.67
18.3 % SP-12 % SPLM	296	415	0.71	0.63
5.0 % CAS-3 % CLM	318	430	0.74	0.71
10.0 % CAS-6 % CLM	322	429	0.75	0.71
20.0 % CAS-12 % CLM	294	399	0.73	0.70

11.4.3.4. *Implications of NRI Phase 2, Part 2 research findings for planning of field work*

125. By July 1996, the results of the on-station testing of the first on-farm rations and the on-farm testing became available. Although these results proved promising for broilers and layers, there was significant scope for improving the ration to increase their production potential and profitability. The SP-based ration in particular required improvement. It was, therefore, decided to test the findings from the NRI Phase 2 Part 2 trials in another phase of on-station and on-farm poultry trials. Broiler and layer rations were developed for field testing a third on-station and second on-farm feeding trials conducted during 1997-1998. These trials tested, *inter alia*, the use of SSF technology and CLM with a view to encouraging on-farm application.

11.4.4. *Development of a feed composition chart for project field site region*

126. In view of the less than ideal results achieved on nutrient content of diets in the first on-station poultry feeding trials using '*book values*' of feed composition (paragraph 177), all potential feeds from the project field site were analysed at NRI for proximate composition, calcium, phosphorus, salt, and amino acid composition. In addition to the feed raw materials used for developing feed mixtures (see Section 11.5.6), other feeds readily available in the project site that were complementary to SP and CAS in ration formulation were also obtained. These were fishmeal, wheatfeed, meat meal, brewers dried grains, blood meal, bone meal, cottonseed cake, rice bran without chaff, broken rice with chaff, oyster shells, palm oil, commercially processed palm kernel meal, and soyabean meal. The metabolisable energy value (AME) values of these feed raw materials were estimated using the EEC-recommended method (EEC, 1986). However, for the feed mixtures used in the NRI Phase 2 feeding trials all diets and excreta were subject to gross energy determination from which the AME values were revised. The comprehensive analyses was supplemented with the price of each raw material in the project site region to result in the development of a Feed Composition Chart. This Chart (Appendix 16.5) served the purposes of the present project in terms of ration development. However, it is expected to also be useful to MRS and other research organisations in Cameroon in any future feed developmental research projects and should enable local government extension agencies to advise farmers on feed resources.

11.5. Research activities in Cameroon

127. The field work may be divided into ten inter-linking components: (i) conducting a poultry production systems characterisation study in the western highlands; (ii) selecting demonstration farms for on-farm stage; (iii) identifying local varieties of SP and CAS and other local agricultural by-products that may be complementary to the root crops for poultry ration development (iv) developing feed mixtures for testing their nutritional characteristics and potential for use in poultry diets for analysis at NRI (NRI Phase 2 studies) which then formed the basis of ration development for field testing; (v) conducting SP and CAS gritting trials for the development of a manual gritting machine; (vi) testing various dietary options in on-station poultry feeding trials before the on-farm trials; and (vii) implementing the farmer-managed on-farm poultry feeding trials by securing farmer participation; (viii) holding group discussions with participating farmers and other economic stakeholders after on-farm trials to assess the impact of the technologies developed; (ix) planning further activities for poultry ration improvement; (x) developing pathways for the diffusion of project-generated technologies to maximise impact.

11.5.1. *Poultry farm characterisation study*

128. The objective of this study was to determine the type of poultry production systems prevailing in the region in terms of the resources, constraints and objectives of farmers, and the feed resources available to them. This information was required for (a) identifying the types of small-scale poultry production systems in which the project concept would make the greatest developmental impact for the target beneficiaries; (b) determining the poultry ration technology that would have widespread applicability, and thus, will be adopted by largest numbers of resource-poor farmers; and (c) the selection of demonstration farms for the project. The report is shown in Appendix 16.3.

129. The main findings of the survey as these related to project development were as follows. There are two types of small-scale poultry production systems in the region: the traditional backyard scavanging chicken, and the modern poultry sector where birds are more productive but require large quantities of feed. Researchers agreed that there was little scope for intensifying the traditional backyard poultry sector. The project focused on the modern poultry sector, as practised by small-scale producers. These producers are characterised by being sufficiently progressive and resource-able to keep hybrid chickens in confinement. These are found in peri-urban areas as a purely an income generating enterprise and in rural areas poultry was a sub-system within a mixed farming system.

130. Eighty-seven per cent and 47 per cent of broiler and layer farms, respectively, had flock size of less than 500 birds, and there was a tendency for farmers to keep chickens as a prinicipal farm activity as flock size increased above 1000 birds. Although an upper limit of 500 chickens of either broiler of layer type may reasonably be used to define a 'small-scale poultry producer' (paragraph 55), following closer study during 1995 researchers agreed that only those farmers who kept less than 500 birds of the broiler type and less than 250 hens of the layer type should be termed resource-poor in the project site region. Thus, farmers maintaining more than these numbers of hybrid chickens were excluded from consideration in relation to ration technology to be developed in this project.

131. The study also showed that for substantial proportion of small-scale producers poultry was a component of a mixed farming system in which the excreta represented a major co-product of the poultry system. Thirty eight per cent of broiler, 31 per cent of layer and 26 percent of mixed broiler and layer producers cited the use of manure for crops as being a major output of the poultry production system. This is related to the fact that in this region, with an average farm of 2 hectares, as much food as is possible, needs to be produced for the family. The high seasonal rainfall leads to considerable leaching of soil nutrients in this type of agro-ecological zone. For smallholders chickens, pigs, goats and rabbits are the important farm livestock manure source. Thus, rations generating excessive quantities of excreta due to low digestibility (as might be expected with fibrous feeds such as palm kernels and leaf meals) are not necessarily a major disadvantage in this production system.

132. The high cost of feeds was the single most important concern for producers, representing 60-64 per cent of the cost of poultry production (Appendix 16.3, Table 44). Since broilers were not marketed by weight but by feed, producers were particularly concerned if they could not sell off all their chickens within a short time of the birds reaching marketable size since each extra day in poultry house would require feed the value of which would not necessarily be recovered from the sale of those chickens. Of particular interest to examine what type of poultry producer practised on-farm mixing of compound diets (Appendix 16.3, Table 23). 77 per cent of farmers who mixed their own feed were those with flock size of more than 2500 birds. Most of these follow a prescribed ration formula that is based on concentrates sold by a large feed company. Significantly, 15 per cent of the total number of farms mixing their own feed were in the <500 flock size category. These farmers, however, do not follow a formulae but dilute purchased feed with on-farm resources in an apparently 'irrational' manner as far as nutrient balance is concerned. However, the fact that they attempt some form of ration mixing is an indication that they derive economic benefits from this practice. Investigations are needed to find out precisely what these benefits are in each case. It was agreed by

the project researchers that this may be a particular target group who could be assisted by the project-generated ration technologies. Other producers in the <500 bird category do not risk diluting commercial feed or preparing own ration formulae due to lack of knowledge of the feed resources available to them.

133. Deep-litter (79 per cent) and slatted-floor made from raffia bamboo (19 per cent) were the predominant poultry housing systems in the region, battery caging system constituting the remainder. This has major implications for the development of rations and transferring them to the target group, particularly for laying hens. To keep costs down and enable more work to be conducted in a short time it is necessary to use caged laying hens for experimental work on-station because this allows individual hen food intakes and egg production to be recorded and statistical analysis of results can be reliably conducted to ensure the validity of feed developmental research. However, transferring feed technology from a caged-hen on-station system to deep-litter and slatted-floor on-farm housing system may cause difficulties due to the higher energy expenditure of birds and the social behaviour associated with the latter group-housed systems. Both these factors might also be flock density-related.

134. The purchase of day-old chicks represented 25 per cent of the cost of broiler production (Appendix 16.3, Table 44), being second to feed costs. In recent years the cost of day-old chicks had risen sharply. Since young broilers are very sensitive to environmental and feed quality factors in terms of the presence of anti-nutritional or toxic compounds (it may take up to 9 days for chicks to develop physiologically) brooding and feeding are vital elements that need to be considered together. Brooding methods used for day-old chicks is of considerable importance in highlands where the nights are cold. Broiler growth will be influenced by this factor, which could then affect the utilisation of diets containing unconventional feeds. Whole house brooding is preferable but this is costly in both house design and energy usage. The survey showed that 91 per cent of producers practiced partial brooding but paid close attention to the chicks during the most sensitive periods. The energy source used were kerosene where bush lamps are used (71 per cent), electricity where light bulbs are used (30 per cent) and wood or charcoal where fire or stoves are used (4 per cent). For nutrition, it is essential to determine at what age various unconventional (nutritionally problematic feeds) should be introduced to chicks.

135. The distribution of the age and sex of poultry producers was of particular interest (Appendix 16.3, Table 33). Fifty two per cent of broiler producers but only 11 per cent of egg producers and 20 per cent of mixed broiler and layer farms were female-owned and operated. Most poultry producers were in the 30-49 age group. In suburban areas a significant proportion of female poultry producers were the wives of well-to-do professionals which excludes them from consideration as a target group under gender concerns. Occasionally, poorer women pool resources to operate a poultry production unit jointly as a group.

11.5.2. *Selection of farm types for targeted poultry ration development*

136. The poultry farm characterisation study formed the basis for selecting farm types for which poultry feed technologies would be developed, so that in turn, the rations would have a good chance of being adopted by target beneficiaries. For this the target poultry roducer was defined. Small-scale resource poor farmers generally operated mixed farming systems of which poultry was a component or operated in peri-urban areas. In either case, the farm types selected were those keeping a maximum of 500 broilers or 250 layers per production cycle. Only producers with slatted-floor and deep-litter poultry systems were considered, since caging systems were costly and beyond the reach of these producers. Thus, farmers who maintained more than these numbers of hybrid chickens were excluded from consideration. This constituted the target group for poultry ration technology adaptation and transfer. Amongst other factors, the ration needed to take account of potential complementary feed resources available to these groups, for example, palm fruit oil processing residues (See Section 11.5.5.)

11.5.3. *Selection of participants for the on-farm feeding trials*

137. The on-farm trials had two objectives. First, it was necessary to test the project-developed rations under the conditions of farmers for whom these would be developed. Secondly, the trials would serve the purpose of promotion and diffusion of project-developed technologies. Thus, in addition to selecting some resource-poor farmers, it was decided to select some individuals and institutions who could promote the technologies developed in the project. The poultry farm characterisation survey showed the need to keep roughly 50:50 percent of male and females in these farms. Although few females kept layers, there was a need to conduct on-farm trials with some women to determine if more could be encouraged in this activity.

138. It was considered that both the objectives for the on-farm trials could be met if the following six categories of farmers and organisations were selected for the on-farm feeding trials:

(a) one small-scale male poultry producers involved in crop-farming and off-farm employment.

(b) one small-scale male poultry producer who with his family was involved in crop-farming but also owned a small-scale animal feed trading shop. This selection was made because it was considered that this person would be able to organise the local production of SP cand CAS by small-scale farmers and then produce and sell cheap feeds to serve the diffusion element in the objectives.

(c) two, small-scale female group poultry producers.

(d) Cameroon Women Income Development Cooperative (CAMWIDCO) a union of women group producers. This organisation is comprised of more than 50 individual women groups producing crops in the rural areas. The project-developed technologies could therefore be easily disseminated to thousands of rural women through its participation.

(e) Presbetarian Rural Training Centre (PRTC), a NGO involved in training agricultural extension workers in all aspects of farming, including crop, livestock and agro-forestry. Thus, it would provide another pathway for diffusion of project-developed technologies. A second reason was that PRTC has an strong engineering component, developing on-farm tools, and equipment for small-scale food processing such as cassava graters for garri production. PRTC has cooperated by contributing some of its own resources to develop the manual gritting machine, which is seen as a vital component of the package of technologies being developed by the project.

(f) one, respected village leader who guides local farming activities.

139. It should, however, be noted that transport costs in the highlands are extremely high and MRS vehicles were old. In order that researchers could coordinate project activities and supervise the on-farm feeding trials, all the participating farms were selected to be in the vicinity of the MRS except for the PRTC, which was furthest at 30 km.

11.5.4. *Identification of local varieties of sweet potato and cassava*

140. CIP has its Central and West Africa Regional Station at Bambui within the facilities of IRA. Mr J. Koi of CIP and Dr P. Tchamo (Chief of IRA) provided valuable advice on the type of sweet potato varieties being cultivated and being considered for future release in different agro-climatic zones of Cameroon. Based on these discussions, three varieties of sweet potato (TIB1, TIB2 and 1112) were cultivated during Year 1 for the on-station poultry feeding trials. The SP were grown by CIP in IRA fields. From Year 2 onwards MRS cultivated the tubers on their fields in order to retain greater control over its production and processing for project work, IRA being 20 km away from MRS.

141. For cassava, MRS sought the advice of IITA, who were still in the process of setting up offices in Yaounde, and evaluating data of potential cassava varieties in Cameroon. High-cyanide varieties of CAS have now largely been replaced by low-cyanide varieties. The two most common varieties cropped all over Cameroon are cassava white and cassava red, which were both low in cyanide, so that the rate of drying chips was not a factor to be taken into consideration for processing (paragraph). Because of their distinctive appearance and abundance it was decided to purchase these varieties from the market for project work rather than growing them, which would have been costly.

11.5.5. *Traditional rural cooking oil extraction from palm fruits*

142. The traditional method oil extraction from palm fruits is elaborate and labour-intensive, using up much of a day. The palm tree is a smallholder cash crop of major importance in West Africa. The tree produces a bunch of fruits (approximately 8 kg of fruits) and yields 2-3 crops a year (year-round cropping). When a bunch is ripe one or two fruits fall down which is the indication that the bunch should be harvested. A person climbs up the palm tree and cuts the bunch which falls to the ground. Villagers process the palm fruit using a pit method for extracting oil for own use and for sale. The process involves boiling the fruit until soft. The boiled fruits are then put in a platform that slants into a pit which is full of water. Men and women stand walk on the boiled fruits squeezing them with their feet whilst holding on to a bamboo pole placed above their head to prevent themselves from slipping and falling. A person stands in the pit and casts pit water into the feet of the the people pressing the fruits to assist in the extraction of high oil pulpy material which then runs into the pit. All the fibrous elements of the palm fruit and the palm kernels remain on the pit platform, from where palm fruit fibre and whole palm kernels (WPK) are separated.

143. After some time the palm oil floats to the surface of the pit water from where it is skimmed off and placed into a large pan. The pan is heated to drive out all the moisture, a point arrived when foaming begins. When clear oil with small particles are left, the clear oil is filtered through a hollow cattle horn that has a hole at the pointed end and a filter made from palm leves is placed inside. The oil is now ready for sale. The palm fruit residue remaining in the pit is termed palm pit sediment (PPS) and dilute slurry. These are normally discarded through a channel, where pigs may be allowed to consume the slurry as a wet feeding system. However, it is common to let out the slurry and sediment to run off quickly because on drying PPS become a hard like concrete-like cake which poses a major pit maintenance problem for the villagers. The run-off, however, represents a pollution problem affecting the local soil and contaminating ground water, of which there may be a shortage in the dry season in many villages in there may be a shortage of water in many village in highlands.

144. The second aspect of traditional rural oil extraction from palm fruits involves the production palm kernel oil, which sells for approximately four times the price of palm oil and is used as cosmetic oil, or for its health properties. Whole palm kernels are ground using a corn mill. Water is added at a ratio of 2:1 and the mixture is boiled over log fire for about 2 hours. Oil floating over the water is collected and more water is added as it evaporates during the oil extraction process. When the oil processing is complete, the water is strained to remove the palm kernel cake (PKC) and oil-

water mix heated to remove the moisture. The oil is then bottled for own use or for sale. Production of palm kernel oil by this method is, however, sporadic and may be considered environmentally unsustainable in terms of energy use.

145. Following the RRA in the prefeasibility study, it was considered that the PPS should have a high energy value (due to the residual oil content) and should contain vitamins, minerals and pigments for yolk and carcass colouration. It could be used for rural poultry production if the sediment was lifted out of the pits using a pan, mixed with sun-dried CAS and SP grits or meals, then further sun-dried to form a tuber- and root-PPS mix feed resource.If the technology was successful it would not only solve a local environmental problem, it would add value to an underutilised or wasted resource. Similarly, WPK and PKC represent potential rural feed resources for peasant poultry production. NRI has promoted a concept of integrated oil milling cum poultry production as an agricultural system in developing countries (Panigrahi, 1995) to assist the viability of rural small-scale oilseed processing and cultivation of traditional crops, which increasingly find it difficult to compete with large-scale industrial processing of introduced oilseeds such as soyabeans. This system of integration promotes rural income generation by resoure-poor farmers in both oil milling and poultry rearing activities. It was, therefore, decided to investigate the use of these resources as complementary feeds to SP and CAS in poultry ration development in the present project.

11.5.6. *Development of adaptive feed mixtures and sampling of complementary feeds for analysis*

146. The purpose of these activities was to adapt the rations to be consistent with the resources, constraints operating and opportunities available to the small-scale poultry farmers identified as the target beneficiaries of the project, in order that the on-farm trials could be appropriately designed. Approximately forty feed mixtures were developed for the assessment of feed texture and nutritional value in MRS and 5-6 kg samples were air-freighted (Appendix 16.4). In addition, during 1994 and 1995 MRS collected samples of a range of different feeds at different seasons of the year which were considered to have potential for use in poultry rations in the project field site, for nutritional analysis at NRI (NRI Phase 2 studies). The local prices of the feed materials were also recorded (Appendix 5). The following feeds and feed mixtures were analysed at NRI: local maize, three varieties of SP and two of CAS (see paragraph 112), PPS, WPK, PKC, solid state fermented SP and CAS, SP and CAS with their respective leaf meals, and a range of other local agricultural and slaughter house by-products. Details of the processing involved in these feed raw materials are as follows.

147. *PPS.* PPS was collected oil extraction pits in Mbwengi. After the farmers had finished extracting oil from palm fruits (paragraphs 140-141), the left-over water in the pit was allowed to stand for one hour to enable the sediment to settle and become thick. The sediment (PPS) was collected into PVC bags and the mouth sewed with nylon ropes. Heavy stones were placed on the bags to squeeze as much of the the excess water out as possible. The thickened PPS was mixed with CAS or SP in different proportions in small batches and sun-dried. However, for the first on-farm feeding trials for logistical reasons (larger quantities required) the thickended PPS was brought to MRS and sun-dried on a cement floor slab for two days. For the PPS sample analysed in NRI and for the material prepared for the first on-farm trials (including the on-station testing stage) the PPS was collected from pits into bags amd pressed at the point of collection. It was transported from Mbengwi to MRS and sun-dried on water proof paper on a cemented slab for about 23 hours. The final dry matter content was 12.1 per cent.

148. *WPK.* The best grade of palm kernels originating from the traditional methods of palm oil processing were purchased from MRS neighbouring markets. These were ground coarsely in a the MRS feedmill for the first on-farm trials.

149. *PKC.* Whole palm kernels of the best grade were ground using a corn mill and processed as described earlier (paragraph 142). The PKC was collected into a bag, which was then pressed to remove more water. The PKC was then removed and sun-dried over 16 hours.

150. *SP and CAS meals*. The dry matter content of the three varieties of SP were around 32 per cent, while for the cassava it was between 40-42 per cent. For the first on-station feeding trials, SP and CAS were processed using the J3 plate of the TRS vegetable preparation machine. The tubers and roots were washed and processed to produce 4-10 cm shreds which were then sun-dried, a process that took 7-10 hours. However, following the tuber and root gritting trials (see section 11.5.10), the AS4 plate of TRS was used for project work as producing the optimal processing and drying characteristics for efficient progress of the project activities. Dried samples were ground for inclusion in the rations.

151. *Solid-state fermented SP and CAS*. For the first NRI Phase 2 studies, SP and CAS were gritted using the J4 plate of TRS. The grits were placed in jute bags and the mouths sealed with nylon ropes. The bags were kept indoors at about 30^{0}C for 24, 48 or 72 hours before being sun-dried (or air-dried indoors using fans when raining). For the third on-station feeding trials (1997-1998), the AS4 plate of TRS was used. Photographs illustrating the drying process are shown in Appendix 14).

152. *Sweet potato leaf and vine meal (SPLM)*. For the NRI Phase 2 studies, sweet potato leaves were collected from farms around MRS. As this collection took place during the rainy season, the leaves were sun-dried whenever the sun was shining and air-dried within the building corridors of MRS using two table fans for one week. The dried leaf meals were ground through a Tecator 1093 grinding mill. The dry matter content was found to be 23.3 per cent. It was then mixed with sun-dried SP at 25:75 or 50:50 ratio.

153. *Cassava leaf meal (CLM)*. The cassava leaves for the NRI Phase 2 studies were also obtained in the rainy season when plants were growing had a high foliage cover. The leaves were sun-dried whenever the sun was shining and air-dried within the building corridors of MRS using two table fans for one week. The dried leaf meals were ground through a Tecator 1093 grinding mill. The dry matter content was found to be 22.08 per cent. It was then mixed with sun-dried CAS at 25:75 or 50:50 ratio. The leaves used in the third on-station broiler and layer feeding trials (1997-1998) were obtained at the end of the dry season when tubers were harvested and plants had low foliage cover. There are several uncertainties to consider in the use of CLM. First, the time of leaf harvest could affect its dry matter content, nutrient content, digestibility of nutrient, and cyanide content (and hence toxicity to chicks). Second, it is not known what effects the method of processing used in this project will have on the cyanide content of samples taken in the wet and dry seasons. With cassava roots, it was found that the rate of drying chips caused a marked reduction in cyanide content and poultry production (Panigrahi, *et al.*, 1992a) but it is not clear whether this applies to cassava leaves. It is generally accepted that tubers need to be chopped with the peel for linamarase to be released to enable the removal of cyanide, but it is again not clear whether leaves should also be chopped before sun-drying to remove cyanide. Third, for both SP and CAS the point in the growing season that leaves are harvested will influence tubers and root yield. This consideration is complicated by the facts that in the rainy season plants have more leaf cover for harvest than in the dry season when tubers are available for harvest, and further that in many farming systems including those in the MHAZ it is necessary to prune the leaves during the growing season as a pest control measure. The CLM samples used in the NRI Phase 2 feeding trial was obtained in the wet season, and it gave good results. However, for the third on-station feeding trial (1997-1998) CLM of necessity was harvested in the dry season so that there was still some uncertainty on its nutritional value for poultry at the time of testing.

154. *Bone meal*. Bone meal is a valuable source of calcium and phosphorus for the rural poultry sector in West Africa, where beef is cut and sold in all rural and urban meat markets. In 1994, due to the enonomic depression, bones were generally discarded in many markets in the project site and so could easily be acquired by small-scale processors to convert into bone meal. However, by 1996, there was a price for it and it appeared to be on the increase. Small scale processors may use several methods of preparing it, the most common in the project site region being either to burn the bones in an oven (or roasted over open fire) until they become grey in colour. Buring is necessary not only to

kill harmful micro-organisms but to render the bone easy to crush. It is generally done using the carcass fat as fuel. The resulting material may be called calcinated bone meal. Feed millers and nutritionists should take note that bone meal may sometimes by contaminated with horns and hoofs of cattle, which have very low calcium and phosphorus contents (Gohl, 1981, p 395-398).

155. *Blood meal.* Blood is available from local slaughter houses in quantities that varies with the season. In the dry season, less blood is available than in the wet season. However, the market for blood meal produced by small-scale processors was not well-established, resulting in low prices. Small scale processors can collect the blood and process them using simple techniques, such as boiling and spray drying. It is commonly boiled in pans over open fire until blood has coagulated and water evaporated. However, the nutritive value is dependent on the temperature of boiling, which should not rise above 120^{o}C at any stage. Blood should be boiled very slowly and stirred continuously and then spread over a concrete floor in a well ventillated room to cool and dry completely (Gohl, 1981, p 393). Whether all processors are aware of this is doubtful so that ration incorporation rate was limited to 2.5 per cent in the present project. A better method for using blood is to absorb it onto wheat middlings or rice bran and then heat from below or spread it in the sun to dry. This recommendation was however not practicable in the project field site due to the fact that blood is already partly coagualated before the small-scale processor can process it.

156. *Other feed raw materials.* Other feed resources available in the project site that were complementary to SP and CAS for ration formulation were sampled for analysis. These included fishmeal, wheatfeed, meat meal, brewers dried grains, cottonseed cake, rice bran (with and without chaff), broken rice, oyster shells, palm oil, commercially processed palm kernel meal, and soyabean meal. The proximate analysis of the feed samples were conducted at the National Nutrition and Biochemistry Laboratory (NBL) in Cameroon (see Appendix 16.3, Table 24). Some of the important analyses required for formulating rations (e.g. the mineral content of feeds) could not be conducted in Cameroon and were conducted in NRI. Subsequently, the scope of this analysis was extended to include amino acid composition and metabolisable energy values of the feeds to develop a feed composition chart (paragraph 107) for the project area. The results of NRI analyses are shown in Appendix 16.5.

11.5.7. *Testing tuber and root-based rations on-station before on-farm feeding trials*

157. The main objective of this project was the development of low-maize or maize-free ration formulae and associated feed technology that would be suited to adoption by small-scale farmers. The tuber and root gritting technology is an essential component of the strategy adopted to meeting this objective, but it was recognised that this technology will require time to develop and its success was by no means assured. The gritting trials and ration formulae development and transfer were, therefore, conducted in parallel in the expectation that if both aspects could be resolved by the final stages of the project, the two components could be packaged for one set of recommendations to small-scale farmers. This approach necessarily entailed the development of ration formulae using mash feed.

158. The NRI Phase 1 strategic research findings concerning the importance of cultivar and processing conditions on the nutritive value of sweet potato (paragraphs 97-108) and cassava were incorporated in the design of the ration development field studies in several ways. First, the three varieties introduced by CIP and cultivated in large quantities in the region (TIB1, TIB2 and 1112) and the two varieties of cassava (red and white) needed to be evaluated in on-station feeding trials in order that the SP and CAS varieties optimal in terms of processing characterics and high nutritive value were used in planning the on-farm rations. Second, all on-station and on-farm poultry feeding trials in relation to ration development were conducted with unpeeled raw materials, since the cost of labour and waste generated from peeling represented costs that were considered to too high to be compensated for by the higher nutritive value (up to 20 per cent as assessed by TDF). Third, the results indicated that field work must be conducted in the dry season (December-March) because of

the possible adverse effect of environmental humidity on nutritive value of SP during drying (as indicated by the results of the NRI Phase 1 studies). Fortunately, this decision was in accord with the farming systems of the region, as sweet potato is the only crop productive enough for the late (second) plantings in July so that it is ready for harvest during the dry season; and because considerably more labour is available in this season for the root processing work required by the ration technology proposed.

159. There were four inter-linking aspects to the on-station poultry feeding trials. These were: (a) assessment of the potential for including sun-dried, local varieties of SP and CAS with suitable agronomic characteristics of high yield and disease resistance, in broiler chick and laying hen diets; (b) assessing the storability of the sun-dried SP and CAS during the rainy season; and (c) developing the nutritional approach for the design of the socio-economically optimal poultry rations for the target beneficiaries; and (d) testing rations designed for farmers under researcher control in order to obtain reliable poultry performance data to ensure the suitability of the rations before on-farm testing under farmer control.

11.5.7.1. *Broiler 1 and layer 1 feeding trials to evaluate local varieties of tubers and roots*

160. For the first on-station trials, it was essential to ensure the purity of the tubers from the TIB1, TIB2 and 1112 varieties of sweet potato. Another consideration was the need for sweet potato to be cultivated specially for the project so as not to disrupt the local economy by the removal of large quantities from the market. For sweet potato cultivation the assistance of the local CIP and IRA research stations (in Bambui) was sought, and a collaborative programme of work agreed. The three varieties were cultivated on separate fields on IRA premises (Bambui) by the local CIP staff. However, due to insufficient planting material, the quantitiy of TIB2 produced proved inadequate for both the broiler chicken and laying hen feeding trial, as required by the experimental design (see below). Nevertheless, sufficient material was available to make valid comparisons of varietal differences.

11.5.7.1.1. *Dietary treatments*

161 The dietary treatments for the broiler trial were:

- A Control diet (containing >60 % maize, as in the commercial poultry feeds)
- B 40 % sweet potato tuber meal (variety TIB1)-based diet
- C 40 % sweet potato tuber meal (variety 1112)-based diet
- D 40 % cassava root meal (variety White)-based diet
- E 40 % cassava root meal (variety Red)-based diet
- F 40 % sweet potato tuber meal (variety TIB1)-based diet including ferrous sulphate-treated cottonseed cake (CSC) at 25%
- G 40 % cassava root meal (variety local white)-based diet including ferrous sulphate-treated CSC at 25%
- H 40 % sweet potato tuber meal (variety TIB1)-based diet including untreated CSC at 25 %

162. The dietary treatments for the layer trial were:

- A Control diet (containing >60 % maize, as in the commercial poultry feeds)
- B 50 % sweet potato tuber meal (variety TIB1)-based diet
- C 50 % sweet potato tuber meal (variety TIB2)-based diet
- D 50 % sweet potato tuber meal (variety 1112)-based diet
- E 50 % cassava root meal (variety local White)-based diet
- F 50 % cassava root meal (variety local Red)-based diet

G 50 % cassava root meal (variety local White)-based diet including ferrous sulphate-treated CSC at 25 %

11.5.7.1.2. ***Nutritional considerations in designing dietary treatments***

163. The main objective of these feeding trials were to determine whether it was technically possible to incorporate high levels of SP and CAS into broiler and layer diets without major losses in production with respect to a maize-based diet, and to select varieties of each commodity for further development of the project. Accordingly, Diets A-E of the broiler trial and Diets A-F of the layer trial tested the use of SP and CAS at 40 and 50 per cent dietary inclusions respectively (Appendix 16.9, Table 1, 3 and 5). For effective comparison, nutritionally-balanced rations were required. The broiler starter diets were formulated to contain 22 per cent crude protein (CP) and 12.25 MJ/kg apparent metabolisable energy (AME); broiler finisher diets 19 per cent CP and 12.75 MJ/kg AME, and the layer diets 16.5 per cent CP and 11.40 MJ/kg AME. However, attempts were made to keep all other major nutrients at the same levels in all experimental diets in order to make comparison valid (Appendix 16.9, Table 2, 4 and 6; *as intended* figures).

164. The limitations of this approach in relation to the financial viability of dietary treatments should be noted. The approach is based on the consideration that to compare the potential of different varieties of a test feed, each variety needs to be analysed for nutritional composition using chemical analysis (SP varieties may differ in CP and AME considerably) and diets then need to be formulated to a common nutrient specification. For this compromises need to be made on both complementary ingredient and nutrient contents of the rations. For ingredients, unconventional complementary feeds needed to be fixed at the same level in all test rations or if toxic principles are present they need to be avoided altogether even if such feeds are the cheapest available and have some potential for use. Thus, the control (maize) diet was forced to contain 2.5 per cent blood meal, the level found to be required for some of the other rations, because there was uncertainty on the quality of the product prepared by small-scale local processors (paragraph 153). The rations omitted CSC, which contains the toxic polyphenolic compound gossypol and cyclopropenoid fatty acids that cause losses in poultry productivity and discolourations in eggs (Panigrahi, 1992). For nutrient, an example of the type of compromise that is inherent in the approach is that if one variety contains a higher lysine content, lysine (synthetic or from other costly feeds such as fishmeal) would need to be added to other diets to bring it up to the lysine content of this ration, even though the rations then contain higher levels of lysine than is required by the chickens. Similar problems arise in balancing other major nutrients.

165. This type of ration manipulation to ensure all diets contain the same level of the major nutrients inevitably leads to diets not being least-cost in relation to the production potential of each. The diets are however least cost within the constraints imposed to balance the nutrients for effective comparison of treatments. Thus, the ration cost was not a major consideration in the design of the feeding trials, the main objective being to compare varieties for their nutritional value. Moreover, in order to balance nutrients, it proved impossible to completely eliminate maize completely from the SP and CAS based rations. Finally, the chemical composition of commercial feeds sold in Cameroon is unknown as there are no legal requirements for this information to be declared on each bag of feed sold (Appendix 16.4, Section 3.2.3.1. d & e). This meant that there was no possibility of ensuring the experimental rations were similar in nutrient content to commercial feeds so that it there was value to including a commercial ration as a treatement in these experiments. The rations tested should therefore be seen as 'developmental diets', intended to guide future project activities. The rations are not suitable for field application.

166. A second objective of the feeding trials was to seek a suitable oilseed cake to complement the SP and CAS-based rations. Root crops are low in CP so that root crops need to be combined with a high protein source such as oilseed cakes, fishmeal or blood meal. The use of fishmeal is costly and many believe to be environmentally unsustainable in the long term. For sustainability, local

oilmilling by-products need to be used in livestock rations. CSC was recognised during the prefeasibilty study (paragraph 60) to be an important feed ingredient of the region due to its low cost and high content of CP, which is also of high amino-acid digestibility. Although CSC contains toxic principles (paragraph 141) NRI conducted a great deal of research on seeking methods for its detoxification, without which it would be impossible to consider high dietary inclusion rates, particularly for laying hens. Treatments F-H of the broiler trial and treatment G of the layer trial were included to obtain some preliminary data of the potential for using SP and CAS in combination with this 'problem' feed to keep open the option that its use may still be viable in the production systems of the target poultry producers. As can be noted from Appendix 16.6, Tables 1-6, the inclusion of CSC with or without ferrous sulphate heptahydrate (FSH) treatment reduced the cost of the ration considerably. It was expected that the knowledge gained on the financial potentials of these particular dietary treatments would lead to the design of rations that were appropriate to the socio-economic circumstances of resource-poor farmers.

167. Several other points concerning the feed composition should be noted. Although in the project region, vitamins and minerals are periodically added to the water supply, it was decided to add the premix (Appendix 16.6, Table 1 for composition) to the feeds (for only these trials) to order to obtain a more homogenous distribution so as to increase the probability of each chicken receiving its fair allocation of these micronutrient. This would reduce the variability in poultry performance so that the any genuine differences between varieties would become amplified. Second, the FSH-treated diets were allowed a slightly higher phosphorus content to overcome any reduction in phosphorus that might occur in the intestine of hens from the formation of insoluble iron phosphates (Panigrahi, 1996b). Third, for broilers different diets were formulated for the starter (0-4 weeks) and finisher (4-8 weeks) stages, in order to match dietary nutrients closely to the requirements of chicks as they grow older. However, it was decided that this approach would not be optimal for rations to be used subsequently in the project because of the high cost of CP associated with root crop based starter rations which generally contain 23-24 per cent. A single ration for the entire production cycle of about 21 per cent crude protein was considered optimal to meet the resources and constraints of the target poultry producers.

11.5.7.1.3. *Processing of feeds for experimental diets*

168. The SP and CAS were shredded using the J3 plate of the TRS food processor. The SP varieties were processed in rotation in order to prevent any one variety rotting more than the other two (rotting is quick with SP and is an additional resource management consideration underlying the development of the proposed technology of gritting and drying). The processing was done in two shifts, one between 7 and 10 am and the other between 12 and 2 in order to allow the TRS food processer to cool down. Each shift processed 150 kg of tubers.Sun-drying was over within 7 hours for the morning shift produced material, but that produced in the afternoon shift needed to be brought indoors to be spread out in the sun the following day. The sun-dried shreds from both SP and CAS were ground and then mixed with the other ingredients of all layer rations. Ground SP and CAS were also used for all the broiler rations except for two of the treatments (Diets F and H) for which it was decided to test SP n the shred form (that is without grinding). Since these two treatments were not part of the main objective of the experiment, it was considered useful to obtain some early indications of the potential for using gritted tubers and roots for direct feeding to chicks.

169. The free gossypol content of local CSC was not known at the time of the trial, but was assumed to be around 500 mg/kg based on previous CSC samples analysed by IRZV researchers. For laying hens, iron treatment was conducted at a 4:1 weight ration of iron to free gossypol assumed to be present. This represented 0.25% of FSH. Based on previous NRI studies (Panigrahi, 1992), the following procedure was adopted for treating CSC: 250 g of FSH was dissolved in 1 litre of water and add very gradually to 25 kg of CSC in a plastic bag. The mixture was shaken vigorously for 20 minutes and the bag left open in the sun for a further 2 hours to allow evaporation of excess water. This method was used because MRS did not have a small feed

mixer to mix small quantities of feeds with liquid materials. For broilers, treatment of CSC with FSH was carried out as for layers except that only 63 g of FSH, representing a 1:1 ratio of iron:free gossypol was used.

170. Since the egg discolouration problem is not of concern with broilers, and FSH is an additional cost and not generally available in the rural areas, it was considered that the real benefits of treating the CSC needed to be determined under field conditions of prices additional treatments (Diets F and H) were included in the broiler trial to determine the benefits of treating CSC with FSH on broiler production.

11.5.7.1.4. *Broiler chick feeding trial facilities and data collection*

171. The Tuber and Root Variety Evaluation Broiler Trial 1 was begun in April 1995. It was conducted with day-old broiler chicks in a open-sided poultry house that allowed ventillation; however, draught was excluded form the pens during the first 3 weeks of the feeding trial (brooding phase). Five hundred and sixty broiler chicks were , obtained from Societe Des Provenderies du Cameroun (SDP) in Bafoussam (Map 2). Seventy chicks were used per dietary treatment, arranged in 5 replicates of 14 chicks. Since it is difficult to determine the breed of broilers with certainty, and the chicks supplied unsexed, 5 replicates per treatment were used instead of 4 that is normally considered sufficient for statistical validity. Birds will be fed the experimental diets *ad libitum.*

172. Round 'enclosures' (brooding guards to keep young chicks warm) of 2 m diameter and 2 feet height were constructed using plywood. Each 'enclosure' was partitioned into two semi-circled experimental units ('pens'), each unit being provided with a feeder and a drinker. One block (area of poultry house) contained 4 of these round 'enclosures', that is 8 experimental units, to permit a complete randomised block design to be used within the 5 blocks. However, since there were two blocks on the right side of the poultry house (Side East) and two blocks on the left side (Side West) the.experiment is of an incomplete randomised block design. Dietary treatments were randomly allocated within blocks but each block contained each of the 8 treatments. The position of the 'sides', blocks, 'enclosures' and 'pens' (shown in Diagram 1) were recorded to enable any systematic non-dietary effects to be taken into account in statistical analysis. The lighting regime was 23 hrs during the first week, 20 hrs during day 8 to day 14, and 12 hours of daylight from there on. The temperature varies between 25 to 35^{o}C (days) and 18-22^{o}C (nights) between March and September. Chicks will be fed the experimental diets *ad libitum.*

173. The following data were recorded: food intakes on a weekly basis, and body weights at 0, 4, and 8 weeks. The efficiency of food utilisation (gain:feed ratio) were calculated for 0-4 and 0-8 weeks. The data were arranged as shown in Table 13 and sent to NRI for statistical analysis.

11.5.7.1.5. *Laying hen feeding trial 1 facilities and data collection*

174. The Tuber and Root Variety Evaluation Layer Trial 1 was conducted using 216 Lohmann Brown laying hens, which were obtained as day-olds from SDP (Bafoussam) in July 1994 and reared on deep litter at MRS. Hens were transferred from deep litter to laying hen cages (individually caged) at 18 weeks of age (point of lay) fed on the control maize layer ration. When 196 hens had each laid a minimum of 3 eggs (April 1995) the layer trial was begun using 28 hens per dietary treatment. The lighting regime was natural (12 hrs of daylight). Birds will be fed the experimental diets *ad libitum*.

Table 14. Arrangement of broiler trial data for statistical analysis at NRI.

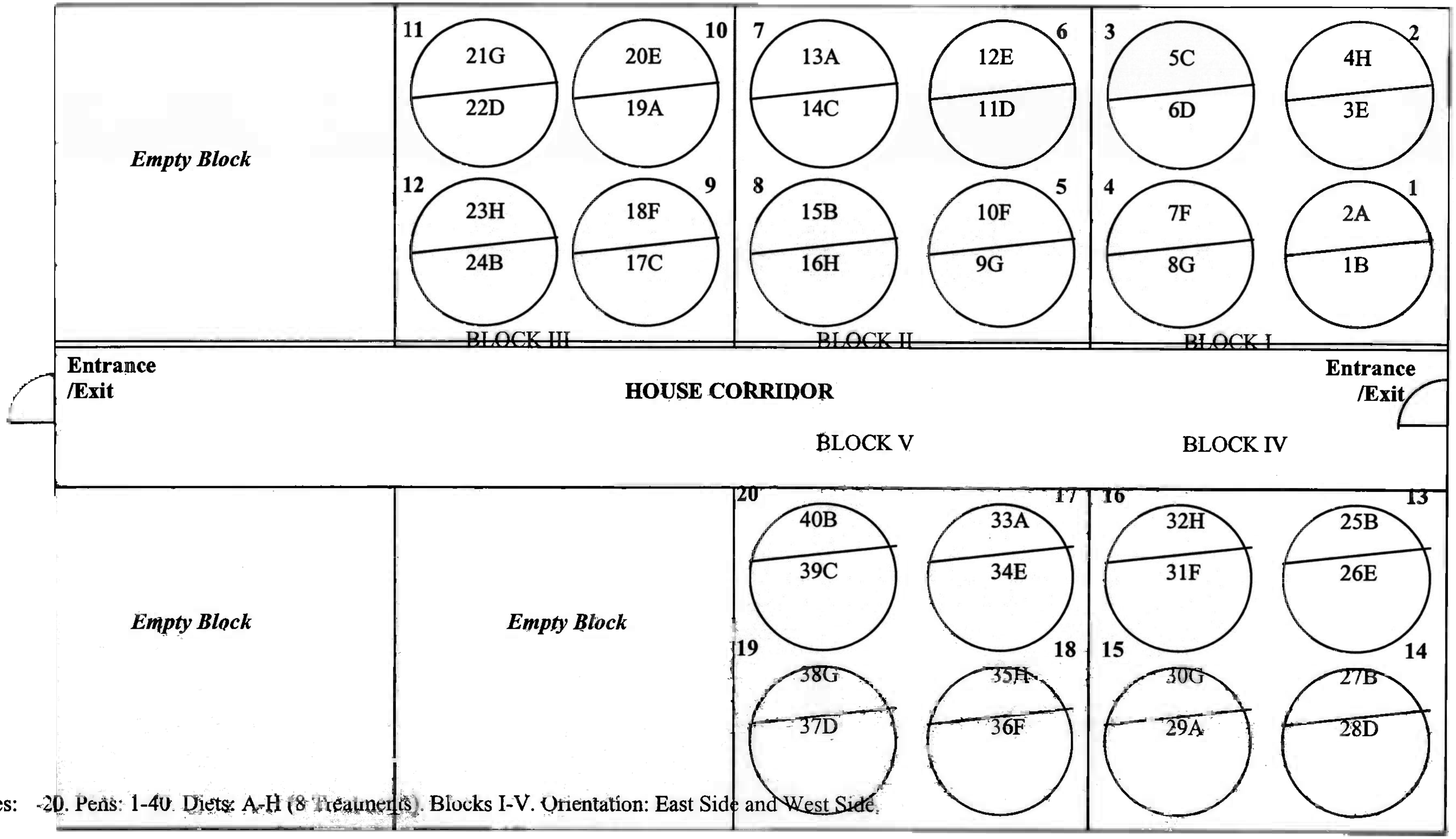
Dietary Treatment	House Side	House Block	House Enclosure	House Pen	Weight gain Weeks 0-4; 0-8	Food intake Weeks 0-4; 0-8	EFU Weeks 0-4; 0-8
B	East	I	1	1			
A	East	I	1	2			
F	East	I	1	2			
D	East	I		2			
C	West	V	20	39			
B	West	V	20	40			

175. The laying hen building has open sides to allow ventillation. An incomplete randomised block design was used, with the two sides of the length of the poultry house opposing each other (one facing the window, the other facing the interior of the hen house) representing 'blocks', and there being three tiers of cages in each block. Allocation of birds to cages was such that each treatment was represented in each tier at least 4 times, randomising allocation within this constraint. The position of the blocks, tiers and cages and treatments are shown in Diagram 3.

Table 15. Arrangement of layer trial data for statistical analysis at NRI.

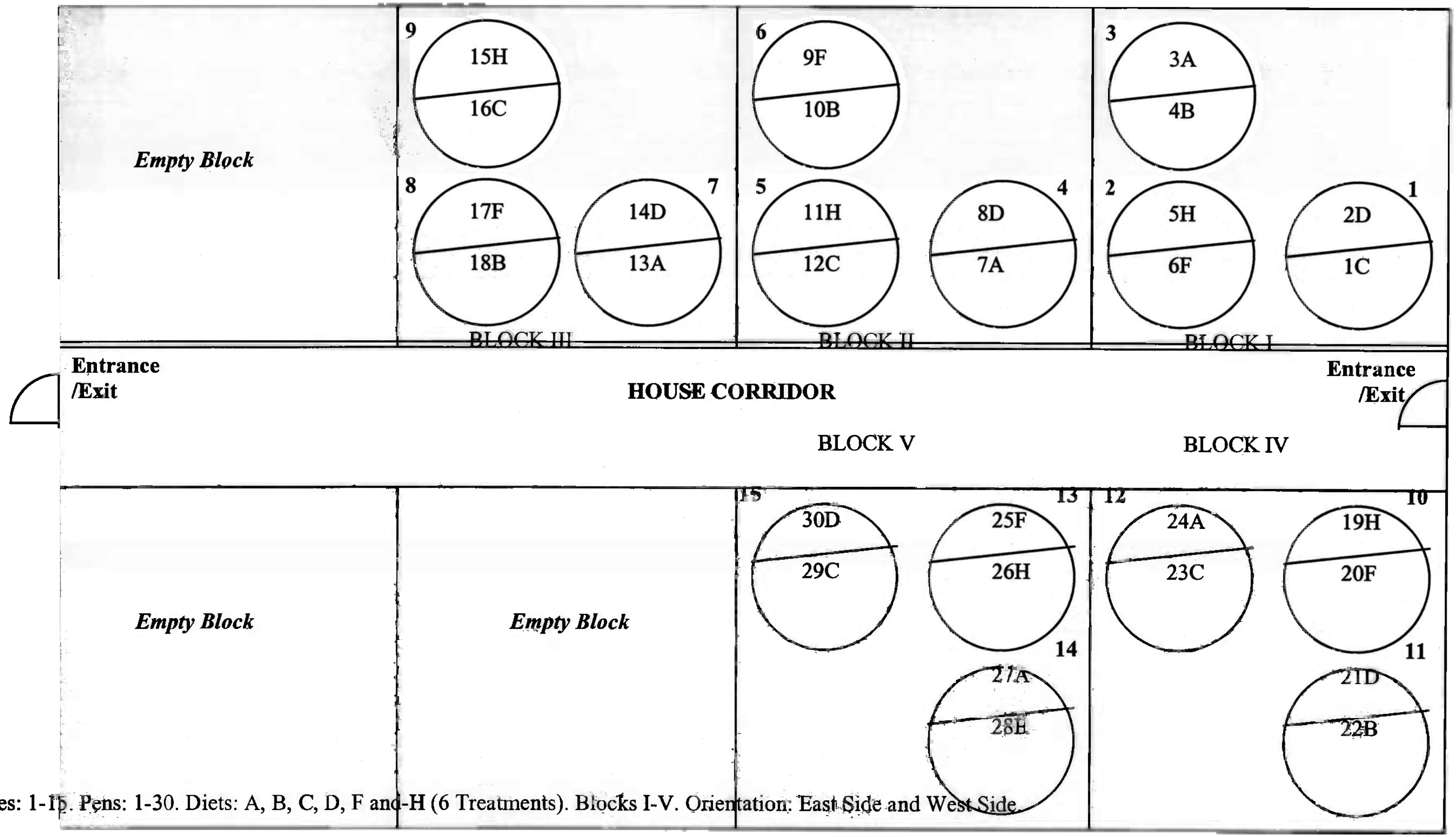
Dietary treatment	Cage	Block	Tier	Food intake Weeks 1, 2, 3...	Egg no Week No 1, 2, 3...	Egg mass Week No 1, 2, 3...,	Body weight on days 56, 112
1B							
2C							
3E							
194A							
195E							
196D							

Diagram 1. Treatment randomisation and house orientation in the Tuber and Root Variety Evaluation Broiler Trial 1.



Key: Enclosures: -20. Pens: 1-40. Diets: A-H (8 Treatments). Blocks I-V. Orientation: East Side and West Side.

Diagram 2. Treatment randomisation and house orientation in the Dried Tuber and Root Shreds Storage Broiler Trial 1.



Key: Enclosures: 1-15. Pens: 1-30. Diets: A, B, C, D, F and H (6 Treatments). Blocks I-V. Orientation: East Side and West Side.

Diagram 3. Treatment randomisation and cage positioning in on-station Layer Trial 1.

***Upper Tier*:** **Window Side (East)**

	32	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1
	D	C	D	C	F	A	G	C	B	A	D	G	D	E	F	B	C	E	B	A	E	B	G	F	B	A	F	G	A	E	F	G

Middle Tier

33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65
A	C	E	B	G	F	E	D	C	G	B	F	A	C	G	D	G	F	E	B	F	B	C	A	G	F	D	E	A	E	D	A	C

***Lower Tier*:**

98	97	96	95	94	93	92	91	90	89	88	87	86	85	84	83	82	81	80	79	78	77	76	75	74	73	72	71	70	69	68	67	66
E	C	F	C	E	B	F	D	C	F	E	B	G	E	D	G	D	A	E	B	A	G	D	B	A	F	C	G	B	F	A	G	D

***Upper Tier*:** **Aisle Side (West)**

	130	129	128	127	126	125	124	123	122	121	120	119	118	117	116	115	114	113	112	111	110	109	108	107	106	105	104	103	102	101	100	99
	G	B	G	D	B	D	E	C	E	B	G	D	A	F	C	F	D	A	D	F	B	E	B	C	F	C	F	G	A	E	A	C

***Middle Tier*:**

131	132	133	134	135	136	137	138	139	140	141	142	143	144	145	146	147	148	149	150	151	152	153	154	155	156	157	158	159	160	161	162	163
B	D	C	B	D	E	C	A	G	F	D	C	F	D	A	F	G	E	A	E	B	E	D	A	F	C	B	C	G	A	G	E	G

***Lower Tier*:**

196	195	194	193	192	191	190	189	188	187	186	185	184	183	182	181	180	179	178	177	176	175	174	173	172	171	170	169	168	167	166	165	164
G	C	D	G	F	C	E	G	F	A	C	D	A	C	D	B	E	D	E	A	B	G	C	E	B	F	B	D	A	F	A	B	E

176. The following data were recorded: weekly food intakes, and daily egg production (the number of eggs laid and weight of each egg laid). The hens were weighed at 0, 8 and 16 weeks. Soft-shelled and broken eggs found on cage tray were recorded. From the data the efficiency of lay was calculated in terms of (a) the number of eggs laid/kg feed consumed, and (b) the mass of eggs laid/kg feed consumed. The significance of these results were assessed in relation to the change in body weight between 0-8 weeks and 0-16 weeks. (It should be noted that because of insufficient material, the treatment C (using SP variety TIB2) was terminated at 8 weeks, but these hens will be left in their positions untill the end of the 16 week feeding trial in order to prevent disrupting the other experimental birds. The raw data were arranged as shown in Table 14 and sent to NRI for statistical analysis.

11.5.7.2. *Broiler trial 2 to determine the feeding value of stored sun-dried tuber and root shreds*

177. The broiler trial was repeated in August 1995 using Diets A, B, C, D, to determine the effects of storing the maize, and shredded and dried SP and CAS (sweet potato TIB1, 1112, and cassava white) under identical conditions (indoors in PVC bags, without any insecticide). Treatments F and H were also included in this storage trial for a different reason. These were tested in the shred form in the first trial but cause severe difficulties of food intake and digestibility. It was, therefore, necessary to test these treatments in in the ground (mash) form to ascertain their feeding value relative to each other and with the major treatments used in the first trial, including most importantly the maize-based control ration. The procedure for the trial was as for the first trial, except that there were 6 replicates of 14 chicks per treatment group randomly allocated (Diagram 2) and due to limitation of raw materials the trial could only be conducted for a 4-week duration using the broiler starter ration.

11.5.7.3. *Factors affecting interpretation of data from on-station broiler 1 and 2 and layer 1 feeding trials*

178. Before examining the results it is necessary to note that three problems were encountered in implementing the feeding trials. First, although a local supplier had assured a supply of synthetic lysine for the feeding trials project staff were let down at the very last minute. Lysine could not be found in the major cities of Yaounde and Doaula either. Thus, although synthetic methionine were added to diets which needed it lysine was not added. The rations could not be reformulated as all other ingredients had already been purchased and some rations had been mixed. The result was that the lysine content of the diets with CSC became especially low, and makes interpretation of the effects of CSC difficult, in particular for the broiler trials which required high levels of synthetic lysine.

179. Second, as mentioned earlier (paragraph 161-165) the approach adopted entailed the use of nutritionally-balanced rations but these was not perfectly achieved (see '*as intended*' versus '*as achieved*' figures in Appendix 16.6, Tables 2, 4 and 6) because lack of time to conduct determnine the nutrient content of the feed raw materials led to excessive reliance being placed on '*book values*' of the composition of local feeds. The calcium content of rations were particularly low, the error subsequently traced to the following raw materials whose actual and assumed values were (in %): fishmeal 4.42 instead of 5.11; maize 0.01 instead of 0.02; and SP 0.08-0.10 instead of 0.12-0.17, respectively. CPs of diets were also lower than intended, due primarily to underestimating the CP content of the maize and SP. It had been assumed that the CP content of SP would not vary greatly between years so that the values analysed for tubers in 1994 were used in ration formulation. However, on subsequent analysis, the values for the 1995 samples were much lower, as follows (figures in percentages with 1994 figures in brackets): SP TIB1 - 4.12 (8.11), SP TIB2 - 5.40 (6.99) and SP 1112 - 4.87 (5.58). This variability might be due to agronomic factors such as differences in fertiliser application or point-of-harvest, or some other factor under which crops were cultivated in the two years. The lysine content of SP were estimated by taking an average of 10 previously

analysed results obtained for different cultivars at NRI, not the values of the varieties used in the feeding trials. The combination of lower calcium and lower protein could explain the generally lower levels of performance that were obtained in the egg production trial than we might have been expecting. Originally, carcass analysis was planned in which samples of chickens and eggs were to be taken, oven-dried and analysed at NRI for gross energy, fat and nitrogen determination. However, because of the nutrient imbalances, carcass analysis was aborted. as results could not now be interpreted with reliability.

180. Third, a different problem arose when it was decided to test the effects of SP for two of the treatments in the broiler trial (Diets F and H) in the shred form, that is without further grinding. Day-old chicks performed poorly on the shreds, as chicks had difficulty consuming the long shreds. It should be noted that the NRI Phase 2 Trail 1 was conducted with crumbed TRS J3 plate-produced shreds and with 5 d-old chicks which could easily consume it. However, even in that trial examination of the excreta showed that most of the crumbed shreds were passing through the gastro-intestinal tract undigested. In view of these results it was decided to include Treatments F and H in the Tuber and Root Storage trial

11.5.7.4. *Results of broiler trials 1 and 2*

181. The results of the broiler feeding trials 1 and 2 are summarised in Table 15. Notwithstanding the nutrient imbalances discussed above, the results of the Tuber and Root Variety Evaluation Broiler Trial 1 showed that SP 1112 had a higher feeding value than SP TIB1 and CAS White had a higher potential as a feed than CAS Red. These findings were consistent with those using grits in the NRI Phase 2 Trial 1. With respect to maize controls, 0-8 week weight gains were 13.5 per cent lower with SP 1112 but only 4.5 per cent lower with the CAS White, with the latter showing the same profitability as the maize controls when results are expressed in terms of weight gain per FCFA spent on feed. Ignoring Treatments F and H for aforementioned reasons, it was of interest to note that whilst growth rate with Treatment G was only 1.43 kg compared with 2.08 kg for controls, it was not unacceptably low and, of major importance for the planning of the project, weight gain per FCFA spent on feed was 2.83 g compared with 2.22 g for the maize based ration, that is it was 27.5 per cent better with the CAS-CSCFe diet. The lower weight gain may be attributed to (a) the low lysine content of the diet arising from the omission of synthetic lysine (paragraph 176), and/or (b) FSH treatment of CSC may have had a deleterious effect on feed palatability. A particular reason for suggesting the latter was the observation that the utilisation of this ration appeared to increase with the length of the feeding period: weight gain up to four weeks was 60 per cent lower than controls but at 8 weeks it was only 31 per cent lower than controls, indicating that chicks were gradually adapting to the ration to exhibit compensatory growth.

182. The Dried Tuber and Root Shred Storage Broiler Trial 2 confirmed the relative differences in the feeding values of SP TIB1, SP TIB2 and CAS White and maize, relative to each other, and provided no indication for any major reduction in the nutritional value of stored tuber and root shreds (comparing the 0-4 week data from Broiler Trials 1 and 2). For Treatments F and H, it shows conclusively that FSH treatment of CSC produced an adverse effect on the utilisation of CSC-based rations. Significantly, for Treatment H the weight gain was lower than the corresponding SPTIB1 ration without CSC (due probably to the lower lysine content of the former) weight gain per FCFA expended on broiler feeds was 3.53 g compared with 2.72 for a standard maize-based ration.

183. Taken together, the overall results of these two broiler feeding trials confirmed that the basic project proposition of developing SP and CAS based rations with a considerable replacement of maize was technically and financially feasible, particularly if CSC (not treated with FSH) was included as the complementary protein source in the ration.

11.5.7.5. *Results of layer trial 1*

184. The results of the Tuber and Root Variety Evaluation Layer Trial 1 are shown in Tables 16 and 17. The three varieties of SP gave similar egg production rates as the maize-based control diet whilst two CAS varieties gave significantly higher production rates than the controls. Among the SP varieties SP 1112 yielded the best results in terms of egg production, but among the two CAS varieties there were no significant differences. When examining the efficiency of lay, the number and mass of eggs laid per kg feed consumed were significantly better for the SP and CAS-based rations than for the maize-controls, primarily due to high food intakes associated with the latter. The excess food intake in the maize controls was laid down as body fat, as indicated by the figures for the change in body weights of hens. Significantly, compared with the maize controls, the profitability of production was approximately 15 per cent higher for the SP 1112- and 27 per cent higher for the CAS White ration. Thus, notwithstanding the differences in the nutrient content of the rations, the results indicated that the basic project proposition of replacing maize with tubers and roots was technically possible and financially viable.

185. Compared with the performance of hens fed on the non-CSC CAS White-based diet (Treatment F), hens fed the corresponding iron-treated CSC-based diet (Treatment G) had significantly lower food intakes and egg production, and lost body weight. There were not significant differences in the quality of eggs produced in the two groups. It is not clear what might have happened if a treatment was included in which the CSC was not iron-treated, but previous NRI studies have shown that at the 25 per cent dietary inclusion rate mottlings and discoulourations would almost certainly take. Significantly, Treatment G was the most profitable group in terms of egg production per FCFA spent on feed, being 41 per cent better than in the control maize group. Thus, overall the results of the layer trial showed that there was considerable potential for developing SP and CAS-based laying hen rations for the project region, although much thought was required on whether CSC should be included and if so whether it should be treated with ferrous sulphate.

186. It was noteworthy that egg production was low generally for the age of the birds. It seems reasonable to speculate that this was caused by the lower calcium content of the rations caused by reliance placed on '*book values*' of composition (paragraph 177). However, it is also possible that the quality of the batch of hens received from the hatchery was not good.

Table 16. Performance of chicks in the Tuber and Root Variety Evaluation and Dried Shred Storage Broiler feeding trials on-station.

Dietary treatments	A Control maize	B SP TIB1	C SP 1112	D CAS White	E CAS Red	F SPTIB1-CSC/Fe	G CAS White-CSC/Fe	H SPTIB1-CSC	SEM	Significance of diet P (=or <)
Tuber and Root Variety Evaluation Broiler Trial 1[1]:										
Weight gain 0-4 weeks (g)	835^{a}	642^{b}	639^{b}	776^{a}	753^{a}	299^{c}	339^{c}	294^{c}	35.2	0.0001
Food intake 0-4 weeks (g)	1359^{a}	1220^{b}	1182^{b}	1176^{b}	1275^{ab}	714^{c}	827^{c}	714^{c}	44.9	0.0001
EFU 0-4 weeks	0.61^{ab}	0.53^{b}	0.54^{b}	0.66^{a}	0.59^{ab}	0.42^{c}	0.42^{c}	0.42^{c}	0.031	0.0001
Weight gain/FCFAon feed (g):	2.51	2.21	2.20	2.52	2.25	2.23	2.26	2.28		
Weight gain 0-8 weeks (g)	2080^{a}	1575^{c}	1801^{b}	1987^{a}	1797^{b}	942^{d}	1433^{c}	813^{d}	51.7	0.0001
Food intake 0-8 weeks (g)	4312^{a}	4009^{b}	4021^{b}	3985^{b}	4033^{ab}	2787^{d}	3103^{c}	2873^{cd}	100.8	0.0001
EFU 0-8 weeks	0.44^{ab}	0.37^{d}	0.41^{c}	0.45^{a}	0.41^{bc}	0.29^{e}	0.40^{c}	0.26^{f}	0.011	0.0001
Weight gain/FCFAon feed (g):	2.22	1.80	1.97	2.21	1.89	2.01	2.83	1.81		
Dried Tuber and Root Storage Broiler Trial 2[2]:										
Weight gain 0-4 weeks (g)	930^{a}	705^{b}	761^{b}	757^{b}		432^{c}		609^{d}	27.4	0.0001
Food intake 0-4 weeks (g/d)	50.6^{a}	43.3^{c}	45.9^{b}	46.5^{b}		34.4^{d}		33.2^{d}	0.86	0.0001
EFU 0-4 weeks	0.66^{a}	0.58^{c}	0.59^{bc}	0.58^{c}		0.45^{d}		0.65^{ab}	0.021	0.0001
Weight gain/FCFA on feed (g):	2.72	2.42	2.41	2.21		2.39		3.53		

Notes: EFU - Efficiency of food utilisation as weight gain: food intake ratio. Least square means are shown after adjusting for Block and Enclosure effects. SEM - pooled standard error of means. Values in the same horizontal line with different superscripts are significantly different ($P<0.05$); residual degrees of freedom Feeding Trial 1, 29. Feeding trial 2, 21. SP and CAS grits were produced between January and February 1995. 1. Experiment started on April 1995. 2. Experiment started on 8th August 1995.

Table 17. Performance of hens fed tuber and root-based diets during 0-8 weeks of the first on-station layer feeding trial.

Dietary treatments	A Control maize	B SP TIB1	C SP TIB2	D SP 1112	E CAS White	F CAS Red	G CAS White- CSC/Fe	SEM	Significance of diet (P=or <)
Food intake (g/hen d)	114.4^{a}	104.1^{bc}	99.2^{bc}	107.8^{b}	100.3^{bc}	101.1^{cd}	97.7^{d}	3.45	0.0001
Change in body weight (g)	64^{a}	-57^{cd}	-19^{bcd}	-19^{bcd}	59^{ab}	111^{a}	24^{d}	28.3	0.0001
Number of eggs laid/d	0.57^{b}	0.61^{b}	0.59^{b}	0.65^{ab}	0.69^{a}	0.68^{a}	0.60^{c}	0.031	0.0001
Egg output (g eggs/hen d)	32.5^{b}	34.8^{b}	33.6^{b}	38.3^{ab}	39.8^{a}	39.8^{a}	32.6^{c}	1.15	0.0001
Number of eggs/10 kg food	50^{a}	61^{b}	60^{b}	63^{b}	68^{c}	68^{c}	63^{ab}	2.10	0.0001
Gms eggs/kg food	288^{a}	346^{bc}	340^{bc}	367^{c}	392^{d}	395^{d}	345^{ab}	10.1	0.0001
Gms eggs/1000 FCFA feed cost	1376	1663	1589	1723	1842	1836	2132		
Number of eggs/10000 FCFA	241	294	280	295	319	315	390		

Notes: Least square means are shown after adjusting for Block and Tier effects. SEM - pooled standard error of meals. Values in the same horizontal line with different superscripts are significantly different (P<0.05). residual degrees of freedom 184.

Table 18. Performance of hens fed tuber and root-based diets during 0-16 weeks of the first on-station layer trial.

Dietary treatments	A Control maize	B SP TIB1	D SP 1112	E CAS White	F CAS Red	G CAS White-CSC/Fe	SEM	Significance of diet (P=or <)
Food intake (g/hen d)	119.1^{a}	104.5^{bc}	108.6^{b}	105.4^{bc}	101.4^{cd}	95.9^{d}	2.45	0.0001
Change in body weight (g)	84^{a}	-67^{cd}	-52^{bcd}	30^{ab}	87^{a}	-87^{d}	32.3	0.0001
Number of eggs laid/d	0.62^{b}	0.63^{b}	0.67^{ab}	0.72^{a}	0.70^{a}	0.55^{c}	0.023	0.0001
Egg output (g eggs/hen d)	36.3^{b}	36.1^{b}	39.5^{ab}	42.2^{a}	41.3^{a}	30.6^{c}	1.24	0.0001
Number of eggs/10kg food	53^{a}	61^{b}	62^{b}	69^{c}	69^{c}	58^{ab}	2.0	0.0001
Gms eggs/kg food	309^{a}	346^{bc}	364^{c}	402^{d}	408^{d}	322^{ab}	9.8	0.0001
Gms eggs/1000 FCFA feed cost	1478	1662	1712	1898	1887	1987		
Number of eggs/10000 FCFA	254	291	291	322	322	359		

Notes: Least square means are shown after adjusting for Block and Tier effects. SEM - pooled standard error of meals. Values in the same horizontal line with different superscripts are significantly different ($P<0.05$). residual degrees of freedom 184. Treatment C discontinued after 8 weeks due to insuffient SP TIB2.

11.5.7.6. *Implications of the results of the first on-station feeding trials for the design of on-farm rations*

187. Several points emerged from these feeding trials that have a bearing on the development of poultry rations of optimal and sustainable rations for the resource-poor rural poultry producers, who are generally characterised by having spare labour but lacking cash. The plane of nutrition needs to be adjusted to the resources and constraints of farmers, so that the broiler production is a intermediate-intensity system (that is not as productive as large-scale commercial systems) the intensity being dependent on what farmers can afford. It is necessary to understand the nutritional implications of minimising cash outlay on feeds to the level that the farmer can afford and then developing a nutrient balance in the ration in accordance with feed availability that maximise productivity.

11.5.7.6.1. *Plane of nutrition: the broiler starter-finisher ration concept*

188. It was inevitable that the broiler rations would be nutrient sub-maximal in terms of the dietary requirements of chicks The difficulty in obtaining synthetic amino acids (lysine and methionine) nd their high cost excluded their use in rations for the projects target group. It was also decided not to use any any vegetable oils due to their high cost as well as for the facts that oils can become rancid, and the target group will not find it easy to mix it with other feed ingredients. These omissions made it impossible to develop the normal broiler rations of 1.25 per cent lysine (starter) and up to 13.10 MJ/kg AME (finisher) phase. As a consequence, the benefits of using a high CP content (23-24 per cent) in the starter ration became questionable, whilst there was now uncertainty of what would be the optimal balance of lysine, CP and AME for maximal growth performance (as there is no reliable guidelines in the literature for such circumstances). Further, if a lower than 23-24 per cent CP was used in the starter phase the concept of starter and finisher rations was considered to become redundant, so that a single ration was developed for the 0-8 week growth period.

189. Another consideration for adopting a single ration broiler feeding system was that a change of ration in the middle of a production cycle (starter 0-4 weeks and finisher 4-8 weeks) could be a disincentive to many small-scale producers because of the practical complications it creates. Farmers need to purchase two types of feeds and keep these feeds separate with appropriate labelling. They then need to monitor the age of the chicks as they grow so that the feed may be changed on a particular day. A change of feed in this manner could also lead to wastage of the starter feed. The feeding system would only work if a feed management system is maintained. This will require a small feed store area that resource-poor producers can ill afford. It was, therefore, considered that the target group should prefer to deal with just one ration for practical reasons.

190. Without any literature guidelines (strategic research on this aspect of poultry nutrition is needed to assist the development of rations for resource poor farmers), the project considered that a CP level of between the starter and the finisher may be suitable as it could enable the compensatory growth phenomenon of broilers to be used to advantage (Yu and Robinson, 1992). This is based on the supposition that chicks would fall behind those on a starter-finisher regime during the starter phase may catch up with the others by the end of 8-week feeding period. The formulation technique adopted was selecting the least cost ration incorporating a minimum of 50 per cent of SP or CAS in a diet of 22 per cent CP, 12.40-12.65 MJ AME/kg, 1.00 per cent calcium, 0.7-0.85 per cent phosphorus, 0.4-0.5 per cent salt, 0.85-0.95 per cent methionine plus cystine and as high a lysine content as can be achieved up to 1.10 without the use of synthetic amino acids.

191. It was, however, recognised that with sub-maximal diets chicks may cause more feed spillage in their search for the nutrients required. Close attention, therefore, needs to the paid to the design of the feed hoppers to reduce feed spillage which will be a cost to resource-poor farmers. This may be achieved by restricting head movement within the hoppers by the use of partitions or by better shape of the edges of the hopper. Alternatively, spilt food may be collected and put back into the hopper,

but this would involve additional labour. Finally, it may be argued that no measures are necessary since chickens will consume subsequent feed from the floor.

11.5.7.6.2. *Age of chicks to be given tuber and root-based rations*

192. The reason for varying the age at which broiler chicks were presented with SP and CAS-based feeds in the NRI Phase 2 adaptive research (Section 11.4.3) was the finding from poultry farm characterisation study that in the western highlands of Cameroon day-old chicks are highly valuable, representing 25 per cent of the cost of poultry production by resource-poor producers. It was considered that farmers may, therefore, be reluctant to risk giving a unconventional feeds to chicks when they are most vulnerable to stress due to climatic and anti-nutritional factors in feeds. This was also the reason that the on-station tuber and root grit feeding trials (Section 11.5.10.2.1) were also conducted with 9-day old chicks instead of day-olds. However, in view of the finding from the two on-station broiler trials that day-old chicks performed well with ground SP and CAS diets (there was no treatment-related mortality) it was decided that it was feasible to present test feeds to day-old chicks in the on-farm testing stage provided that chicks received adequate brooding (paragraph 132). As a result of these deliberations, it was decided to conduct the first on-farm feeding trials (in which mash feeds were to be used) with day-old chicks rather older birds. Introducing feeds from day-old would be more appropriate for small-scale producers who would otherwise need to purchase some commercial feed to start their chicks on. A feeding regime requiring a switch from one ration to another could cause additional work and confusion for some resource-poor poultry producers and was one of the reasons that dual starter-finisher concept for broilers was also abandoned (paragraph 165). Thus, developing ration technology that can be fed to day-old chicks was considered to be a major objective of the project and which applies as much to rations presented as mash as to rations in which SP and CAS are included as grits.

11.5.7.6.3. *Development of feed composition chart for project field site*

193. In view of the proven inadequacy of '*book values*' of composition of feeds for project implementation (paragraphs 176-177), the nutritional analysis conducted in NRI (paragraph 124) was extended to the determination of the amino acid composition. Whereas the AME content of all feeds were estimated according to the European Table for metabolisable energy value of feeds (EEC, 1986), the correct approach is to use the real AME values as determined for each locally available feed ingredient used as complementary feeds, by conducting metabolism studies under controlled environment feeding trials. The NRI Phase 2 studies were extended to review the AME values of local feeds by determining the gross energy values of all diets and excreta voided by chicks. The calcium content of broiler and layer diets were particularly low so that the local oyster shells, bone meal, and other raw materials were analysed for this mineral. Based on these comprehensive analysis, a feed composition chart that would allow least-cost poultry ration formulation in the region of the project site was constructed (Appendix 16.5), and formed the basis of the development of rations for all subsequent project feeding trials. This Chart will, however, be useful to IRZV in their future feed developmental work and will also enable other local government agricultural extension agencies.

11.5.7.6.4. *Selection of sweet potato and cassava varieties*

194. Since SP 1112 gave the best production of all SP varieties tested in both broilers and layers, it was decided to cultivate this variety on MRS fields for the on-farm trials. CAS White was selected for use as this variety had a higher nutritional value than CAS Red in the tuber and root cariety evaluation feeding trials.

11.5.7.6.5. *Use of cottonseed cake with or without iron treatment*

195. NRI's previous studies have shown that there are minor beneficial effects on broiler performance of treating CSC with crystalline ferrous sulphate (unpublished). The Tuber and Root Storage Broiler Trials 1 and 2, however, showed that there were deleterious effects of treating CSC with FSH on weight gain and efficiency, although it was not clear whether this was simply a palatability problem or a toxicological problem. For laying hens the performance of hens fed the iron-treated CSC was significantly lower than controls (Tables 17 and 18).

196. Whilst researchers agreed that CSC must be used in the ration the question, because it was considerably cheaper than soyabean meal which may be imported into the country (Appendix 16.3, Table 26). However, how much CSC should be used and whether it should be treated with ferrous sulphate were vexing questions. It appears that the NRI suggestion of solution treatment was not successful in the field, particularly for laying hens (Panigrahi, 1992b). However, it is also possible that the technology did not work in the field due to inadequate diet mixing. Since MRS did not have a small mixer to mix experimental diets, plastic bags were used, which could have led to different reactions taking place in the feed than found in NRI studies. Further, it was not clear whether addition of FSH in the crystalline form would also have given better, similar or even worse results in the field. Thus, much uncertainty was introduced on the ration formulation strategy to be pursued in project development. Further research was considered necessary to test a few combinations of rations with different methods of FSH treatment before any firm conlusions could be drawn. However, there were no funds, and more importantly time, to conduct this work in the present project.

197. In view of these considerations, different approach was adopted for broilers and layers. For broilers, the beneficial effects from NRI studies were minor so that it was decided to use CSC at up to 25 per cent inclusion rate without any iron treatment. A more important reason for not using iron salts was that in common with synthetic amino acids (paragraph 186) these are not generally available in the rural areas, and treatment of the CSC was likely to create confusion in the minds of users, which could potentially lead to disastrous results if too high a quantity was inadvertently used. Further, researchers considered that there were no serious meat quality problems in relation to the presence of gossypol in chicken meat to consider, since the CSC variety locally available was low in gossypol. It should be noted that analysis completed in 1996 showed that the free gossypol content 8 samples of CSC taken from different sources in Cameroon contained 715, 715, 880, 980, 1130, 1250, 1300 and 1380 mg/kg; but MRS researchers believe that the local expeller CSC from Sodccoton mill in Kaele contains only around 500 mg/kg of gossypol and is consequently exported to France because of its high quality.

198. However, for layers a different set of considerations apply. Will egg discolourations take place and will egg production decline, if CSC was limited to below the 15 per cent of the diet in the on-farm rations? If there was a serious danger of the eggs becoming unmarketable because of discolourations, then addition of some FSH would be desirable, but the question then would be whether to use a lower than the generally recommended concentration of a 4:1 weight ratio of iron:gossypol, and whether it should be added in crystalline form or in solution. Other questions were will there be long term adverse effects of feeding CSC at this level on egg production and health of birds?. At more than 25 per cent inclusion rate researchers were reluctant to use CSC without iron treatment, particularly since treatment with FSH in the first on-station feeding trial had depressed production but this was still most profitable ration. Pending further strategic research to address the technical issues identified above, the only practical option was, therefore, to limit the CSC inclusion rate to about half the inclusion rate to see if this will prevent the egg discolouration problems whilst ensuring a high level of egg production. Lack of access to FSH for peasant poultry production and practical complications related to feed mixing supported this approach. It was, however, essential to test these first in an on-station trial before deciding whether the rations would be suitable for transfer to resource-poor farmers. Thus, in the on-station testing of first on-farm layer trial it was decided to use untreated CSC at a maximum of 13 per cent inclusion rate, using least cost diet formulation.

11.5.7.7. *First tentative rations designed for target beneficiaries*

199. The project objective was to design SP-based and CAS-based, low-in-cereal or cereal-free poultry rations for the target beneficiaries in the project site region. Since the ultimate test of the success of the project would be the relative profitability of these rations with current farmer practices, at this stage the project needed to develop and test one of each type of these rations and to compare the performance of chickens fed on these rations with the best commercial feeds (as indicated by the price) that was sold in the project site region. The commercial ration selected wa that made by the company Elevage Promotion Afrique (EPA). Ultimately, the success of the project would be based on testing (and demonstrating) the rations under farmer conditions in their premises. Thus, the treatments for the next stage of feeding trials were:

Broiler:
A. Ration with SP 1112 (cereal-free) for 0-8 weeks
B. Ration with CAS White (cereal-free) for 0-8 weeks
C. Commercial ration - EPA Starter for 0-4 weeks, followed Finisher for 4-8 weeks

***Layer*:**
A. Treatment ration with SP 1112 (cereal-free)
B. Treatment ration with CAS White (very low in cereal)
C. Commercial ration - EPA Layer.

200. Apart from the nutritional implications arising from the first series of on-station broiler and layer trials discussed in the previous section (paragraphs 164-175) the findings from the NRI Phase 2 Part 1 on local agricultural feed resources (paragraphs 94-99) needed to be considered for incorporation in the SP and CAS-based rations. Besides SP and CAS, oilseed byproducts such as PPS and WPK were considered to be of considerable importance as potential feed resources for small-scale rural poultry production and used in the rations. At a more general level, it is suggested that cereal milling by-products (local rice bran), rural slaughter house by-products (local blood and bone meals), brewery by-products (eg brewers dried grains from a brewery in Bafoussam) and products from local mining activities (eg limestone) need to be utilised in rations as far as possible since it not only makes rations cheaper because this reduces the use of materials that have to be imported into the area (such as imported soyabean meal and concentrates), it assists rural development by adding value to the by-products and, as in the case of PPS, the waste products of local small-scale agro processors and industries. Thus, the rations which take account of the resources and constraints of the target poultry producers also become consistent with the wider local agricultural system. The nutritional approach may, therefore, be described as animal nutrition for sustainable livestock development.

201. The third component of the rations for the target beneficiaries is the form of presentation of SP and CAS in the rations. The use of grits of the appropriate dimensions was believed to be important technolgy as it by-passed the grinding process and made savings not only on the cost of feed production, utilisation by chickens of the rations was improved. However, socio-economically optimal technology was not available or even guaranteed in terms of the development of manual griiting machine. Two prototypes had been developed by September 1995 (paragraphs 271-272) but these were the grits produced were too large for day-old chicks although these could be sun-dried within one day. It was, therefore, not appropriate to use grits at this stage. The option of testing their use doing so once a suitable gritting machine was developed was however kept open.

Table 19. Composition of the first tentative broiler rations designed for target users (% unless otherwise stated).

Treatment rations	Sweet potato-based diet (A)	Cassava-based diet (B)	Commercial diet (C)	
			Starter	Finisher
Ingredients:				
Fishmeal	10.185	10.431		
Oyster sea shells	0.478	0.939		
Bone meal	0.868	0.301		
Cottonseed cake	18.368	20.294		
Blood meal	2.000	2.050		
Salt	0.142	0.105		
Palm pit sediment	-	6.000		
Sweet potato tuber meal - 1112	53.663	-		
Cassava root meal - White	-	50.000		
Whole palm kernels	14.296	9.88		
Total	100	100	100	100
Ration cost (FCFA/kg)	137.11	121.81	250	230
Calculated analysis:				
Crude protein	22.00	22.00	25.5	22.5
Metabolisable energy (MJ/kg)	12.40	12.45	12.12	12.33
Calcium	1.00	1.00	1.20	1.00
Phosphorus	0.75	0.70	-	
Available phosphorus	-	-	0.50	0.40
Lysine	1.10	1.08		
Methinine+cystine	0.93	0.93		
Salt	0.40	0.40		

202. The rations are shown in Tables 18 and 19. The same consideration concerning each ingredient was not applied to the four broiler and layer test rations in order to explore different ration options since the project was still at the exploratory stage in terms of the design of rations for use on the farm. For example, PPS was only included only in the CAS-based broiler ration. However, whole palm kernels were included in each of the four ration because it was very cheap in the rural areas, being sold at 25 FCFA per kg in 1995.

203. The SP and CAS-based diets Treatment Rations A and B were formulated on the basis of nutrient analyses and prices shown in Appendix 16.6. practice in the poultry production systems of the region. However, for AME values were different as the NRI Phase 2 studies had not been completed at the time of the feeding trials It should be mentioned that AME values are always 'guesstimates' and the poultry nutritionist always needs to keep these values under review. The difference in the nature of the rations designed for the target group and the diets used in the first on-station Tuber and Root Variety Evaulation Trials (Appendix 16.7, Tables 1-6) is apparent in the much lower plane of nutrition (see calculated analyses) which makes the rations for the target group (farmer rations) nutrient-sub-maximal (expected to result in lower productivity unless the principles of compensatory growth come into play), and the considerably lower cost (to reduce cash outlay by the farmers). Another difference between the first on-station feeding trials and those planned for on-farm trials is that in the latter vitamins and minerals would be provided in the drinking water, as is the practice in the production systems of the project region.

Table 20. Composition of the first tentative layer rations designed for target beneficiaries (% unless otherwise stated).

Treatment rations	Sweet potato-based diet (A)	Cassava-based diet (B)	Commercial layer diet (C)
Ingredients:			
Fishmeal	9.384	9.020	
Oyster sea shells	8.191	8.737	
Bone meal	1.653	1.414	
Cottonseed cake	11.400	13.000	
Blood meal	1.000	1.414	
Salt	0.142	0.146	
Sweet potato tuber meal 1112	50.000	-	
Cassava root meal -White	4.561	50.000	
Maize	-	3.623	
Whole palm kernels	13.669	12.646	
Total	100	100	100
Ration cost (FCFA/kg)	129.12	115.45	200.0
Calculated analysis:			
Crude protein	17.00	17.00	17.0
Metabolisable energy (MJ/kg)	11.60	11.64	11.7
Calcium	3.80	3.90	3.60
Phosphorus	0.75	0.73	-
Available phosphorus	-	-	0.40
Lysine	0.87	0.85	
Methinine+cystine	0.80	0.77	
Salt	0.40	0.40	

11.5.7.8. *On-station poultry feeding trials to test the first set of tentative on-farm rations*

204. There were three reasons of relevance to project development for which it was necessary to test the above rations in on-station feeding trials before testing them on-farm. First, the on-farm trials were to be left largely under farmer control under the terms of farmer participation so that the data obtained on the productivity and profitability of the rations could not be expected to be very reliable unless a large-scale experimentation was conducted with several replicates of each farmer type. Project funds only permit a limited scale of on-farm trials with no replication. It was, therefore, appropriate to base any recommendations arising from the project outputs on a combination of on-station under researcher control and on-farm trials. Second, pre-testing of rations would leave open the scope for modifying the ration if productivity and profitability were not likely to be sufficient to encourage adoption. Thirdly, researchers needed to develop some confidence in the rations, as the rations developed are specific to the resources and constraints of farmers in the project location, an approach that has not been attempted before with poultry as far as the researchers were aware.

205. For these trials SP 1112 an CAS White were processed through the AS4 plate of the TRS since this was believed to be optimal if the grits produces were to be further ground before being mixed with other ration ingredients. The broiler trial was conducted with day-old chicks (paragraph 169), using eight replicates of 14 chicks each, randomly allocated to the pens, enclosures and blocks, but using only blocks I-IV shown in Figure 2.

206. The layer trial was conducted with the same batch of laying hens used in the first on-station feeding trial, which were now 18 months of age (8 months into lay), and their hen day production rate was around 50 per cent. Ideally, newly laying hens should have been used, but these would have

had to be reared on station from May 1995 to be available for the feeding trial in December. Since chicks were being reared from day-old for transfer to the first on-farm trials that were to take place in January-February 1996, there were no facilities left on MRS to rear another batch of chicks to point-of-lay for on-station tests. Rearing also entails considerable costs in terms of chicks, feeds, veterinary care and labour time for animal husbandry, so that it appeared more reasonable to use the old hens already in cages from the previous experiment. Hens were allocated to diets and cages randomly using 16 hens per treatment, using an incomplete randomised block design to take account the tier effects. Hens were fed the three experimental diets for 8 weeks, and data were recorded as described previously (paragraphs 5-154).

11.5.7.9. *Results of the on-station testing of first tentative broiler rations (broiler 3)*

207. The results of the broiler trial are summarised in Table 20. After 4 weeks of feeding, the liveweights of chicks fed on the SP- and CAS-based diets were 46 and 23 per cent lower than those of chicks fed the commercial ration, the figures being 51 and 20 per cent respectively by 8 weeks of feeding. Similarly, food intakes of chicks fed on the SP- and CAS-based diets were 32 and 17 per cent lower than those of chicks fed the commercial ration, the figures being 34 and 17 per cent respectively by 8 weeks of feeding. The efficiency of food utilisation (EFU) during 0-4 weeks of the SP- and CAS-based dietary groups were 21 and 8 per cent lower than for the commercial diet group, the figures being 26 and 12 per cent, respectively, for the 0-8 week period.

208. The lower productivity of chicks fed on the test rations was not unexpected in view of the nutrient sub-maximal rations used, but the scale of the lower productivity was surprising. It was evident that compensatory growth phenomeonon did not take place in the manner expected, possibly because of feed texture. When fed in mash form tubers and roots are very powdery (dusty) so that intakes are also depressed regardless of the nutrient content of the ration. The texture may be ameliorated by the use of vegetable oils which facilitates higher food intakes. This was the reason for allowing in palm oil into these rations in the Tuber and Root Variety Evaluation broiler and layer trials (Appendix 16.6, Tables 1, 3, and 5). It was not used in the present trials primarily because of the high cost. However, other factors that might have contributed to the lower productivity were the coarsely ground nature of WPK (finely ground was used in the NRI Phase 2, Part 1 trials), and the chicks were from a poor batch sent by the hatchery as indicated by the fact that even those fed the control ration could not reach more than 2 kg by eight weeks of feeding.

209. However, small-scale broiler producers rarely keep chickens throughout the year liveweights and efficiencies are not the appropriate criteria for judging the suitability of the ration for onfarm testing. In most situations, chicken begin to be sold in small quantities from 8 weeks of age and the entire batch may not be sold even 4 weeks later. Further, meat chickens are not sold by weight in the project site but by appearance of size. Since feed costs represents 60-65 per cent of the costs of poultry production and the cost of day-old chicks represents 25 per cent (Appendix 16.3, Table 44) when these factors are considered together, the most relevant criteria for guaging the suitability of the rations for transfer to the target group is the cost of feed per kg liveweight gain over the entire production cycle. Assuming all chickens would be sold at 8 weeks, it cost 619 FCFA per kg of feed consumed to produce chickens using the commercial ration, as against 478 FCFA for the SP-based ration and only 360 FCFA for the CAS-based ration. Thus, the savings on cost of broiler meat production were 23 per cent for the SP-based ration and 45 per cent for the CAS-based ration. Thus, notwithstanding the lower productivity in comparison with the best commercial feed sold in the area, the on-station testing showed that both test rations had considerable promise for developing an intermediate-intensity poultry production system that met the needs of the poultry producers in the project region.

210. A small percentage of broilers in the broiler trial developed leg problems, mainly in the cassava-based treatment group. A possible cause of this may have been low calcium and phosphorus. There was no time to analyse to diets to confirm the cause, and since the overall results were good, it

was decided to proceed with the on farm testing of rations unchanged. Possible sources of the problem may be the oyster shell or bone meals used. It may be more appropriate to formulate rations to contain 1.2 per cent calcium to take account of the lower than expected bioavailability of this mineral in oyster shells. A sample of bone meal was analysed subsequently (1997 sample in Appendix 6)and found to adequate calcium and phosphorus contents. Inadequate mixing of rations may also cause loss of minerals when dusty feeds such as tubers and roots are involved. For this reason it is necessary to provide small-scale poultry producers with a package of poultry technology including how to mix small quantities of feeds (see Appendix 16.8).

11.5.7.10. *Results of the on-station testing of first tentative layer rations (layer 2)*

211. The results of the layer trial are summarised in Table 21. The CAS-based ration produced a similar rate of egg production in terms of hen-day production and mass of eggs laid but the production rate with SP-based ration was 21 per cent lower. Food intakes were highest on the commercial ration, followed by the CAS-based ration, and lowest on the SP-based ration. In laying hens the efficiency of lay is not easily measured over short periods of feeding, particularly with diets associated with anti-nutritional factors (such as trypsin inhibitors in SP) including unsuitable feed texture such as the powdery nature of tubers and roots. However, figures for number and mass of eggs per kg feed consumed were best for the CAS-based ration followed by commercial ration and then the SP-based ration. The lower food intakes in the SP-based ration compared with the CAS-based rations may indicate that the texture of this feed is worse than that of SP, and resulted in the lower productivity of hens. The coarsely ground nature of WPK could also have had a deleterious effect on food intake.

212. However, for the same consideration as those applied for broilers (paragraph 186) it is necessary to examine the 'bottom line' when determining whether the rations might be suitable for on farm transfer. Due to the higher food intake associated with the commercial diet, the cost of feed used to produce a tray of 30 eggs were 951, 650 and 1306 FCFA for the SP-based ration, CAS-based ration and the commercial ration, respectively; the corresponding profit margins being 399, 700 and 44 FCFA. Using this criteria, it was still considerably more profitable for small-scale producers to use the SP- and CAS-based rations.

213. The eggs produced by the various treaments were also checked for egg quality by assessing yolk colour (using the Roche colour fan), Haugh Units, Shell weight and thickness, and meat and blood spots. The only significant finding was the paler yolks of the yolks in the SP- and CAS-based diet groups. It is, however, not clear whether the yolk colours were too pale to be acceptable to consumers. There were no signs of gossypol-related brown yolk discolorations in freshly laid eggs arising from the inclusion of CSC in the rations. Egg storage studies were not conducted.

Table 21. Summary of results from the on-station testing of broiler chick diets designed for the first on-farm broiler feeding trials. Feeding trial took place during December and January 1995-1996.

	Sweet potato-tuber-based diet		Cassava root -based diet diet		Commercial		SEM		Significance of dietary effect (P<or=)	
Weeks of feeding	**0-4**	**0-8**	**0-4**	**0-8**	**0-4**	**0-8**	**0-4**	**0-8**	**0-4**	**0-8**
Liveweight (kg)	0.394^{a}	0.882^{a}	0.562^{b}	1.439^{b}	0.734^{c}	1.819^{a}	7.09	27.68	0.0001	0.0001
Food intake (kg)	0.952^{a}	3.077^{a}	1.163^{b}	4.116^{b}	1.408^{c}	4.657^{a}	20.01	62.72	0.0001	0.0001
EFU (gain/feed)	0.407^{a}	0.289^{a}	0.477^{b}	0.341^{b}	0.518^{c}	0.389^{a}	0.0065	0.0054	0.0001	0.0001
Cost feed/kg gain (FCFA)	337.0^{a}	477.7^{a}	257.2^{b}	360.1^{b}	464.7^{c}	619.0^{a}	4.96	7.95	0.0001	0.0001
% Savings on Diet C	27.33^{a}	22.83^{a}	44.65^{b}	41.83^{b}			1.26	1.46	0.0001	0.0001

Each figure is the mean of 8 replicates. SEM = Pooled standard error of means. Within each of the 0-4 and 0-8 week data, values in the same line with different superscripts are significantly different (P<0.05).

Table 22. Summary of results from the on-station testing of layer rations designed for the first on-farm layer feeding trials. 20 month-old individually caged laying hens were fed for 8 weeks. Feeding trial took place during November and January 1995-1996.

Treatments	SP-based diet	CAS-based diet	Commercial diet	RMSE	*Significance* (P=<) Tier	IWT	Diet
Total food intake (g)	5008^{a}	5239^{a}	5730^{b}	506.3	0.4674	0.0004	0.0069
Food intake (g per hen d)	89.4^{a}	93.5^{a}	102.3^{b}	9.04	0.4674	0.0004	0.0069
Total number of eggs laid	21.75^{a}	29.49^{b}	27.55^{b}	6.218	0.6283	0.9029	0.0047
Hen day production	0.388^{a}	0.527^{b}	0.492^{b}	0.111	0.6283	0.9029	0.0047
Change in body weight (g)	-118^{a}	-84^{ab}	-17^{b}	93.98	0.2105	0.0008	0.0509
Total mass of eggs laid (g)	1274^{a}	1672^{b}	1626^{b}	329.4	0.6578	0.6812	0.0048
G eggs per hen d	22.75^{a}	29.86^{b}	29.03^{b}	5.88	0.6578	0.6812	0.0048
Mean egg weight (g)	58.57	57.19	59.26	2.958	0.7104	0.0551	0.1801
G eggs per kg feed	256^{a}	319^{b}	286^{ab}	57.4	0.5426	0.1862	0.0136
Number of eggs laid per kg feed	4.38^{a}	5.65^{b}	4.86^{ab}	1.098	0.5236	0.0877	0.0080
Feed cost per kg eggs (FCFA)	525^{a}	370^{b}	751^{c}	50.2	0.5687	0.1621	0.0001
Feed consumed per tray of eggs (kg)	7.36^{b}	5.62^{a}	6.39^{ab}	1.766	0.5982	0.1196	0.0310
Feed cost per tray of eggs (FCFA)	951^{a}	650^{b}	1306^{c}	251.2	0.6237	0.1542	0.0001
Profit margin per tray of eggs (FCFA)	399^{a}	700^{b}	44^{c}	251.2	0.6237	0.1542	0.0001

Notes: Least square means adjust for Tier and initial body weight (IWT) as covariates; RMSE Root Mean Square Error. No of hens per treatmet 19 in Diets A and B, 15 in Diet C. Diet Cost (FCFA/kg): A 129.11, B 115.45, C 200. Farmgate price for a tray (30) of eggs - FCFA 1350. Values in the same line with different superscripts are significantly different (P<0.05).

11.5.7.11 *Implications of the findings of on-station testing of first tentative rations for the on-farm testing stage*

214. Although the production rate achieved on the SP-based rations was lower than desired, the broiler ration in particulary was sufficiently more profitable in relation the commercial ration. The CAS-based rations were even more profitable for both broilers and layers, although there was some concern that the yolk may be too pale in colour to be acceptable in the region. Of particular relevance to the target poultry producer these rations significantly reduced their cash outlay on feed considerably from current practice of total reliance on commercial feeds. A vast majority small-scale poultry producers in the region are also involved in crop production so that they would be able to generate their own SP or CAS. Most smallholders also own one or two palm trees, and the palm fruits are processed in village pits to extract oil leaving behind the PPS and WPK. Thus potentially, with 50 per cent SP- or CAS, 14 per cent WPK and 6 per cent PPS 70 per cent of the ration could be farm-produced feed.

215. It was decided to proceed with on-farm testing of the rations developed without any modifications of the rations. However, in addition to the profitability of the cereal-free rations, two aspects of farmer responses would in particular be monitored: the acceptability of production rates achieved; and the acceptability of resulting yolk colour.

11.5.8. *Testing the first project developed poultry rations in on-farm trials*

216. The main objective of the on-farm trials was to test the project-developed tuber and root-based poultry rations under farmer conditions to determine their applicability. Three diets were to be compared: (a) a SP-based ration; (b) a CAS-based ration, and (c) the 'best' commercial diet (Tables 18-19). The project-developed feeds and chickens were provided to be provided to farmers for testing under their own management conditions. The second objective was to demonstrate the use of of low-cereal or cereal-free poultry feeds to small-scale poultry producers and to promote the technology to other producers and potential producers in the western highlands of Cameroon. This was to be achieved by a combination of (a) selecting appropriate participants for the on-farm trials; (b) organising visits by people interested in poultry rearing to these premises, the on-farm trials thus serving as 'demonstration' trials); and (c) organising public meetings at the research station with project participants and other economic stakeholders. The selection of one male farmer who owned a small-scale animal feed shop, the village leader, and the PRTC were based on the consideration that these participants represented possible diffusion pathways for the promotion of project-generated technologies (paragraphs 117-119). Thus, the terms of farmer participation was an important consideraton in project design.

11.5.8.1. *Terms of farmer participation*

217. Apart from the considerations discussed earlier (paragraphs 109-119) other criteria were important for selection in relation to the 'ration testing' objective. All farmers should have had at least 1 year of experience in poultry rearing of the broiler or layer type so that they did not make mistakes in animal husbandry (refesher training would be provided in this). Participants must also have poultry houses that are suitable for partitioning into three segments so that birds could be fed the three dietary treatments in separate compartments but within the same building to ensure that they were subject to similar conditions for comparison. All potential participants were interviewed and only those selected who agreed to maintain records of poultry performance. This would be daily food intakes in the case of broilers, and for egg production, daily record of food intakes and eggs laid, with eggs being graded according to small, middle and large eggs . Training and appropriate data sheets would be provided in each aspect prior to the feeding trials. Researchers will however weigh the birds at the start middle and end of the feed trial periods due to the greater accuracy equipment required.

218. To assist the 'demonstration' objective particpants were also required to allow visits to their premises during the on-farm trials by resource-poor poultry producers or those expressing a wish to start poultry rearing activities. To minimise inconvenience to participants these would be group visits regulated by MRS rather than haphazard individual visits.

219. To induce participation and because of the uncertainty on whether the rations developed would be successful, the participants would be given chickens and feeds free of charge and would be allowed to keep the proceeds from sales of chickens and eggs. However, farmers dropping out of the trials would be required to return the laying hens to MRS. Each participant was to be given up to 75 newly laying hens (reared at MRS from day-old) and up to 75 day-old broiler chicks for allocation to the three dietary treatments at 25 chicks per treatment although in the event fewer birds were given (see below). Logistical problems prevented the use of more than one replicate per farm. Sufficient test diets would be given to enable feeding for a period of 15 weeks for layers and 8 weeks for broilers.

11.5.8.2. *Particulars of particpants and their poultry facilities*

220. *Male Farmer A*. Mr. John Ngwa was a driver living in Muwachu: 2 km West of IRZV, Akemnebang village in Mankon. and also rears rabbits and chickens of both the broiler and layer strain and grows crops. He kept 39 chickens in the main building in another partition he keeps 3 hens and a cock and a similar number in a third room. His fertile eggs are bought by a local person who incubates them. His reported that 7 out of 10 eggs hatch out, but 3 develop and are unable to hatch. The poultry house was on stilts and the floor made of the raffia bamboo with slits that to allow rain water to escape. However, other associated advantages of this system is that litter (such as wood shavings) are not required and excreta can fall through for easy collection and use as manure or kept for sale (Some farmers maintain a mixed floor system with part deep litter and part slatted floor, the latter being raised somewhat so that birds invariably perch on it for excretion).

221. Mr Ngwa followed a ration for laying hens and breeders that comprised of (%): maize 62.5 CSC 15.0, fishmeal 7.5, rice bran 4.5, bone meal 1.0, oyster shells 9.0, salt 0.5. The estimated nutrient content of this ration is as follows: CP 18.25; AME 11.42; calcium 3.81; phosphorus 0.82; salt 0.70; lysine 0.84; and methionine+cystine 0.98. The cost is 167 FCFA/kg compared with 200 FCFA/kg for commercial feeds. Mr Ngwa buys whole dry fish and grinds it himself in an electric mill owned by a relative for grinding maize brought to the mill by local farmers. He enquired whether he could use PKC from the traditional method (paragaph 121) for feeding chickens, but was especially concerned about maize. The high cost of maize has led him to keep a look out for infested maize in the market which is available in large quantities towards the end of the dry season. For this Mr Ngwa goes to rural households and purchases them at a third of the market price of good quality maize. Some farmers in the low lying swampy areas (where water accumulates) of this high rainfall highlands may obtain up to 3 crops a year of maize. The first crop is harvested in August so that there are still many rainy months ahead. This crop needs to be artificially-dried indoors using log fire ovens to ensure that the moisture content is kept 12 per cent. However, small-scael farmers are not able to afford artificial oven drying systems which are also environmentally unsustainable in view of the diminishng fuelwood resources in the region. Consequently, it is common for them to rely on a combination of sun-drying in between rain showers and indoor drying. This means that the first crop in particular is not well dried. Insect infestation and fungus colonisation takes place on stored maize. When the time for marketing arrives farmer separates the good maize from the bad maize (has green elements of fungus and is insect infested) selling each separately.

222. Mr Ngwa enquired whether it was safe for him to use 'bad' corn. Not much research has been done in this aspect of poultry nutrition, but it is probable from the fungus evident in samples and the 'stackburned' colour that mycotoxins (aflatoxins, trichothecenes, etc) would be produced during storage and harm chickens in terms of reduced growth of broilers and depression of egg

production in layers. Mr Ngwo complained about the low viability of the eggs from his breeders, which may be associated with aflatoxin-contaminated maize, particularly when consumed with the gossypol arising from the high level of CSC he uses. It is possible that the harmful effects of fungus infested maize would not not persist if the ration is changed to the use of good quality maize periodically. His own experiments with maize gave Mr Ngwa the ideal profile for the demonstration of the project concept of replacing maize with SP and CAS, which, unlike maize, is available in large quantities as the beginning of the dry season and can be gritted and sun-dried (that is without the use of fossil fuel) and stored for feeding to chickens for up to six months, as indicated from the on-staiton Tuber and Root Storage Broiler Trial 2 (paragraph 159). Further, the resource management issues surrounding maize for small-scale resource poor farmers revealed in this case study exemplifies the importance of the present project in developing countries.

223. For the on-farm trials Mr Ngwa was given 60 day-old broiler chicks and 45 laying hens. His poultry houses consisted of the following.

Broiler house: This was a windowed-building had walls made of plastered sun-dried muc blocks on the walls and roofed with corrugated zinc sheets. The cemented floor was covered with wood shavings as litter. The room was partitioned with raffia bamboo/mats and eucalyptus poles. In each brooding pen there was one standing hover (40 cm above floor level) covered with empty used bags and 3 kerosene bush lamps (0-3 weeks of birds age). Two powdered milk tin (1 litre capacity) with two holes placed laterally at the edge and inverted on a plastic tray served as drinkers up to 2 weeks of birds age. From there on, a 5-litre plastic bucket also with two lateral holes and inverted on a larger plastic tray was used. For feeding, two plastic trays were used during the first week and one wooden trough per pen during the rest of the feeding trial.

Layer house: The building was an all-raffia bamboo wall structure with raised bamboo slatted floor (80 cm above floor level), roofed with corrugated zinc sheets. Eucalyptus poles were used for framing. Partitioning was done with poles and raffia bamboos. Laying nests were made of plywood material and divided into six boxes. One -litre plastic bucket with lateral holes and inverted on a plastic tray served as a drinker. A wooden feeding trough was provided per pen.

224. *Male Farmer B*. Mr Wilfred Fai was a retrenched civil servant and is involved in crop farming, poultry rearing and petit trading. The trading includes mixing and selling animal feeds to small-scale livestock producers. He is based in Ntarkah: 1 km east of MRS. There was a special reason for selecting this farmer. Small-scale agroprocessing is a vital component of agricultural systems as they provide a valuable service to the local community. Small-scale manufacture of compound animal feed is a highly neglected area of development. This farmer mixing feeds using bucket and floor mixing techniques provide small quantities of mixed feeds to local small-scale livestock owners, and can therefore serve as a vehicle for the adoption of the outputs of this project. Large-scale feed millers using sophisticated milling technology are unable organise the feed developmental work necessary to adopt the technology of the project, but small-scale millers with good local contacts with farmers and who are stakeholders in the the local community will, it is believed, be able to. There were at least 50 small-scale livestock producers of chickens, pigs, rabbits and cattle who purchased feeds from Mr Fai and relied on him for advice on animal feeding. It was therefore considered that this person would be an appropriate candidate for on-farm testing as this could lead to a market forces driven diffusion of the project developed technologies. For this reason, in addition to seeking his participation in the on-farm demonstration trials further advice was given to this Test farmer at the end of the on-farm trials (Appendix 16.8). For the feeding trials Mr Fai received 72 day-old broiler chicks and 45 laying pullets.

Broiler & layer house: The building was an all-raffia bamboo (see Appendix 14 Plate 2) wall structure roofed with corrugated zinc sheets and with a bared floor covered with a 10 cm thick wood shavings litter material. Partitioning was done with eucalyptus poles and raffia bamboos. There were 3 pens for broilers and the same for layers, within the same room. Polyethylene sheets were used as insulator and placed round the whole building. In each broiler pen, there was one standing cardboard paper framed for partial (one-third of room space) brooding (0-3 weeks of bird age) and equipped with one kerosene bush lamp. Two powdered milk tin (1 litre capacity) with two holes placed laterally at the edge and inverted on a plastic tray served as drinkers up to 2 weeks of birds age. From there on, a 5-litre plastic bucket, also with two lateral holes, and inverted on a larger plastic tray was used. In each layer pen, one 5-litre bowl containing a weight (stone) was provided for daily fresh water supply. For feeding, two plastic trays were used during the first week and one wooden trough per broiler pen during the rest of the feeding trial. In each layer pen, a wooden trough feeder was placed. Per pen, a laying nest unit made of raffia bamboo material and divided into four boxes was provided.

225. *Female Farmer A*. Mrs Esther Geh was a retired nurse and involved in crop farming and poultry rearing. She lived in Nitop, about 5 km east of MRS (Akemnebang). She was given 60 day-old broiler chicks.

Broiler house: This was a windowed-building had walls made of plastered cement blocks for the walls and the roof with corrugated zinc sheets. The cemented floor was covered with wood shavings as litter. The room was partitioned into three pens using raffia bamboos, card board papers and eucalyptus poles. Brooding was done using a hanging hover with one 100 watt electrical bulb per pen. Two powdered milk tin (1 litre capacity) with two holes placed laterally at the edge and inverted on a plastic tray served as drinkers up to 2 weeks of birds age. From there on, a 5-litre plastic bowl put on the floor but protected with a standing fish-like nest trap made of tree branches to keep chickens away from getting into it served as a drinker (Appendix 14 Plate 6). For feeding, two plastic trays were used during the first two weeks and one wooden trough per thereafter.

226. *Female Farmer B*. Mrs Fride Makambou was a housewife and engaged in crop farming, poultry rearing and petit trading. She lived in Old Town, 10 km East of MRS (Akemnebang). She was given 60 laying pullets.

Layer house: This was a windowed, all-concrete building was made of plastered cement blocks on the walls and roofed with corrugated zinc sheets. The cemented floor was covered with wood shavings as litter. The room was partitioned into three pens each having a separate window. Laying nests were made of plywood material and divided into four boxes. One 5-litre plastic bucket with lateral holes and inverted on a plastic tray served as a drinker. A wooden feeding trough was provided per pen. Two powdered milk tin (1 litre capacity) with two holes placed laterally at the edge and inverted on a plastic tray served as drinkers up to 2 weeks of birds age. From there on, a 5-litre plastic bucket, also with two lateral holes, and inverted on a larger plastic tray was used. In each layer pen, one 5-litre bowl containing a weight (stone) was provided for daily fresh water supply. For feeding, two plastic trays were used during the first week and one wooden trough per broiler pen during the rest of the feeding trial. In each layer pen, a wooden trough feeder was placed, and a laying nest unit made of raffia bamboo material divided into four boxes was provided.

227. *PRTC*. The Centre is located 30 km north of IRZV Mankon in Mfonta, a village in Bambui, Tubah district. Their major activities are religious worship and the training of rural farmers, demonstrating agriculture technolgies and undertaking rural developmental projects. Their work was conducted with youth, women and men. They train people to go to the villages and give advice on farming. Prior to 1993, PRTC used to prepare poultry feeds for their own use in the training centre for the purposes of training people in poultry husbandry, and selling this feed to people whom came to buy it. However, their poultry project folded due to high cost of feeds and chickens. The previous rations used are shown in Table 22. Taking the laying hen ration as an example the cost was approximately the same as for commercial layer's mash. the nutrient contents of all diets were imbalanced as seen for example in the phosphorus contents.

Table 23. Poultry rations used by the Presbytarian Rural Training Centre prior to the project.

	Layer Starter chick	Layer Grower chick	Laying hen
Maize	51	41	50
Soyabean meal	27	16	30
Rice bran	17	37.5	10.5
Bone meal	4.5	5	9
Salt	0.5	0.5	0.5
Cost (FCFA/kg)	192	133	206
Estimated nutrient analyses			
Crude protein	18.1	15.1	18.6
AME	11.60	11.53	10.98
Calcium	1.71	1.87	3.33
Phosphorus	1.26	1.56	1.88
Lysine	1.03	0.83	1.08
Methionine+cystine	0.75	0.62	0.77
Salt	0.55	0.56	0.56

228. Although staff could not show the broiler rations used, it is most likely to have been similar to the layer chick starter diet in terms. Not surprisingly, these rations became uneconomic in relation to large-scale competitors who are able to afford much higher standards of housing, husbandry and veterinary care for the chickens than small-scale resource-poor poultry rearers with the consequence that the feeds cannot be as productive in the latter's production system. There also appeared to be a lack of knowledge concerning feed quality. For example, it was stated that CSC was used at one time but discontinued because one batch became 'mouldy'. This exemplified how much training these trainers of rural extension workers required in poultry feeding to ensure that resource-poor farmers received reliable advice The idea is to make simple feeds, but at what cost and no use of cheap local material. PRTC was therefore considered an ideal NGO to serve the purposes of 'a demonstration farm particularly since it has easy access to the farmers of the region. Indeed, it was fortunate for the project to find this group within easy access of the MRS. PRTC were given 60 one day-old broiler chicks and 60 laying pullets for the on-farm trials.

Broiler house: This was an open-sided building made of sun-dried mud blocks plastered half way from the bottom and chicken wire at the top. Polyethylene sheets were used to cover the chicken wire to preserve heat during brooding. The building was roofed with corrugated zinc sheets. The cemented floor was covered with rice hull litter. The room was partitioned with raffia bamboo and eucalyptus poles. Partial brooding was done on one-quarter of the pen using a box. On the first night, one kerosene bush lamp (KBL) was used and was found insufficient. This was increased to three per pen.

Layer house: This is shown in Appendix 14, Plate 2. The building had an all-raffia bamboo wall structure with raised bamboo slatted floor (40 cm above floor level) roofed with corrugated zinc sheets. Eucalyptus poles were used for framing. Partitioning was done with poles and raffia bamboos. One 10 litre plastic bucket (Appendix 14, Plate 5) served as drinker. This was secured on the slats with a wooden frame. Laying nests were made of plywood, divided into six boxes (Appendix 16.11 {Plates and). A wooden feeding trough per pen was used.

229. *CAMWIDCO*. CAMWIDCO offices were based in Ntarikon, 1 km East of IRZV Mankon (in Bamenda). Their major activities were joint farming and marketing projects exclusively for women. They were involved in crop and livestock production in rural areas. The farmer was given 60 one day-old broiler chicks, and 60 laying pullets.

Broiler & layer house: The layer house was a windowed building with walls made of plastered sun-dried mud blocks, and a roof of corrugated zinc sheets. The cemented floor was covered with wood shavings as litter. The room was partitioned with Indian and Raffia bamboos and eucalptus poles. There were three pens for broilers and 3 pens for layers, within the same room. Brooding was done using one 100-watt electrical bulb per broiler pen. One chick fount (5 litres capacity) and two metal feeder troughs were provided for each broiler pen. In each layer pen birds had access to water through a 5-litre metallic drinker and fed from a metallic trough feeder. Laying nests were made of plywood (Appendix 16.11, Plates 7 and 8) and divided into six sections.

230. *Village leader*. Mr S.A. Angwafor was the traditional ruler of Mankon village and a political figure in village Ntor, 8 km south of IRZV, Mankon. He was involved in mixed farming activities (crop and livestock). Village leaders traditionally are regarded as owning the lands (even though government records may show them as national lands) and determined the farming systems in terms of what work was conducted in the villages and which land was to be left fallow or cultivated in the rotations. Mr Angwafor was respected in the village and it was for these reasons that he was selected for demonstration of the project concept, after much deliberation because of his priviledged and wealthy position in the area. He was given 60 one day-old broiler chicks and 60 laying pullets.

Broiler house: This was an open-sided building made of sun-dried mud blocks (Appendix 14, Plate 3) plastered three-quarters way from the bottom and chicken wire at the top portion. Polyethylene sheets were used as insulator for brooding purposes. The building was roofed with corrugated zinc sheets. The cemented floor was covered with a mixture of rice hulls and wood shavings as litter, with cost and water absorption characteristics being relevant in determining the mixture portions used (wood shavings rot easier than rice hulls that contains silica and is, therefore, more suitable for direct incoporation of poultry litter produced in the soil as manure). The room was partitioned with raffia bamboo, eucalyptus poles and plywood sheets. Brooding was done using a hanging hover with a 100-watt electrical bulb per broiler pen. One chick fount (3 litres capacity) and one metallic feeder trough was provided for each pen.

Layer house: The layer house is shown in Appendix 14, Plate 2. The building was a three-walled all-raffia bamboo and one walled un-plastered sun-dried mud blocks structure with raised bamboo slatted floor (60 cm above floor level) roofed with corrugated zinc sheets. Ecucalyptus poles and raffia bamboos were used for framing and partitioning. Laying nests were made of plywood (Appendix 14, Plate 7). One 3-litre plastic chick fount served as drinker. One metallic feeding trough per pen was provided.

11.5.8.3. *Training given to participants*

231. To maximise the impact of the project, it was necessary to give explain the structure of the project and identify the roles of researchers and participants. Paricipants responsibilities included the supply of housing, feeders, management of birds and data collection while the project supplied chickens, drugs and feed, and analysed the data obtained. Training was given to participants in two specific aspects: (a) responsibilities in relation to poultry husbandry; and (b) poultry nutrition and feed production.

11.5.8.3.1. *Training on general poultry husbandry*

232. For broiler chicks, the participants were told of the importance of brooding day-old chicks correctly. Farmers were advised to observe young chicks for their behaviour to see if brooding management was correct: if chicks they too cold, they would crowd around the heating source; if the were too hot, chicks would run away from the heat source; but if they are just comfortable, chicks would move all over the room feeding, drinking and playing. For the feeding and drinking

equipment, farmers were told of the need to have a sufficient number of these to enable *ad libitum* feeding conditions a vital assumption for the project. These equipment needed to be adapted to the chickens' age and size so that chickens should were free to eat and drink at will. The height of the equipment should be at the birds shoulder height level or slightly below. Each group of chickens would have its own broiler diet to be fed throughout the feeding trial. Participants were informed that although broiler chickens were routinely fed broiler starter and finisher rations in this on-farm trial, chickens would be fed the test rations from 0-8 weeks of age, but the commercial ration in its starter and finisher forms. Laying hens would be given layer diets at 18 weeks of age. As in the broiler trial, each group of chickens will be given a separate layer diet to be fed throughout.

233. The prevention of diseases and poultry house hygiene were important factors during the trials. House cleaning was essential, comprising of sweeping, scrubbing, cleaning, washing and disinfecting. A foot bath should be added at the entrance (inside) of the poultry house. The disease prophylactic programme consisted of a routine medication and vaccination programme for broilers and layers are shown in Tables 23 and 24, respectively.

Table 24. Disease prophylactic programme for first on-farm broiler feeding trials

Bird age (days)	Disease problems	Medication and doses
0-3	Stress	Anti-stress: stress-stop, 5 g/3 litre water
6-7	Stress	Anti-stress: stress-stop, 5 g/3 litre water
8	NCD/Gumboro	Pestos and gumboral vaccination
8-9	Stress	Vitamin: 5 g/5 litre water
11-14	Bacteria Coccidiosis	Antibiotics and cocciostat drugs 5 g/5 litre water
15	Deficiencies	Vitamin: 5 g/5 litre water
19-20	Stress	Antistress: stress-stop, 5 g/5 litre water
21	NCD	Booster dose (Lasota) vaccination
21-22	Stress	Vitamin: 5 g/5 litre water
26-29	Bacteria	Antibiotics drugs
29-30	Deficiencies	Vitamin: 5 g/10 litre water
40-44	Bacteria Cocciodiosis	Antibiotics and coccidiostat drugs 5 g/litre water
44-45	Deficiencies	vitamin: 5 g/10 litre water
49-52	Stress	Antistress: stress-stop, 5 g/5 litre water

Table 25. Disease prophylactic programme for first on-farm layer feeding trials

Bird age (weeks)	Disease	Medication and doses
24	Stress	Anti-stress, 5 g/litre water for 3 days continuously
26	Deficiencies	Vitamins, 5 g/10 litre water for 3 days
28	Stress/worms	Stress-stop, 5/litre
30	Stress	Stress-stop, 5 g/5 litre water for 3 days
32	Deficiencies	Vitamins, 5 g/10litre water for 3 days
34	Stress	Stress-stop, 5 g/5 litre water for 3 days
36	Stress/worms	Stress-stop, 5 g/5 litre water for 3 days continuously; followed by 2 days with vitamin (5 g/10 litre water)
38	Stress	Stress-stop, 5 g/5 litre water for 3 days, continuously
40	Deficiencies	Vitamins, 5 g/10 litre water for 3 days continuously
etc.		

234. The floor density was an important factor. The following guidance was given:

For broilers	25 birds should occupy a square metre from 0-2 weeks of age. 15 birds should occupy a square metre from 3 to 4 weeks of age. 8-10 birds should occupy a square metre above 4 weeks of age.
For layers	3-4 birds should occupy a square metre above 20 weeks of age

235. Finally, farmers were explained that accurate record keeping was a vital component of the project without which no analysis could be conducted of how successful the rations were in achieving the project objectives. For the laying hen trial, eggs were to be collected daily and sorted into three classes based on visual scores: small, medium and large. Samples of the egg grades were provided to farmers. Farmers were to sell graded eggs and keep records. Feed was measured into feeders using variable cups/cans (Appendix 16.11. Plates 9 & 10). Each farmer had his/her own cup. The same cup was used by farmer for layer and broiler mash. The actual weight of cup content per each farm was the average weight of ten measures taken by farmer.

236. For broiler chickens, daily feed intake (how may cups or cans of feed given), mortality count, and sales of chickens were to be recorded by farmers, but body weight at 4 and 8 weeks were to be conducted by researchers. Sample of broiler and layer data sheets for recording are shown in Tables 26 and 27. To minimise the risk of mistakes each room/diet had its own data sheet, and feeds were appropriately labelled, for example, 'Diet A fed to chickens in room A' (there is a high level of literacy in this nglophone area of Cameroon). For laying hens, chicken weighings were jointly carried out by the MRS team and farmer (Appendix 16.11, Plates 11, 12 and 14). daily feed intake (use a cup/can) and mortality count.

237. Participants would record the price at which project chickens were sold. This was to be done by hand 'feeling' of weights (Appendix 16.11, Plate 13) (meat-type chickens sold at 1500-1800 FCFA per chicken depending on size). For eggs visual grading of eggs into trays of 30 eggs each would be done (Appendix 16.11; Plate 13) (eggs were sold at 1200, 1350 and 1500 FCFA for small, medium and large eggs, respectively).

Table 26. On-farm data sheet for broiler chickens.

Farmer's name: Room/Diet

Date	Feed given (cups)*	Numbers dead	Observation/Medication
15/3/96	2	0	Stress stop 5 g / 3 litre water
16/3/96	2	1	Stress stop 5 g / 3 litre water

Note: See Appendix 19 for photographs of types of cups used. Each cup was calibrated for feed content weight, and the total number of cups of feed given then multiplied with the estimated per cup weight of each of three diets to obtain food intakes per diet.

Table 27. On farm data sheet for laying hens.

Farmer's name Room/Diet:

Date	Feed given (cups)	Number dead	Eggs collected and grade			Observations/Medication

Note: See Appendix 16.11 for photographs of types of cups used. Each cup was calibrated for feed content weight, and the total number of cups of feed given then multiplied with the estimated per cup weight of each of three diets to obtain food intakes per diet.

11.5.8.3.2. *Training poultry nutrition and feed production*

238. Whilst it was appreciated by project researchers that there was a limited amount of technical training that could be provided by the project or will be understood by the project participants, it was also considered appropriate that this was the only means of generating awareness of the quality of feed in terms of nutrients. Simple languages were worked out to do this (Box 1).

Box 1. Adapting nutrition to a language suitable for training peasant poultry producers.

Nutrients were 'chemical substances' found in food when taken in the correct amounts enable plants and animals to grow well or maintain their health and weight. 'Bad' feedstuffs or poorly mixed feedstuffs in terms of 'proportions' used or 'old' and 'mouldy' ingredients give poor quality feed. If 'good' feed is adulterated to make it last longer, say with rice bran, it makes nutrients available in wrong amounts to the chickens which than does not grow as well or lay as many eggs. The nutrients of a feed can are obtained in a laboratory. Using the chemical composition, quantities of each feed item are determined to include in a ration for each kind of animal. One can use a hand calculator to determine these amounts but it is easy in a computer.

Chickens need energy for which fat, for example palm oil, is the richest source. The residues from the extraction of oil from seeds such as groundnuts, soyabeans, palm kernels and palm pit sediment (called oilcakes) also supply fat as well as reduce dustiness. However, the main energy source for poultry feed is maize but since there is a high demand for corn by people for food, other energy sources include cassava, sweet potato, the oilcakes, rice bran, etc. need to be used. Excess energy in the ration will give rise to very fatty chicken. Thus, consumer's taste must be considered.

Chickens also need protein for muscle building, for which fishmeal is the richest source. However, fishmeal is expensive because there is a high demand for it and at times it is scarce. Other protein sources include the oilcakes, brewer's dried grains, blood and meat meals and leaf meals. Protein in costly and too much protein in the ration is a waste of money because the body cannot store it and must convert it into fat or excrete it. So, inclusion rates must be fairly exact. Some oilcakes such as cottonseed cake contain poisons, which means there is only a certin amount of it that can be added into the ration.

Chickens also need vitamins but in tiny amounts. They are found in leaf meals and fish meals. These too have been extracted and are sold in various vitamin mixes on the market. Minerals are essential for good functioning of the body and for bone formation. Some are needed in very small amounts (for example, iron) while others are needed in larger quantities, for example calcium and phosphorus. The major sources of minerals are bone meal, oyster sea shells, egg shells and calabar chalk (limestone).

Feeds must be kept dry because a high-moisture content will give rise to mouldy feed. However, too low a moisture content will make the feed too dusty for easy handling so a balance is needed.

11.5.8.4. *Feed and bird rearing preparations for the first on-farm feeding trials*

239. The rations for the first on-farm trials were unchanged from those used at the on-station testing stage (paragraph 200) (Tables 18 and 19). Rations were mixed at MRS. Day-old broiler chicks were purchased a day before delivery to the farms. Laying hens were reared from day-olds at MRS and were all in lay in February 1996 when the on-farm trials commenced.

11.5.8.5. *Results of the first on-farm broiler feeding trials (broiler 4)*

240. The results of the broiler feeding trials from individual farms are shown in Table 28 and those from all six farms are summarised in Table 29. After 4 weeks of feeding, the liveweights of chicks fed on the SP- and CAS-based diets were 27 and 30 per cent lower than those of chicks fed the commercial ration, the figures being 23 and 14 per cent, respectively, by 8 weeks of feeding; the differences were statistically significant. Food intakes of chicks fed on the SP- and CAS-based diets

were also lower but there was variability in the data among farms. The EFU during 0-8 weeks of the SP- and CAS-based dietary groups were 18 and 4 per cent lower than for the commercial diet group. The combined results from on-station and on-farm testing of broiler diets give the same trends (Table 30).

241. The lower productivity of chicks fed on the test rations was consistent with the results obtained in the on-station trials except that the rate of broiler growth with SP-based ration was considerably better. As at the on-station testing stage the SP- and CAS-based rations were more profitable than the commercial ration, when figures were converted to cost of feed used per kg liveweight gain, which were 382, 292, and 533 FCFA, respectively. Over the 8 week period, there were savings of 25 per cent and 46 per cent savings on feed costs by the SP- and CAS-based rations in relation to the maize-based commercial starter and finisher rations. The on-farm broiler trials confirmed the on-station data on each of the 6 demonstration farms. When the results of trials on farmers premises are pooled with the results found on-station (Appendix 16.11, Table 2) the same trend in production and profitability of production is observed. It would therefore appear reasonable to conclude that the project has achieved a sustainable, cereal-free, intermediate-intensity poultry production system based on SP- or CAS- that is appropriate both to the needs of resource-poor farmers and achieves efficient resource management from the point of view of the country.

Table 28. Results on-farm broiler feeding trials in the six farms.

Rations	Sweet potato-based		Cassava-based		Commercial	
Weeks of feeding	**0-4**	**0-8**	**0-4**	**0-8**	**0-4**	**0-8**
Male Farmer A:						
Liveweight (kg)	0.807	2.086	0.625	1.971	1.010	2.546
Food intake (kg)	1.819	5.601	1.334	5.008	1.695	5.918
Efficiency (gain/food)	0.443	0.373	0.469	0.394	0.585	0.430
Cost feed/kg gain	309.64	368.21	259.88	309.43	410.74	557.97
% Savings on Diet C	24.62	34.01	36.73	44.54		
Male Farmer B:						
Liveweight (kg)	0.531	1.604	0.515	1.775	0.636	1.743
Food intake (kg)	0.919*	3.302	1.124*	3.954	0.608	3.679
Efficiency (gain/food)	0.578	0.486	0.406	0.449	1.046	0.474
Cost feed/kg gain	237.39	282.23	300.39	271.35	229.58	506.94
% Savings on Diet C	-3.40	44.33	-30.84	46.47		
Female Farmer A:						
Liveweight (kg)	0.757	1.621	0.571	1.711	0.843	2.005
Food intake (kg)	1.565	4.546	1.388	4.610	1.278	4.585
Efficiency (gain/food)	0.484	0.357	0.377	0.372	0.689	0.437
Cost feed/kg gain	283.46	384.40	323.05	328.16	348.55	549.12
% Savings on Diet C	18.68	29.997	7.32	40.24		
CAMWIDCO - Womens group:						
Liveweight (kg)	0.442	1.163	0.627	1.422	0.884	1.810
Food intake (kg)	1.388	3.300	1.148	2.675	1.709	3.894
Efficiency (gain/food)	0.319	0.353	0.547	0.532	0.492	0.465
Cost feed/kg gain	430.23	388.94	222.89	29.13	488.63	516.59
% Savings on Diet C	11.95	24.71	54.39	55.65		
Village Leader :						
Liveweight (kg)	0.699	1.771	0.602	1.747	0.854	2.140
Food intake (kg)	1.739	5.955	1.291	5.254	1.411	5.149
Efficiency (gain/food)	0.441	0.297	0.459	0.333	0.518	0.416
Cost feed/kg gain	311.09	460.94	265.25	366.26	463.62	577.83
% Savings on Diet C	32.90	20.23	42.79	36.61		
PRTC - NGO:						
Liveweight (kg)	0.424	1.344	0.580	1.983	0.814	2.193
Food intake (kg)	0.689	3.988	0.869	3.943	1.454	4.475
Efficiency (gain/food)	0.543	0.337	0.570	0.503	0.507	0.490
Cost feed/kg gain	252.58	406.87	213.69	242.15	473.71	489.85
% Savings on Diet C	46.68	16.94	54.89	50.57		

Notes: Commercial ration: EPA Broiler Starter (0-4 weeks) and Finisher (4-8 weeks). * Figures are unreliable - assumed that 1 cup = 0.33 kg in calculations.

Table 29. Summary of results of broiler chick feeding trials from all farms in the first (1995-96) on-farm trials. The trial took place in February-June 1996.

	Sweet potato tuber-based ration		Cassava root based ration		Commercial ration		SEM		Significance of Dietary effect (P<or=)	
Weeks of feeding	0-4	0-8	0-4	0-8	0-4	0-8	0-4	0-8	0-4	0-8
Liveweight (kg)	0.61[a]	1.60[a]	0.59[a]	1.77[ab]	0.84[b]	2.07[b]	0.028	0.065	0.0042	0.0290
Food intake (kg)	1.35[a]	4.45[a]	1.19[a]	4.24[a]	1.36[a]	4.62[a]	0.087	0.229	0.6801	0.8019
EFU (gain/feed)	0.47[a]	0.37[a]	0.47[a]	0.43[a]	0.64[a]	0.45[a]	0.033	0.014	0.0842	0.0691
Cost feed/kg gain (FCFA)	304.9[a]	381.9[a]	264.2[a]	291.1[b]	402.5[b]	533.0[c]	17.39	11.66	0.0154	0.0001
% Savings on Diet C	21.9[a]	25.0[a]	24.7[a]	45.7[b]			7.69	3.18	0.7252	0.0088

Notes: Each figure is the mean of 6 farms (one replicate per farm). SEM = Pooled standard error of means. Within each of the 0-4 and 0-8 week data, values in the same line with different superscripts are significantly different ($P<0.05$).

Table 30. Summary of results testing the first tentative rations developed for target beneficiaries in all locations (on-station and on farm testing) (1995-1996).

	Sweet potato tuber-based ration		Cassava root-based ration		Commercial ration		SEM		Significance of Dietary effect (P=<)	
Weeks of feeding	**0-4**	**0-8**	**0-4**	**0-8**	**0-4**	**0-8**	**0-4**	**0-8**	**0-4**	**0-8**
Liveweight (kg)	0.58[a]	1.50[a]	0.58[a]	1.72[ab]	0.82[b]	2.04[ab]	0.027	0.068	0.0017	0.015
Food intake (kg)	1.30[a]	4.25[a]	1.19[a]	4.22[a]	1.37[a]	4.62[a]	0.076	0.205	0.6354	0.6804
EFU (gain/feed)	0.46[a]	0.36[a]	0.47[a]	0.42[ab]	0.62[b]	0.44[b]	0.029	0.014	0.0592	0.0479
Cost feed/kg gain	308.9[a]	395.6[a]	263.2[a]	300.9[b]	411.4[b]	545.3[c]	15.08	12.06	0.0026	0.0001
% Savings on Diet C	22.7[a]	27.6[a]	30.0[a]	45.1[b]	-	-	6.62	2.71	0.5970	0.0027

Notes: All on-farm feeding trials were conducted with one replicate per dietary treatment, whereas the on-station tests were conducted with 8 replicates per dietary treatment. SEM = Pooled standard error of means. Within each of the 0-4 and 0-8 week data, values in the same line with different superscripts are significantly different (P<0.05).

11.5.8.6. *Results of the first on-farm egg production trials (layer 4)*

242. The results of on-farm layer trials are summarised in Table 31. The production rates achieved with both the SP- and CAS-based test rations were 50 and 57 percent than that obtained with the commercial diet. This was due to the lower food intakes associated with the tuber and root meals. The profitability of production on the SP-based diet was also poor when expressed in terms of the mass of eggs laid per 1000 FCFA spent on feed; however, profitabililty in terms of the number of eggs laid per 1000 FCFA spent on feed was more attractive on the SP- and CAS-based rations than on the commercial ration, due to the larger egg sizes in the latter. Overall, the results of the layer trial were not encouraging and differed from the findings from the promising results obtained in the on-station ration testing stage. It was also found that replacing maize with tubers and roots resulted in paler than acceptable yolks, and the diets need to be supplemented with a pigment source to make them marketable.

Table 31. Summary of the results of on farm layer feeding trial from all six farms (0-9 week data).

Diet	Sweet potato tuber-based ration	Cassava root based ration	Commercial ration	SEM	Significance P= or <
Hen day production	0.40^{a}	0.45^{a}	0.78^{b}	0.025	0.0001
Food intake (g/ hen d)	93.2	93.6	144.1	10.8	0.1202
G eggs/hen d	22.9^{a}	26.1^{a}	45.7^{b}	1.5	0.0001
G eggs/kg food intake	284.2	301.8	358.6	22.9	0.4039
Number of eggs/kg food intake	4.96	5.24	6.16	0.396	0.4511
Number of eggs/1000 FCFA on feed	38.4	45.3	30.8	2.61	0.1083
G eggs/1000 FCFA on feed	178.1	225.7	228.4	9.73	0.0911
Mean egg weight (g)	57.5	57.6	58.3	0.49	0.7781
Change in body weight (g/hen/d)	0.6^{a}	0.3^{a}	4.9^{a}	0.3	0.0001

243. The on-farm trials were conducted with newly laying hens (6 month old) in deep litter or raised slatted bamboo floor systems whereas the on-station testing stage of the same rations were conducted with 20 month-old caged laying hens. A number of explanations are being considered: (1) the age of the laying hen (that is the stage of production) may influence the acceptability of rations incorporating nutritionally-problematic feeds such as SP; that is, it is possible that laying hens, especially those at an age that is capable at producing at a high rate (of around 90 per cent production), should not be fed for attaining high profitability; whereas such diets might be highly appropriate later in the egg production cycle when hen-day production has fallen to around 50 per cent. (2) hens housed in caged and deep litter systems give different production responses because they consume more feed in the former and have a higher maintenance requirement in the latter owing to higher physical activity; or (3) differences in laying hen behaviour associated with the two housing systems may account for the different production responses. If either explanation (2) or (3) are correct, it may mean that only caged systems are suitable when unconventional feeds are used. However, a combination of factors may be involved so that the interpretation of data obtained thus far is obscure.

244. Another possibility to be considered is that if hens were used to feeding on the tuber and root-based rations early in life when gut morphology can change in response to feed characteristics, hens would then be adapted to such rations so that food intakes would be high when fed similar rations in the laying period. In the on-station testing of on-farm rations, 20 month old hens that had been fed for 16 weeks early in lay on SP and CAS based rations were used. It is therefore necessary

to conduct a feeding trial with laying hens in which SP and CAS-based rations are fed to chicks from day-old to the laying period using layer chick starter, layer chick grower and laying hen rations in order to determine whether hens can be adapted in this manner.

11.5.8.7. *Discussions with participants and public after the first on-farm trials*

245. The project research results were presented to the public that consisted of participating farmers, IRA/CIP managers, IRZV researchers, and economic operators in the town. Twenty five persons attended the session held on 11 October 1996. The following reactions to project results were recorded.

246. For broiler meat production, the general reaction was good. However , all participants agreed that the chickens fed the SP-based ration should be made to reach about 1.8 kg liveweight at 8 weeks as for the cassava white-based diet, even if it meant a slightly higher feed cost. As for the laying hens, farmers were also concerned that layers produced much less eggs than would be acceptable. Researchers explained to the farmers that they were not clear on why production and productivity rates were so low. However it was further explained that this was a research project designed to identify solutions that would be appropriate to the needs of the resource-poor farmer and the project will continue to seek these solutions in particapation with the main target beneficiaries in the region.

247. Given that broiler keeping is considerably more important to resource-poor farmers than layer keeping (the reason being a complex issue related to a mixture of investment costs and an inability to compete in the market place with commercial feeds in basic housing systems, and other factors), participants and the public were extremely keen to follow up the recommendations of the project due to the very high price of maize. The logistics of disseminating the relevant technologies were discussed. The IRA and CIP managers suggested that if the demand for tubers and roots increased as a result of the project findings, they could make all the necessary tuber and root planting materials available to multiplication farmers at a cost of 2 FCFA for each 30 cm cutting. The President of the women group participating in the project (CAMWIDCO) said that tubers could be produced in the quantities required by her group all year round. This comment was supported by other meeting attendants.

248. Participants voiced their wish to acquire a large corn-mill type manual and/or motorised gritting machine that can be jointly purchased by women and youth groups. The principal of the PRTC (project particpating NGO) said that he would look into the possibility of the basic design of the said machine following the first prototype chipper that was commissioned by the project (paragraphs 247-). Other economic operators attending the meeting said that the multiplication of the gritting machine developed would not be a problem once a suitable prototype was designed. This should then lead to large-scale production of SP and CAS grits.

11.5.8.8. *Implications of the results of first on-farm trials for target beneficiaries*

249. The feeding trials conducted thus far using rations incorporating ground SP and CAS have yielded mixed results. On the one hand, the broiler rations developed showed considerable promise for application on-farm although the results were not as good as researchers had expected. The layer trials were also not good, due to the feed texture or the coarsely ground nature of WPK. Thus, although the feeding trials demonstrated that maize-free rations can be developed using roots and tubers which farmers will adopt, there is still much scope for improving the rations to make these cheaper and better in terms of their production potential. The follow-up discussions with participating poultry producers showed that the sweet potato broiler ration in particular needs to be improved. In January 1997, additional funds were sought from the LPP to conduct another phase of adaptive research on ration development and the development of the gritting machine.

11.5.9. *Design of feeding trials for improving the first project-developed poultry rations*

250. At this stage the results of the NRI Phase 2 Part 2 trials with SSF SP and CAS and cassava leaf meal (CLM) were available (Section 11.4.3.3). The indications in those '*look-see*' trials were that SSF technology may improve food intakes of ground SP and CAS-based rations, while CLM might be used to supply protein and yolk pigmentation. Thus, it is possible that improvements to both the broiler and layer rations could be achieved by using finely-ground WPK instead of coarsely-ground material; using a higher inclusion rate of palm pit sediment and using it for broilers as well as layers; using 48-hour solid-state fermented roots and tubers instead of unfermented material; using tuber and root grits instead of the meals (the value of grits being demonstrated in the preliminary gritting trials conducted); and using cassava leaf meal to supply protein, but more importantly for layers, pigmentation for yolk colour. An additional problem encountered was the lower than expected calcium bio-availability of the local oyster shells due to the low-technology used in the production process; it is, therefore, necessary to raise the calcium content of rations above those used in the previous feeding trials. The problem of data interpretation in the on-farm layer trial (paragraphs 225-227) will be resolved by testing selected layer rations under different conditions.

251. To address both the above issues, a set of broiler and layer rations were designed for testing beginning in March 1997. The dietary treatments for the broiler trial are:

Treatment A -Unfermented SP
Treatment B -48 hrs solid state fermented SP before sun-drying.
Treatment C - Unfermented CAS
Treatment D - 48 hrs fermented CAS before sun-drying
Treatment E - 48 hrs fermented CAS before sun-drying + 5 % cassava leaf meal (CLM)
Treatment F - Optimal 48 hrs fermented CAS-based diet for project site region
Treatment G - Optimal 48 hrs fermented SP-based diet for project site region
Treatment H - Best Commercial starter (0-4 weeks) and finisher (4-8 weeks) diets.

252. The dietary treatments for the layer trial are:

Treatment A -Unfermented SP, with 3.5 % CLM
Treatment B -Unfermented CAS, with 6.5 % CLM +fine-ground whole palm kernels (WPK)
Treatment C - Best Commercial ration
Treatment D - Unfermented SP, with coarse-ground WPK
Treatment E - Unfermented SP, with fine-ground WPK
Treatment F - 48 hr fermented SP, with fine-ground WPK
Treatment G - Unfermented CAS, with coarse-ground WPK
Treatment H - Unfermented CAS with fine-ground WPK
Treatment I - 48 hr fermented CAS, with fine-ground WPK

253. The composition of the rations are shown in Tables 26 and 27. The treatment considerations relating to the two types of chickens had similiarities but also major differences. However, for each rations were designed to build on the knowledge already gained in the previous trials, that is regarding those results as the worst case scenario for both broilers and layers. Since there were no major differences in the response of broilers between the previous on-station and on-farm testing stages of rations, the broiler rations will be tested only in on-station conditions to reduce costs and improve the reliability of results. However, in view of the different results obtained in the two situations in the previous layer ration testing three of the treatments, namely Treatments A, B and C, will be tested using the same age of hens in on-station caged system, on-station deep-litter system, and on-farm deep-litter (two farmers) and slatted-floor systems.

254. The SSF was conducted in the same manner as was done for the samples prepared for the NRI Phase 2 Part 2 studies (Section 11.4.3.3), but using the AS4 plate of the TRS food processor.

The use of this plate was identified as being optimal in terms of ease of processing and drying, but not nutritionally (paragraphs 247-). Care was taken to ensure that the drying process is completed to below 12 per cent moisture. Since a manual gritting machine of the appropriate specifications is still not available or guaranteed to be developed (see paragraphs 250-), the sun-dried fermented SP and CAS were ground for inclusion in the feeds. The CLM was prepared in the same manner as was done for the NRI Phase 2 Part 2 studies (paragraph 108).

255. For broilers, Treatments F and G are the type of CAS- and SP-based rations that is believed to produce the maximum benefits to resource-poor farmers and achieve optimal resource management in the project site region if the rations show potential for implementation. First, rations for promotion should be nutritionally and economically the optimum diet for the target beneficiaries. It may be noted that Broiler Treatment F is priced at only FCFA 114 per kg (Table 26), which is significantly cheaper than the rations being tested in the first on-farm trials and, at the same time, the nutritional profile is considerably better at 22.43 % CP, 12.84 MJ AME/kg and 1.14 % lysine, when previously the respective ration achieved figures of only 22 %, 12.45 MJ AME/kg and 1.08 % lysine, respectively. The optimal nature of this ration arises from least cost feed formulation in which the SP or CAS content of the ration is not fixed and all feed ingredients are considered for inclusion up to their maximum permissible inclusion rates in pure nutritional terms. The Treatment also tests CLM, PPS and WPK at high levels and should, therefore, give yield information on the potential for using these feed materials in combination that take account of associative effects. Testing these rations alongside the other treatments should lead to the full set of research data to make final recommendations for promotion and extension.

256. At the time of the planning of the these trials, only limited funds were guaranteed (the post-FTR funds for the sub-component project F0060). This was only sufficient for raising 235 hens for the on-station layer caged part of the feeding trials and the on-station broiler trial. Whilst subsequent approval of the requested project extension was welcome, on-station deep litter and on-farm floor systems required another 500 point-of-lay hens which could not be obtained to start at the same age as the 235 hens already reared (a critical element in the design of layer feeding trials). Hens will, therefore, be specially reared to reach the same age as the 235 hens currently being used in the feeding trial, before the rations are tested in the different floor systems of production on-farm and on-station.

257. For these reasons, a separate work plan was agreed for the 500 additional hens. Lohman Brown chicks will be obtained as soon as possible and reared at MRS on deep litter on rations selected from those recommended to Male Farmer B (Appendix 16.8). The rations for testing are shown in Tables 34, 35 and 36. The SP and CAS needed for all additional work funded by the project extension will be purchased from local market. There will be four experimental SP- or CAS-based rearer rations (Treatments A, B, C and D) which will be compared with a commercial control ration (Treatment E), chicks being transferred from starter rations (Table 34) to the respective grower rations (Table 35) at 8 weeks of age. At 18 weeks hens will be transferred to laying hen rations in cages and sub-divided into 8 experimental SP-, or CAS-based groups (Treatments A1, A2 , B1, B2, C1, C2 and D1, D2) and a commercial control (Treatment E) consistent with their previous feeding regime (Table 36). For example, hens previously fed Ration A will be fed A1 or A2, etc. The effect of the reeding regime on the onset of lay (age at first lay, lay weight, layer feed consumed to first egg, and first egg weight), and subsequent impact on egg production will be recorded. Production responses will be recorded until 2 weeks before hens reach the age when they are ready for transfer to the on-farm stage of the main laying hen feeding trial.

258. When hens are transferred to on-farm deep litter (2 replicates) and slatted-floor (2) systems they will be fed for two weeks on commercial ration for acclimatisation before being transferred to Treatments A, B, and C in Table 33. Production responses will be monitored for 16 weeks.

259. The quantity of SP 1112 cultivated on MRS fields was also only sufficient to enable the on-station layer and broiler trials originally planned with the post-F0060 FTR funds. The rations for the additional hens will, therefore, be made using SP purchased from the local markets.

Table 32. Treatments for the broiler feeding trial in deep litter system on-station. All WPK is fine-ground. Figures are in percentages unless otherwise indicated.

Treatments	A Unfer-mented SP	B 48-hr fermented SP	C Unfermented CAS	D 48-hr fermented CAS	E Unfermented CAS + CLM	F Optimal CAS (fermented) diet for region	G Optimal SP (fermented)- diet for region	H Best Commercial starter and finisher rations
Ingredients:								
Salt	0.024	0.024	0.232	0.232	0.116	0.124	0.098	
Cassava leaf meal (CLM)	-	-	-	-	6.000	6.000	-	
Palm pit sediment (PPS)	10.000	10.000	-	-	10.000	10.000	10.000	
Whole palm kernels (WPK)	13.318	13.318	14.296	14.296	-	-	8.948	
Blood meal	3.000	3.000	3.000	3.000	2.589	2.910	3.000	
Bone meal	0.544	0.544	1.076	1.076	1.537	2.015	0.799	
Cottonseed meal	8.739	8.739	20.295	20.295	20.294	20.294	16.252	
Oyster shells	0.989	0.989	0.844	0.844	0.482	0.076	1.178	
Fishmeal	13.386	13.386	10.257	10.257	8.982	8.706	9.724	
Sweet potato tuber (SP)	50.000	50.000	-	-	-	-	30.000	
Cassava white (CAS)	-	-	50.000	50.000	50.000	49.874	20.000	
Total	100	100	100	100	100	100	100	100
Ration cost (FCFA/kg)[1]	168.45	168.45	139.07	139.07	114.89	114.01	139.78	240
Calculated analyses:								
Crude protein	20.500	20.500	22.75	22.75	22.34	22.43	21.02	?
Metabolisable energy (MJ/kg)	12.17	12.17	13.20	13.20	12.85	12.83	12.50	?
Calcium	1.200	1.200	1.200	1.200	1.200	1.200	1.200	?
Phosphorus	0.700	0.700	0.800	0.800	0.800	0.850	0.700	?
Salt	0.400	0.400	0.500	0.500	0.400	0.400	0.400	?
Lysine	1.163	1.163	1.140	1.140	1.129	1.140	1.090	?
Methionine+cystine	1.047	1.047	0.912	0.912	0.910	0.900	0.909	?

Note: 1. Rations took into account the new price of WPK of 125 FCFA/kg in 1997 (rising from 20 FCFA in 1995-1996).

Table 33. Treatments for layer trials using newly laying hens. Diets A, B and C will be tested in deep-litter on-station and on-farm and slatted-floor system on-farm; all diets will also be tested in on-station caged-hen system. Figures are in percentages unless otherwise indicated.

Treatments	A Unfer-mented SP fermented CAS	B fine-ground WPK, unfer-mented CAS	C Best Commercial ration	D coarse-ground WPK, unfer-mented SP	E fine-ground WPK, unfer-mented SP	F fine-ground WPK, 48-hr fermented SP	G commercial control-repeated	H fine-ground WPK, unfer-CAS	I fine-ground WPK, 48-hr mented CAS
Ingredients:									
Salt	0.025	0.287	-	-	-	-	-	0.288	0.288
Cassava leaf meal	3.500	6.500	-	-	-	-	-	10.000	10.000
Palm pit sediment (PPS)	10.000	-	-	10.000	10.000	10.000	-	5.394	5.394
Whole palm kernels (WPK)	-	1.141	-	7.381	7.381	7.381	-	-	-
Blood meal	2.000	2.500	-	2.000	2.000	2.000	-	2.205	2.205
Bone meal	1.176	3.033	-	0.920	0.920	0.920	-	3.222	3.222
Cottonseed meal	5.037	13.000	-	3.626	3.626	3.626	-	13.000	13.000
Oyster shells	8.137	7.695	-	8.290	8.290	8.290	-	7.559	7.559
Fishmeal	12.840	7.026	-	14.000	14.000	14.000	-	6.143	6.143
Sweet potato tuber (SP)	40.000	8.818	-	53.783	53.783	53.783	-	-	-
Cassava white (CAS)	17.285	50.000	-	-	-	-	-	52.190	52.190
Total	100	100	100	100	100	100	100	100	100
Ration cost (FCFA/kg)	149.15	112.72	200	165.44	165.44	165.44	200	99.67	99.67
Calculated analyses:									
Crude protein	17.00	17.25	?	17.00	17.00	17.00	?	17.28	17.28
Metabolisable energy (MJ/kg)	11.40	11.55	?	11.25	11.25	11.25	?	11.64	11.64
Calcium	3.800	4.000	?	3.800	3.800	3.800	?	4.000	4.000
Phosphorus	0.700	0.850	?	0.700	0.700	0.700	?	0.850	0.850
Salt	0.400	0.500	?	0.401	0.401	0.401	?	0.500	0.500
Lysine	1.016	0.913	?	1.022	1.022	1.022	?	0.900	0.900
Methionine+cystine	0.954	0.700	?	0.994	0.994	0.994	?	0.700	0.700

Note: For method of mixing PPS with roots and tubers see text. Rations changed to take account of the new price of WPK of 125 FCFA/kg in 1997 (rising from 20 FCFA in 1995-1996).

Table 34. Experimental layer chick starter rations to be fed in deep-litter system on-station from 0-8 weeks.

	Layer Chick Starter (0-8 weeks) A	*Layer Chick Starter (0-8 weeks) B*	*Layer Chick Starter (0-8 weeks) C*	*Layer Chick Starter (0-8 weeks) D*	*Best Commercial Chick Starter (0-8 weeks) E*
Ingredients (kg):					
Salt	0.251	0.257	0.191	0.176	
Palm pit sediment	5.000	-	5.000	-	
Rice bran - no chaff	15.000	15.000	-	-	
	4.347	3.186	12.293	2.691	
	2.000	2.000	0.095	2.000	
	0.786	0.621	1.442	1.216	
	7.000	7.000	7.000	7.000	
	1.696	1.721	0.870	0.972	
	4.311	5.365	7.108	7.272	
	15.000	15.000	15.016	10.193	
	15.000	15.000	-	18.000	
			40.000	40.000	
	29.609	34.850	7.985	6.480	
			3.000	4.000	
	(in water)	(in water)	(in water)	(in water)	
	100	100	100	100	
Cost per kg (FCFA)	83.1	86.8	135.0	115.5	>200
Analyses (% calculated):					
Crude protein	19.15	19.15	19.15	19.15	
	1.20	1.20	1.20	1.20	
	0.80	0.80	0.70	0.70	
	0.45	0.45	0.40	0.40	
	11.65	11.65	11.60	11.60	
	0.95	0.96	1.05	0.98	
	0.73	0.75	0.80	0.85	

Notes: 1. Mix wet palm pit sediment with sun-dried cassava root grits or chips as follows: (i) Determine the approximate dry matter (DM) content of a sample of drained PPS. (ii) Assuming a dry matter content for sun-dried cassava of 90 per cent, calculate the weights of drained palm pit sediment and sun-dried cassava to obtain the ratio in the ration as fed (e.g. 5 kg: 29.609 kg for Chick Diet A). (iii) Prepare the necessary quantity of the wet palm pit sediment-cassava mixture, and sun-dry to below 12 per cent moisture. (iv). Grind the dried palm pit sediment-cassava mixture (if necessary) for blending in the ration.

2. These must be good quality feeds.

3. This must be collected and dried very quickly after it is released by the brewery.

4. Chipped (or gritted), sun-dried and ground.

Table 35. Experimental layer chick grower rations to be fed in deep-litter system on-station from 8-18 weeks.

	Layer Chick Grower (8-18 weeks) A	*Layer Chick Grower (8-18 weeks) B*	*Layer Chick Grower (8-18 weeks) C*	*Layer Chick Grower (8-18 weeks) D*	*Best Commercial Chick Grower (8-18 weeks) E*
Ingredients (kg):					
Salt	0.298	0.257	0.207	0.223	
Palm pit sediment	4.261	-	5.000	-	
Rice bran - no chaff	19.379	19.944	17.338	16.836	
Blood meal[2]	0.786	0.448	2.000	2.000	
Bone meal	0.701	-	0.407	0.163	
	7.000	7.000	7.000	7.000	
	2.000	2.560	2.239	2.182	
	2.549	3.161	3.504	6.142	
	20.000	20.000	-	15.454	
	15.000	15.000	21.397	-	
			30.000	30.000	
	28.026	31.630	10.908	20.000	
	(in water)	(in water)	(in water)	(in water)	
	100	100	100	100	
Cost per kg (FCFA)[5]	59.8	63.9	75.8	90.2	150
Analyses (% calculated):					
Crude protein	16.41	16.40	16.40	16.40	
	1.20	1.20	1.20	1.20	
	0.80	0.73	0.70	0.70	
	0.45	0.40	0.40	0.40	
	11.45	11.40	11.40	11.40	
	0.73	0.73	0.76	0.88	
	0.60	0.61	0.70	0.64	

Notes: 1. Mix wet palm pit sediment with sun-dried cassava root grits or chips as follows: (i) Determine the approximate dry matter (DM) content of a sample of drained PPS. (ii) Assuming a dry matter content for sun-dried cassava of 90 per cent, calculate the weights of drained PPS and sun-dried cassava to obtain the ratio in the ration as fed (e.g. 5 kg:30 kg for Chick Diet C). (iii) Prepare the necessary quantity of the wet palm pit sediment-cassava mixture, and sun-dry to below 12 per cent moisture. (iv). Grind the dried palm pit sediment-cassava mixture (if necessary) for blending in the ration.
2. These must be good quality feeds.
3. This must be collected and dried very quickly after it is released by the brewery.
4. Chipped (or gritted), sun-dried and ground.

Table 36. Experimental laying hen rations for feeding in cages from 18 weeks to the point when hens are transferred to on-station and on-farm deep-litter and on-farm slatted-floor systems to be fed rations A, B and C in Table 33 (these to be fed after 2 weeks acclimatisation on commercial ration in floor housing systems.

	Laying hen (18 weeks-) ration A	*Laying hen (18 weeks-) ration A1*	*Laying hen (18 weeks-) ration B*	*Laying hen (18 weeks-) ration B1*	*Laying hen (18 weeks-) ration C*	*Laying hen (18 weeks-) ration C1*	*Laying hen (18 weeks-) ration D*	*Laying hen (18 weeks-) ration D1*	*Best Commercial Laying hen ration E*
***Ingredients (kg)*:**									
Salt	0.187	0.156	0.200	0.171	0.083	0.077	0.088	0.094	
Palm pit sediment	5.000	5.000	-	-	5.000	5.000	-	-	
Rice bran - no chaff	0.709	-	-	1.975	5.224	5.941	10.785	9.721	
Soyabean meal	13.727	9.908	13.932	10.560	6.803	6.120	4.362	4.989	
	1.811	1.347	1.803	1.157	0.573	0.414	0.267	0.337	
	7.000	7.000	7.000	7.000	7.000	7.000	7.000	7.000	
	9.108	9.150	9.323	9.593	9.852	9.935	10.000	10.000	
	4.448	7.572	5.277	7.980	10.814	11.354	12.000	11.407	
	-	14.789	-	11.564	-	2.159	2.498	-	
Brewers dried grains	15.000	-	13.151	-	2.651	-	-	3.452	
Sweet potato tuber	-	-	-	-	30.000	30.000	30.000	30.000	
Cassava roots	43.010	45.077	49.314	50.000	20.000	20.000	20.000	20.000	
Palm oil	-	-	-	-	2.000	2.000	3.000	3.000	
	(in water)	(in water)	(in water)	(in water)	(in water)	(in water)	(in water)	(in water)	
	100	100	100	100	100	100	100	100	
	109.1	111.4	115.9	118.3	133.4	133.9	137.7	136.7	200
***Analyses (% calculated)*:**									
Crude protein	17.50	17.50	17.50	17.50	17.50	17.50	17.50	17.50	?
Calcium	4.00	4.00	4.10	4.10	4.10	4.10	4.10	4.10	?
	0.70	0.70	0.70	0.70	0.70	0.70	0.76	0.74	?
Salt	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	?
Metabolisable energy (MJ/kg)	11.50	11.50	11.50	11.50	11.50	11.50	11.50	11.50	?
Lysine	0.87	0.94	0.89	0.96	0.97	0.98	0.99	0.97	?
Methionine+cystine	0.75	0.75	0.75	0.75	0.90	0.90	0.90	0.90	?

11.5.9.1. *Feed preparation for feeding trials*

260. The use of PPS is a crucial element of considerable local environmental significance. More extensive use of the PPS is being attempted in the present feeding trials but it is necessary to take care in using this feed to prevent it from deteriorating. Researchers visited the villages in Mbengwi to collect the material only after all other feeds had become ready for mixing. The proportions of wet matter to be used in drying on to sun-dried SP and CAS shred was important. The procedure adopted for the various dietary treatments needed to be the same to make effective comparison between treatments, and to ensure rapid drying. Detailed calculation of quantities should be made as shown in Box 2.

Box 2. Method of preparing palm pit sediment (PPS) for use in experimental rations.

Note: if dry matter (DM) determination is not possible, assume 90 per cent DM for sun-dried SP and CAS and 60 per cent DM for well-drained PPS.

For broiler rations (Tables 27):
Diets A & B. (1). Determine the DM of drained PPS. (2). Determine the DM of sun-dried SP. (3). Calculate the weights of drained PPS and sun-dried SP to obtain a ratio of 10:50 as fed. (4). Prepare the necessary quantity of PPS-SP mixture for drying. (5). Grind dried PPS-SP mixture for use in the diet.

Diet E. (1). Determine the DM of drained PPS. (2). Determine the DM of sun-dried CAS. (3). Calculate the weights of drained PPS and sun-dried CAS to obtain a ratio of 10:50 as fed. (4). Prepare the necessary quantity of PPS-CAS mixture for drying. (5). Grind dried PPS-CAS mixture for use in the diet.

Diet F. (1). Determine the DM of drained PPS. (2). Determine the DM of sun-dried CAS. (3). Calculate the weights of drained PPS and sun-dried CAS to obtain a ratio of 10:36.085 as fed. (4). Prepare the necessary quantity of PPS-CAS mixture for drying. (5). Grind dried PPS-CAS mixture for use in the diet.

Diet G. (1). Determine the DM of a sample of drained PPS. (2). Determine the DM of sun-dried SP and CAS. (3). Calculate the weights of drained PPS and sun-dried SP and CAS to obtain a ratio of 10:30 SP+15.162 CAS as fed. (4). Prepare the necessary quantity of PPS-SP & CAS mixture for drying. (5). Grind dried PPS-SP & CAS mixture for use in the diet.

For layer rations (Tables 28):
Diet A. (1). Determine the DM of drained PPS (found to be around 60 per cent). Determine the DM of sun-dried SP and CAS. (3). Calculate the weights of drained PPS and sun-dried SP and CAS to obtain a ratio of 10:40 SP+17.285 CAS as fed. (4). Prepare the necessary quantity of PPS-SP&CAS mixture for drying. (5). Grind dried PPS-CAS mixture for use in the diet.

Diets D, E & F. (1). Determine the DM of drained PPS. (2). Determine the DM of sun-dried SP. (3). Calculate the weights of drained PPS and sun-dried SP to obtain a ratio of 10:50 as fed. (4). Prepare the necessary quantity of PPS-SP mixture for drying. (5). Grind dried PPS-SP mixture for use in the diet.

Diets G, H & I. (1). Determine the DM of drained PPS. (2). Determine the DM of sun-dried CAS (or assume 90 % DM). (3). Calculate the weights of drained PPS and sun-dried CAS to obtain a ratio of 1.427:50 as fed. (4). Prepare the necessary quantity of PPS-CAS mixture for drying. (5). Grind dried PPS-CAS mixture for use in the diet.

For rations with PPS in Tables 29-31, similar calculations are required.

11.5.9.2 *Egg quality testing*:

261. In view of the use of CSC that causes yolk discolourations (Section 11.5.7.6.5) and the use of CLM as a source of yolk pigmentation egg quality testing is required in these tests. Between 7 and 8 weeks of feeding laying hens, sufficient eggs will be collected from each hen for examination of

yolks by Roche fan colour assessment and for assessing the development of brown yolk, apricot yolk and pink albumen discoulorations. Some eggs will also be kept room temperature, and some in the fridge, for examination following 1 month and 3 months of storage. Some freshly laid eggs will be opened on petri dishes and placed in a desiccator; 1 mls of ammonium hydroxide solution will be placed in the well, the lid of desiccator closed to expose yolks ammonia gas for 30 minutes. The colour of yolks will then be examined.

262. For the caged laying hen experiments, the following data will be recorded: weekly food intakes, and daily egg production (the number of eggs laid and weight of each egg laid). The number of soft-shelled and broken eggs found on cage tray, will be noted and expressed as a percentage of total number of eggs laid; also, the estimated weight of these eggs will be added to the mass of eggs laid each week. Finally, the efficiency of lay will be expressed by calculating (a) the number of eggs laid/kg feed, (b) the mass of eggs laid/kg feed, and (c) the change in body weight 0-8 weeks and 0-16 weeks.

263. For the on-farm stage of the laying hen feeding trials, the farmers poultry house will be divided into three compartments, one each for Treatments A, B and C. Total food intake per treatment and egg production (number and weight of eggs produced) will be recorded for 16 weeks.

11.5.9.3. *Results of feeding trials conducted during 1997-1998*

264. Only two of the proposed feeding trials (see Section 11.5.9) could be completed. Institutional changes at IRZV during the year. IRZV and IRA were combined to form the Institute of Agricultural Research for Development (IRAD) in August 1997, and the Project Manager of F0060, Dr Banser retired from IRAD in December 1998. It seemed unlikely that all the proposed work would be completed because of this; hence the decision to write up and submit the Final Technical Report at this point. However on 10th March 1998 IRAD sent in the results of the first phase of the Replacement pullet feeding trials (see paragraph 256) to NRI for statistical analysis. This phase relates to Table 34. It is therefore now expected that the second and third phases (those relating to Tables 35 and 36, will now be completed by October 1998). The results of all three phases need to be analysed as a whole since there are carryover effects of rearing diet on laying performance expected. Results will be reported in due course.

11.5.9.3.1. *Broiler chick feeding trial*

265. These results are summarised in Table 37. Although growth rate with the tuber and roots-based diets were significantly lower than that with the Best commercial diet, by 8 weeks performace with the CAS-based diets were a respectable (in terms of marketability) 1.6 to 1.7 kg range. The 48 hour fermented CAS-based diet (Diet D) in fact had a significantly higher efficiency of feed utilisation (EFU) than the commercial diet. Fermentation did not produce a significant beneficial effect on broiler performance, although with SP by 8-9 weeks of feeding there was a slight improvement. The 500 g SP/kg diets were slowest to grow and had the poorest EFU. These treatments need to be continued by an additional 2-3 weeks to arrive at a weight ready for the market. At the 300 g SP/kg diet level final body weight was a respectable weight by 9 weeks.

266. The benefits of the tubers and roots-based rations however are clear when one examines the all-important parameters of Feed cost/kg liveweight gain and Feed cash outlay per day. These are crucial factors for resource poor farmers and constitute the bottom line. All the rations were more profitable than the commercial rations, and excepting the 500 g SP/kg diets by a considerable amount. For example, Diet F (Optimal ration for the Bamenda region) containing about 500 g CAS/kg cost 284 FCFA/kg liveweight gain compared to 562 for the commercial diet. For all the tubers and roots-based diet, the cash outlay per day on feed was roughly one-third that of the

commercial diet. Thus, the results show that cereal-free practical tubers and roots-based broiler rations appropriate to the circumstances of resource poor farmers can be developed.

11.5.9.3.2. *Laying hen feeding trial*

267. These results are summarised in Table 38. Fermentation appeared to make the diets slightly better, particularly for cassava root. However, overall these sub-optimal diets are not likely to produce high rates of egg production. It may be that their use is more appropriate when egg production has fallen to around 50 per cent in the flock, since it is dictated by their low ability to consume the feed, as was indicated from the earlier on-station caged feeding trials. However, when examning the results on a weekly basis (not shown) there was a continuing improvement in production with passing weeks. Further, it is apparent that in terms of cash outlay per egg, the roots and tubers resulted in performance that were still better than those obtained with the commercial diets. The drop in body weight is not of great concern as hens gain weight in all groups after the initial drop in body weight. Overall, under certain circumstances the use of cereal-free tubers and roots-based laying hen rations can be very profitable, although not as profitable as broiler rations.

11.5.9.3.3. *Replacement pullet feeding trials*

268. These results will be reported in October 1998.

Table 37. Performance of broiler chicks fed various fermented and unfermented sweet potato (SP) and cassava (CAS) based diets in on station trial (Cameroon).

Treatments	A Unfer- mented SP	B 48 hr fermented SP	C Unferm ented CAS	D 48 hr Ferm fented CAS	E Unferm entedCAS + CLM	F Optimal diet ration unfer mented CAS	G Optimal SP (unfermented- based diet	H Best Comm. Start/Finish Rations	SEM	Signifacance (P=<)
0-4 weeks:										
Weight gain (g)	244^{a}	281^{a}	527^{c}	487^{c}	479^{c}	505^{c}	346^{b}	919^{d}	6.92	0.0001
Food intake (g)	616^{a}	617^{a}	937^{cd}	878^{bc}	1012^{d}	1043^{d}	786^{b}	1529^{e}	15.31	0.0001
EFU[1]	0.393^{a}	0.378^{ab}	0.537^{d}	0.541^{d}	0.468^{c}	0.475^{c}	0.435^{bc}	0.598^{e}	0.006	0.0001
Total feed cost (FCFA)	104^{a}	104^{a}	130^{b}	122^{ab}	116^{ab}	119^{ab}	110^{ab}	367^{c}	2.53	0.0001
Feed cash outlay/day (FCFA)	3.7^{a}	3.7^{a}	4.7^{b}	4.4^{ab}	4.2^{ab}	4.3^{ab}	3.9^{ab}	13.1^{c}	0.09	0.0001
Feed cost/kg gain (FCFA)	440^{c}	449^{c}	260^{a}	257^{a}	246^{a}	241^{a}	323^{b}	403^{c}	6.83	0.0001
0-8 weeks:										
Weight gain (g)	1007^{a}	1088^{a}	1722^{c}	1713^{c}	1640^{c}	1724^{c}	1348^{b}	2514^{d}	23.07	0.0001
Food intake (g)	2677^{a}	2795^{a}	3816^{bc}	3609^{b}	3895^{bc}	4242^{c}	3443^{b}	5861^{d}	71.5	0.0001
EFU[1]	0.327^{a}	0.334^{a}	0.429^{d}	0.460^{e}	0.398^{bc}	0.402^{bcd}	0.374^{b}	0.427^{cd}	0.004	0.0001
Total feed cost (FCFA)	451^{a}	471^{a}	531^{a}	502^{a}	447^{a}	484^{a}	481^{a}	1407^{b}	11.42	0.0001
Feed cash outlay/day (FCFA)	8.1^{a}	8.4^{a}	9.5^{a}	9.0^{a}	8.0^{a}	8.6^{a}	8.6^{a}	25.1^{b}	0.204	0.0001
Feed cost/kg gain (FCFA)	516^{d}	504^{d}	325^{b}	302^{ab}	288^{a}	284^{a}	377^{c}	562^{e}	3.89	0.0001
0-9 weeks:										
Weight gain (g)	1166^{a}	1333^{ab}					1555^{c}		54.6	0.0496
Food intake (g)	3357	3601					4265		201.5	0.2178
EFU[1]	0.321	0.320					0.360		0.113	0.0008
Total feed cost (FCFA)	565^{a}	607^{a}					596		34.41	0.7885
Feed cash outlay/day (FCFA)	9.0^{a}	9.6^{a}					9.5^{a}		0.51	0.8664
Feed cost/kg gain (FCFA)	525^{b}	527^{b}					392^{a}		9.55	0.0003

1. EFU - efficiency of food utilisation (weight gain: food intake). Comm - commercial. CLM - cassava leaf meal.

Table 38. Performance of caged laying hens (Least squares means) fed unfermented and fermented sweet potato tuber- and cassava root-based diets in on-station feeding trial (1997-1998)

Dietary treatments	A	B	C	D	E	F	G	H	I	SEM	Significance (P= or <) Block	Tier	Diet
Egg production:													
Food intake (g/h/d)	84.8^{ab}	96.2^{d}	142.6^{e}	87.0^{bc}	77.8^{a}	81.7^{ab}	140.3^{e}	93.9^{cd}	100.4^{d}	0.87	0.0354	0.0001	0.0001
Hen day production	0.44^{a}	0.48^{ab}	0.77^{c}	0.49^{ab}	0.43^{a}	0.47^{ab}	0.73^{c}	0.45^{a}	0.52^{b}	0.007	0.9241	0.0001	0.0001
G eggs per hen d	26.1^{a}	27.9^{ab}	47.2^{c}	28.8^{ab}	25.8^{a}	27.6^{ab}	44.5^{c}	26.6^{a}	30.3^{b}	0.44	0.8440	0.0001	0.0001
Number of eggs per kg feed consumed	5.10^{abc}	4.89^{ab}	5.42^{cd}	5.59^{cd}	5.29^{bcd}	5.75^{d}	5.19^{abc}	4.77^{a}	5.15^{abc}	0.061	0.8811	0.0006	0.0046
Number of eggs per 1000 FCFA spent on feed	342^{b}	434^{c}	271^{a}	338^{b}	320^{b}	347^{b}	260^{a}	478^{d}	517^{e}	4.6	0.8988	0.0003	0.0001
Mass of eggs laid per kg feed consumed	305^{abc}	287^{a}	330^{cd}	330^{cd}	320^{bcd}	335^{d}	317^{bcd}	282^{a}	299^{ab}	3.3	0.8068	0.0001	0.0002
Mass of eggs laid per 1000 FCFA spent on feed	2048^{b}	2543^{c}	1653^{a}	1993^{b}	1935^{b}	2027^{b}	1585^{a}	2825^{d}	2995^{d}	24.1	0.5789	0.0001	0.0001
Change in body weight 0-8 weeks	-401^{ab}	-428^{a}	-130^{c}	-380^{ab}	-383^{ab}	-421^{a}	-131^{c}	-389^{ab}	-339^{b}	7.6	0.2080	0.0001	0.0001
Change in body weight 0-16 weeks	-304^{abc}	-305^{abc}	-63^{d}	-287^{bc}	-293^{bc}	-367^{a}	-75^{d}	-346^{ab}	-259^{c}	8.2	0.0581	0.0001	0.0001
Egg quality:													
Roche colour score	10.22^{b}	9.14^{a}	15.00^{f}	10.61^{bc}	10.61^{bc}	11.78^{e}	-	11.47^{de}	11.00^{cd}	0.08	0.4916	0.3363	0.0001
Haugh Units	92.6	89.6	90.1	91.5	93.2	91.8	-	90.5	90.1	0.47	0.7653	0.8802	0.4571

Note: Dietary treatments: A unfermented sweet potato (SP); B - fine-ground whole palm kernel (WPK), unfermented cassava root (CAS); C and G - Best commercial ration; D - coarse-ground WPK, unfermented SP; E - fine-ground WPK, unfermented SP; F - fine-ground WPK, 48 hour fermented SP; H - unfermented CAS; I - 48 hour fermented CAS. Least squares means adjust for Block and Tier effects.

11.5.10. *Tuber and root gritting trials*

269. This project was predicated on the availability of some kind of implement or machine to convert large quantities of SP and CAS into small particles suitable for incorporation into mixed feeds. The widespread practice of chipping tubers and roots into oblong shaped chips in developing countries where pig production is of considerable importance (eg countries of the Far East) is economically justified due to the suitability of the dried material for pigs which, unlike chickens, can chew. Production of chips requires a simple design chipping machine and it uses less energy to produce chips. The design of a chipper that slices tubers and roots into 4 mm thick oblong chips, as used in the NRI Phase 1 experiments (Section 11.4.1) does not pose any technical difficulties to local engineering firms in developing countries. For poultry production in these countries, the chips can then be ground into particle sizes suitable for incorporation into mixed mash feeds. However, where pig feeding is of lesser importance in terms of demand for feeds, it may be economically optimal to introduce tuber and root gritting technology instead, in which a higher processing cost in terms of the design of the required equipment and operation is largely offset by other benefits.

270. The aim of this adaptive research was to produce dried tuber and root particles that are about half the size of a maize grain, and which, that upon drying could be directly used in chicken rations can be readily consumed by chickens without the need for grinding into mash form. If SP and CAS could be gritted easily for direct feeding to poultry, this would bypass the grinding process in the production of poultry feeds to reduce processing costs, and would contain dustiness, reduce economic losses associated with handling meals, improve poultry performance by increasing food intakes and efficiency of food utilisation and to produce a feed more apropriate to small-scale backyard poultry production than is mash feed. It was considered that if this could be achieved there would be substantial cost savings to be made by poultry producers and the production system would also be enhanced because dustiness in feed would be reduced. This is particularly relevant consideration for small-scale poultry producers, for whom grinding not only represents an additional cost in terms of money, time and labour, but this group does not always have access to a grinding mill. Dustiness of dried roots is a major feed handling problem for agroprocessors and poses a nutritional problem for chickens which suffer respiratory problems when feeding. Thus, the dustiness of root crops, due to their low oil content, is widely acknowledged to represent a major impediment to their large-scale utilisation for poultry feeding in developing countries.

271. A preliminary feeding trial was conducted in the NRI Phase 2 Part 1 studies in which shreds produced by the J3 plate of TRS were crumbed and presented to 6-day-old broiler chicks to determine effects on food intake and growth (paragraph 84). The results were extremely encouraging for CAS in that food intake, dry matter retention, efficiency of food utlisation, and weight gain were similar to the maize controls. With SP (variety 1112) weight gain was only 8.5 per cent lower than the maize controls, although this was achieved by increasing food intakes to compensate for the lower digestibility of these grits. The results indicated that grits improved food intakes but may reduce digestibility in the case of SP but not CAS.

272. It was, however, considered that the shape and dimensions of SP and CAS grits may be an important factor affecting utilisation in terms of food intakes and digestibility. For this reason extensive gritting trials were undertaken at MRS using the TRS to determine the optimal size of SP and CAS grits that would be suitable for young birds and adult hens. TRS is a sophisticated electric food processing machine with a range of plates and grids which may be combined to produce chips, shreds and grits of various dimensions from vegetables. It was considered that the knowledge gained from this strategic research could then be adapted to develop a manual gritting machine for use by resource-poor farmers on-farm and other low-income groups interested in producing animal feeds.

273. The research had two aspects: (a) determination of the processing attributes of tubers and roots; and (b) assessment of the nutritive value of tuber and root grits.

11.5.10.1. *Processing attributes of tubers and roots*

274. Tuber and root processing trials were carried out to evaluation the physical and economic (as manifest in energy and time use) aspects of producing and sun-drying SP and CAS grits of different sizes using the TRS food processor. It should be stated that these trials are still not considered complete in relation to the detailed records required for basing judgements on the optimal economic procedures and equipment that should be followed Appendix 8 shows the type of studeis needed to assess the potential of using different particle shapes and sizes of tubers and roots. The aspects of the studies that were completed are presented here. Factors with practical implications that were assessed are divided into three inter-related components: (a) time required for tuber and root preparation; (b) time required to process tubers and roots in the gritting machine; and (c) time required for tuber and root grits of different sizes to dry.

11.5.10.1.1. *Time required for tuber and root preparation*

275. Since tubers are not graded, it is necessary to sort out unwanted portions or wastes (these wastes are not discarded but are suitable for feeding to pigs). The tuber and root end portions are fibrous which reduce the performance of gritting in terms of throughput and causes excesssive wear and tear in the machine. Similarly, the tubers and roots need to be washed before processing since sand particles are also abrasive on the moving parts in the processor. Thus, the activities in tuber and root preparation were determined to be: (i) weighing of graded tubers and wastes; (ii) chopping with knife of large pieces to fit into the TRS food processor; (iii) removing the unwanted portions and (iv) washing or removal of dirt/soil on tubers.

276. It took two persons about 5.5 minutes to weigh 100 kg of tubers and roots and 21 minutes to prepare these for grinding. Wastes represented approximately 6.5 per cent for SP and 6 per cent for CAS (Table 39).

Table 39. Time spent in selected activities with a labour force of one man and one woman.

Tuber/Root	Time taken for weighing and chipping 100 kg (minutes)	Time taken for slicing and washing 100 kg (minutes)	Wastes produced (%)
Cassava white	5.13	21.77	6.0
Cassava red	5.03	22.83	6.0
Sweet potato TIB1	5.99	18.51	6.5
Mean time	5.38	21.04	
SEM[1]	0.249	1.061	

Note: 1. Pooled standard error of means.

11.5.10.1.2. *Time required to process tubers and roots in the TRS food processor*

277. Four kg batches of SP and CAS were processed using various TRS foor processor plate and grid combinations (Appendix 16.7). From an initial assessement, plate/grid combinations that supplied particles larger than that estimated to have potential for direct feeding to chickens were eliminated from the study. The following combinations (-denotes no use of grid) were selected for detailed evaluation plate/grid: AS3/-, AS4/-, J3/-, J4/-, J7/-, C2, C2/FS10, C2/MS8, C2/MS10, C5c/MS8, C6/MS8, C6/MS10 and C10/MS8. 4 kg of Selected shreds/chips and grits produced after sun-drying are shown in Plates 1-8. It was significant that SP samples, particularly using the J3/- and J4/- blades were sticky, elastic and shrunk in size as they dried whereas CAS samples were not sticky and did not shrink.

278. The results of these trials (Table 40) showed that it took longer to process CAS red variety through the J3/- plate than CAS (White), the throughput values being 1.84 and 1.24 min/ kg. The differences were less much less noticeable with other plate/grid combinations. However, SPTIB1 was much easier to process than CAS, taking 0.52 min/kg. The reason for the higher time needed of 0.47 min/kg for SP compared with 0.31 min/kg for CAS using AS3/- is not clear. This experiment needs to be repeated. The most efficient plate in terms of speed of processing were AS3/-, C5c/MS8, C6/MS8 and C6/MS10. Plate/grid combinations such as J3/-, C2/-, C2/FS10 and C10/MS8 were the slowest. It would appear that speed of processing was related to both water content of the tubers and roots and physico-chemical starch characteristics. SP is softer and, therefore, easier to process than CAS which is more fibrous. Another disadvantage of CAS processing is that the larger roots compared with SP requires to be cut with a machete into smaller sizes for insertion into the processing machine, whereas for SP most long tubers can be inserted whole while rounder ones can be easily cut with a knife. The greater thickness of CAS peel also slows its processing throughput in comparison with SP.

Table 40. Evaluation of the performance of TRS plate/grid combinations for the processing of sweet potato and cassava into grits.

Plate/grid combination	Time for tuber and root varieties (min/kg) CASRed	CASWht	SPTIB1	Mean time(min/kg) for plate/grid	SEM[1]
AS3/-	-	0.31	0.47	0.39	0.06
AS4/-	-	0.31	0.30	0.31	0.01
J3/-	1.84	1.24	0.52	1.20	0.31
J4/-	0.59	0.59	0.30	0.49	0.08
J7/-	-	1.56	1.25	1.40	0.11
C2/-	1.43	1.39	0.85	1.22	0.15
C2/FS10	1.25	1.32	1.17	1.25	0.04
C2/MS8	-	0.78	0.62	0.70	0.06
C2/MS10	0.93	1.17	0.64	0.91	0.13
C5c/MS8	-	0.31	0.30	0.31	0.01
C5c/MS10	0.49	0.40	0.32	0.40	0.04
C6/MS8	-	0.31	0.30	0.31	0.01
C6/MS10	-	0.30	0.31	0.31	0.01
C10/MS8	-	1.56	0.62	1.09	0.33
Means	1.09	0.83	0.57		
SEM	0.19	0.13	0.08		

Note: 1 Pooled standard error of means. CASRed Cassava Red; CASWht Cassava White; SPTIB1

11.5.10.1.3. *Time required for tuber and root grits of different sizes to dry*

279. The rationale for this component was that the optimal grit size that minimsed labour requirements were those that could be sun-dried to below 13 per cent moisture within one day (8.00 am to 6.00 pm) during the dry season in the project field area so that operators did not have to gather-in semi-dried material at the end of a day only to have to spread it out in the sun the following day to finish off the drying. Drying rate is, however, also related to the density at which the grits are spread. The first stage was therefore to determine the optimal loading density. For this experiment only the AS3 plate of TRS was used. Four kg batches of each tuber and root variety were processed and sun-dried at the loading densities of 1.0, 1.1, 1.3, 1.6, 2.0, 2.7, 4.0, and 8.0 kg per metre square. The processed tubers were spread evenly on a navy blue tarpaulin in the sun (Appendix 14, Plates 1-2). The experiment was repeated threee times on separate days, beginning at 8.00 am. Temperatures over the grits varied from 20°C to 42°C, while relative humidity varied between 40 per cent and 86 per cent. At 6.00 pm, samples were taken for determination of dry matter in a Gallenkamp force-draft oven set at 105°C.

280. The results of these drying trials are shown in Table 41. As expected the dry matter content increased with a reduction in loading density. SP dried quicker than CAS for this particular plate/grid combination despite the former's higher water content in the fresh state. CAS and SP behaved differently during drying, the former not changing in size but the SP shrivelling into a smaller size, and CAS producing more dust than SP. Wear and tear of the cutting blade on the TRS were also more severe when gritting CAS than SP due the higher dry matter and fibrous nature of the former. Between the two CAS varieties there were also differences, which may be directly related to their water content in the fresh state (Appendix 4, Table 24).

Table 41. Dry matter content (per cent) of tuber and root shreds produced from AS3 plate of TRS after one day (8 am to 6 pm) of drying.

Tuber/Root	Loading density (kg/m^2)/Floor surface area for spreading 4 kg (m^2)							
Variety	1.0/4.0	1.1/3.5	1.3/3.0	1.6/2.5	2.0/2.0	2.7/1.5	4.0/1.0	8.0/0.5
CASRed	8.2	9.9	11.0	14.5	22.6	24.2	23.1	29.2
CASWht	10.9	9.3	10.6	15.5	17.7	25.3	27.3	35.9
SPTIB1	9.3	7.1	6.9	9.6	11.1	15.3	15.8	13.3
Means	9.5	8.8	9.5	13.2	17.1	21.6	22.1	26.1
SEM	0.64	0.7	1.07	1.49	2.72	2.59	2.74	5.47

Note: 1 Pooled standard error of means. CASRed Cassava Red; CASWht Cassava White; SPTIB1.

11.5.10.2. *Assessment of the nutritive value of tuber and root grits*

281. This study evaluated the potential for feeding SP and CAS grits of different dimensions to broiler chickens of different ages. Two feeding trials were conducted using the same batch of broiler chicks to test the effect of using grits from SP and CAS on broiler performance.

11.5.10.2.1. *Design of broiler chick feeding experiment*

282. Two hundred and eighty five unsexed broiler chicks were obtained from SPC-Cameroon and fed on a commercial mash diet. Three diets were formulated (Tables 42 and 43) a CAS (variety White)-based diet (A), a SP (variety 1112)-based diet, and a maize-based diet. At 9 days of age birds were allocated to 10 experimental treatments (5 CAS plate/grid combinations, 4 SP plate/grid combinations, and one maize-based ration) using 2 replicates per treatment, with each replicate consisting of between 14 and 17 chicks. The mean initial chick liveweights for different treatments were equalised. The CAS-based groups represented grits using the following TRS plate/grid combinations: J4/-, J7-, C2/MS8, J3/-, C2/MS10. The SP-based groups represented grits produced by J7/-C2/MS8, J3/- and C2/MS10 combinations. These combinations were selected after examination of the grits (Plates 1-8) showed that grits of other dimension were not suitable for direct feeding due to their large size.

283. At 30 days of age birds were randomised and fed to commercial feed. At 40 days of age birds were allocated to 26 experimental treatments, (12 CAS plate/grid combinations, 13 SP plate/grid combinations, and one maize-based diet) using 2 replicates for each CAS-and SP-based treatments (except for SP-C2/FS10 and SP J7/- which had only one replicate) and 3 replicates for maize-based diets, with each replicate consisting of 4 chicks. The CAS-based groups represented grits using the following TRS plate/grid combinations: AS3/-, C6/MS10, J4/-, C2/-, C6/MS8, J7/-, C2/MS8, J3/-, C2/FS10, C2/MS10, C5/MS10, and C5/MS8). The SP treatments included these combinations and C10/MS8. The mean initial chick liveweights for different treatments were equalised.

11.5.10.2.2. ***Results of broiler chick feeding experiment***

284. The results of these feeding trials are summarised in Tables 44-47. These showed that there were major differences in the performance of chicks fed SP and CAS grits produced by different TRS plate/grid combinations. In general, bird performance was significantly better with CAS-based diets than the maize-based diet and was lowest with the SP-based diets, reflecting the higher digestibilities of the diets. However, within the CAS and SP-based diets there were wide differences between treatments relecting the feeding value of grits of different sizes. Significant interactions of dietxplate/grid combination for weight gain, food intake and food conversion efficiency for chicks of both ages showed that the raw materials differ such that the same plate/grid combination may not be be optimal for CAS and SP. For SP, the results were best with the J3 and C2/MS10 plate/grid combination, but results of feeding trials with grits were not good as with CAS due it appears to the lower digestibility (confirming the results obtained in the Phase 2 NRI trial). However, this effect may be offset by the high food intakes associated with grits so that at the small farmer level it would still be profitable for farmers to adopt the gritting technology for SP. It should also be noted that some of the high food intakes in particular groups were related to excessive spillage due to the large particle sizes. For CAS, C2/MS8 appeared to give the young chicks whereas C2/MS10 and J3/- combinations was best for adult chicks. Thus, for CAS there were significant benefits to be had by gritting the roots and tubers, although beyond a certain size of grits feed spillage was high so that the costs of feed wastage outweighed the benefits. Further, the benefits were greater for young chicks between 9 and 30 days of age as shown in Table 38; however, a point to note in these trial is that mean treatment liveweights were equalised before the start of the old broiler trials (40-61 days) so that it would be expected that the benefits of gritting for CAS grit fed chicks will be continued through to slaughter weight in normal feeding situations.

Table 42. Composition of the broiler starter diets (9-30 days) used in the tuber and root grit experiment (% unless otherwise stated).

Diets	Sweet potato-based	Cassava-based	Maize-based (control)
Ingredients:			
Fishmeal	10.5	6.5	9.5
Oyster shells	0.6	0.6	0.6
Bone meal	1.0	1.2	1.5
Blood meal	1.5	1.5	1.5
Soyabean meal	16.0	33.0	17.0
Salt	0.3	0.3	0.3
Methionine-DL	0.2	0.3	0.2
Palm oil	5.0	5.7	0
Rice bran	12.0	0.9	0
Maize	12.9	10.0	62.4
Cassava White	0	40.0	0
Sweet potato 1112	40	0	0
Total	100	100	100
Calculated analyses:			
Crude protein	19.44	22.74	20.98
AME (MJ/kg)	12.07	13.60	12.12
Calcium	1.12	1.06	1.19
Phosphorus	0.8	0.69	0.86
Lysine	1.25	1.45	1.24
Methionine+cystine	1.12	1.2	1.16
Salt	0.56	0.46	0.53
Cost (FCFA/kg)	240.63	263.12	242.3

Note: The gritting trials were not conducted with a full knowledge of the nutritional composition of the ingredients so that diets were not nutritionally-balanced. Diets were also not formulated to least-cost.

Table 43. Composition of the broiler finisher diets (40-61 days) used in the tuber and root grit experiment (% unless otherwise stated).

Diets	Sweet potato-based	Cassava-based	Maize-based (control)
Ingredients:			
Fishmeal	10.0	10.0	7.5
Oyster shells	0.6	0.6	0.6
Bone meal	1.5	1.5	2.0
Blood meal	2.0	2.0	2.0
Soyabean meal	12.0	23.0	11.0
Salt	0.3	0.3	0.3
Methionine-DL	0.1	0.1	0.1
Palm oil	7.0	6.0	1.5
Rice bran	12.0	0	0
Maize	14.5	16.5	66.0
Cassava White	0	40.0	0
Sweet potato 1112	40.0	0	0
Palm kernel cake	0	0	9.0
Total	100	100	100
Calculated analyses:			
Crude protein	17.79	21.32	18.62
AME (MJ/kg)	12.59	14.09	12.62
Calcium	1.24	1.26	1.25
Phosphorus	0.82	0.76	0.80
Lysine	1.15	1.37	1.03
Methionine+cystine	0.95	1.06	0.95
Salt	0.55	0.53	0.48
Cost (FCFA/kg)	231.77	247.01	219.64

Note: see footnote in Table 1

285. The conclusion from these tuber and root gritting trials were that young and old broiler chicks performed well on tuber and root grits of most of the dimensions tested. The use of grits is, therefore, preferable to mash feed in developing practical tuber and root-based poultry feeding

systems. The grits produced by a machine must be such that day old chicks can consume it, or else the ration will have to be switched after some time, which can cause confusion and additional work for poultry producers. Overall, researchers agreed to a manual gritter was required that could produce grits of 4mm *x* 3mm *x* 2mm amounting to 40-60 per cent of the material with the remaining particles being smaller than this and ideally some ground feed also being produced which will be consumed by the day-old chicks.

Table 44. Summary of broiler performance on tuber and root grits produced by various TRS plate/grid combinations.

TRS Plate-grid combination	**Young broilers (9-30 days of age)**			**Old broilers (40-61 days of age)**		
	Weight gain (g)	***Food intake (g)***	***FCR***	***Weight gain (g)***	***Food intake (g)***	***FCR***
SP-AS3/-	-	-		1027	3206	3.123
SP-J3/-	465	843	.885	944	3017	3.205
SP-J4/-	-	-		986	3190	3.242
SP-J7/-	416	736	1.771	1006	3250	3.234
SP-C2/-	-	-	-	963	3384	3.526
SP-C2/FS10	-	-	-	964	3049	3.234
SP-C2/MS8	390	847	2.154	1085	3501	3.221
SP-C2/MS10	457	806	1.768	927	3330	3.605
SP-C5c/MS8	-	-	-	1035	3162	3.056
SP-C5c/MS10	-	-	-	960	3151	3.288
SP C6/MS8	-	-	-	1114	3015	2.698
SP-C6/MS10	-	-	-	1021	3282	3.220
SP-C10/MS8	-	-	-	920	3069	3.355
CAS-AS3/-	-	-	-	1121	2950	2.628
CAS-J3/-	535	716	1.341	1373	3234	2.353
CAS-J4/-	547	736	1.404	1216	2955	2.434
CAS-J7/-	564	759	1.319	1183	2979	2.524
CAS-C2/-	-	-	-	1059	2607	2.463
CAS-C2/FS10	-	-	-	1121	2824	2.517
CAS-C2/MS8	632	802	1.291	1089	2824	2.593
CAS-C2/MS10	607	793	1.337	1225	2941	2.409
CAS-C5c/MS8	-	-	-	1139	2859	2.509
CAS-C5c/MS10	-	-	-	1064	2667	2.509
CAS-C6/MS8	-	-	-	958	2690	2.896
CAS-C6/MS10	-	-	-	1111	2926	2.636

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Diet Means						
SP	432^a	808^b	1.895^b	996^b	3200^b	3.231^a
CAS	577^b	761^a	1.339^a	1138^a	2871^a	2.539^b
Maize (ground)	529^b	744^a	1.556^a	1247^a	2876^a	2.321^b
SEM	12.6	10.5	0.30	15.4	29.7	0.036
Significance (P=<)	0.0002	0.0898	0.0001	0.0001	0.0001	0.0001
Plate/grid Means						
AS3/-	-	-		1074	3078	2.876
J3/-	500	780	1.614	1159	3126	2.779
J4/-	547	736	1.404	1101	3072	2.838
J7/-	490	748	1.545	1094	3114	2.879
C2/-	-	-	-	1011	2996	2.995
C2/FS10	-	-	-	1043	2936	2.875
C2/MS8	511	824	1.723	1087	3162	2.907
C2/MS10	532	799	1.553	1076	3135	3.007
C5c/MS8	-	-	-	1087	3011	2.783
C5c/MS10	-	-	-	1012	2909	2.899
C6/MS8	-	-	-	1036	2852	2.797
C6/MS10	-	-	-	1066	3104	2.928
C10/MS8	-	-	-	920	3069	3.355
SEM	24.2	11.3	0.0802	19.4	41.2	0.086
Significance (P=<)	0.9567	0.1690	0.8495	0.8855	0.9404	0.9946

Notes: SEM - Pooled standard error of means. Plate/grid combinations refer to TRS Dito Sama Food Processor (refer to Plates 1-8 and Appendix 7 for the appearance of grits. Flakes were generally considered unsuitable. FCR - Feed Conversion Efficiency (food intake:weight gain). Number of replicates per diet: Young chicks - A 10, B 8, G 2; Old chicks - A 24, B 26, G 4.

Table 45. Significance of main effects on broiler chick performance using cassava and sweet potato grits (analysis of covariance).

Factors	**Young broilers (9-30 days of age)**			**Old broilers (40-61 days of age)**		
	Weight gain (g)	***Food intake (g)***	***FCR***	***Weight gain (g)***	***Food intake (g)***	***FCR***
Effect of diet						
SP	433^a	809	1.897^b	997^b	3204^b	3.231^b
CAS	575^b	759	1.336^a	1137^a	2866^a	2.540^a
Maize (ground)	532^b	748	1.560^a	1250^a	2886^a	2.320^a
SEM	16.4	13.4	0.039	21.2	38.9	0.051
Significance (P=<)						
IWT (covariate)	0.5433	0.3067	0.6667	0.0677	0.0042	0.9613
Diet	0.0004	0.0778	0.0001	0.0001	0.0001	0.0001
Effect of plate/grid						
IWT (covariate)	0.1815	0.6693	0.3928	0.0001	0.1300	0.8710
Plate/grid	0.7790	0.2070	0.7439	0.9112	0.9590	0.9951

Notes: SEM - Pooled standard error of means. Initial weight (IWT) for Diets (g): Young chicks - A 114, B 115, G 117; Old chicks - A 984, B 995, G 989.

Table 46. Least squares means of data from broiler chick feeding trials with cassava and sweet potato grits (excludingTreatments A-C and B-M for factorial analysis of variance).

TRS Plate/grid combination	Young broilers (9-30 days of age)			Old broilers (40-61 days of age)		
	Weight gain (g)	*Food intake (g)*	*FCR*	*Weight gain (g)*	*Food intake (g)*	*FCR*
SP-AS3/-	-	-		1012	3152	3.119
SP-J3/-	466	852	.902	938	2998	3.204
SP-J4/-	-	-		980	3171	3.241
SP-J7/-	415	726	1.753	1000	3231	3.232
SP-C2/-	-	-	-	973	3416	3.528
SP-C2/FS10	-	-	-	975	3087	3.237
SP-C2/MS8	390	842	2.146	1097	3542	3.225
SP-C2/MS10	458	822	1.795	919	3302	3.602
SP-C5c/MS8	-	-	-	1064	3264	3.064
SP-C5c/MS10	-	-	-	964	3166	3.290
SP-C6/MS8	-	-	-	1111	3005	2.697
SP-C6/MS10	-	-	-	1013	3255	3.218
CAS-AS3/-	-	-	-	1113	2922	2.626
CAS-J3/-	535	720	1.348	1365	3204	2.351
CAS-J4/-	-	-	-	1213	2945	2.433
CAS-J7/-	564	759	1.320	1184	2982	2.525
CAS-C2/-	-	-	-	1056	2597	2.462
CAS-C2/FS10	-	-	-	1118	2813	2.516
CAS-C2/MS8	631	790	1.271	1081	2795	2.591
CAS-C2/MS10	607	790	1.334	1219	2922	2.408
CAS-C5c/MS8	-	-	-	1136	2848	2.509
CAS-C5c/MS10	-	-	-	1076	2709	2.512
CAS-C6/MS8	-	-	-	959	2693	2.896
CAS-C6/MS10	-	-	-	1125	2976	2.640
RMSE	43.0	18.8	0.095	95.7	178.2	0.263
Significance (P=<)						
IWT	0.9508	0.1955	0.6404	0.1037	0.0044	0.8753
Diet (D)	0.0003	0.0027	0.0001	0.0001	0.0001	0.0001
Plate/grid (P/G)	0.6036	0.0039	0.1494	0.7655	0.4361	0.9736
P/GxD interaction	0.1289	0.0037	0.0459	0.0396	0.0601	0.1331

Notes: RMSE - Root Mean Square Error.

Table 47. Cost-effectiveness of feeding young broilers with SP and CAS grits in relation to a maize based control diet.

Diet	9-30 days-old broilers			40-61 days-old broilers		
	LWT gain	FCR	Feed cost/kg LWT gain	LWT gain	FCR	Feed cost/kg LWT gain
CAS-based (A)	577	1.34	351	1138	2.54	627
SP-based (B)	432	1.90	456	996	3.23	748
Maize-based control	529	1.56	378	1247	2.32	510

11.5.10.3. *Implications of the findings from tuber and root gritting trials*

286. The project concept was predicated on the availability of a machine to at least produce chips from tubers and roots. Lack of availability of a machine that could produce the type of grits that chickens can consume was the reason that the project ration development was conducted using ground feeds. The development of a chipping machine does not pose any technical difficulties (paragraph 248). The engineering firm CAIPCIG which was identified in the prefeasibility study in 1994 (paragraph 68) had indicated that it could produce a low-cost manual chipping machine. The RRA also revealed that MRS also already had a small diesel-powered cassava grater developed in an earlier research project on '*garri*' production (paragraphs 59-60). PRTC also had two manual cassava graters (Type G/H Machine Nr1, and costing 60,000 FCFA) which were designed by the Director, Mr Hans Ichar. These machines could be adapted to using electricity or be converted to diesel-powered operation. However, grating tubers and roots is an energy-intensive process requiring much labour, and the throughput achieved in the gritting machine was considered too slow for producing large quantities of poultry feeds (paragraphs 248-249). However, there was scope for designing suitable cutting blades to the replace existing the grating plates on these machines for poultry feed production.

287. Although more research remains to be conducted to determining the economic potential of different SP and CAS grits of different dimensions by assessing their sun-drying characteristics, texture, dustiness, clumpiness, ease of crumbling of grits (Appendix 16.8), the implications of results obtained thus far for project work concerned the use of technology for producing mash feed, and the need to develop a manual tuber and root gritting machine for on-farm use.

11.5.10.3.1. *Implications for developing poultry rations using ground tubers and roots*

288. The first on-station feeding trials (Section 11.5.7.1) were conducted using tubers and roots produced by the J3 plate of TRS because the results of these gritting trials were not available until much later. However, as Table 33 shows this TRS plate consumes considerable energy as indicated by the slow throughput. It was, therefore, not considered a practical option in economic terms, and its use in the project work was also discontinued. For large scale processing, the AS3 and AS4 plates combinations were considered suitable, with the latter being selected for project use due to its faster throughput of SP compared with AS3. On the basis of the drying trials, the loading density selected for most of the studies in the project was 1.3 kg/m^2. If chipping technology is considered, a chipper that produced AS4 type of shreds may be optimal for SP and CAS (Plates 2 and 7).

11.5.10.3.2. *Implications for the development of manual gritting machine for on-farm use*

289. The tuber and root gritting investigations conducted using the TRS electric food processor demonstrated the benefits of the gritting technology. However, sophisticated electric food processors of the type used in this study are not generally available in developing countries and even if they were to become available they would be outside the ability of resource-poor farmers to acquire. The gritting technology, therefore, needs to be adapted to the resources and constraints of the target beneficiaries.

11.5.10.4. *Specifications for the manual gritting machine*

290. In considering options for the design of a suitable gritter several of the research findings were important. First, the trials identified different optimum sizes and shapes for SP and CAS (see paragraphs 72-77). Further, CAS and SP behaved differently during drying, the former not changing in size but the SP shrivelling into a smaller size, and CAS producing more dust than SP. Wear and tear of the cutting blade on the TRS were also more severe when gritting CAS than SP due the higher

dry matter and fibrous nature of the former. There was also the need to ensure that SP and CAS grits could be sun-dried within a day in the weather conditions prevailing in the western highlands. The latter objective is important to save time and labour inputs that would otherwise be required if operators had to gather and bring semi-dried material indoors at the end of each day only to take it out and spread it in the sun the following day to complete the drying process. Chickens of all ages needed to be able to utilise the grits produced from a single technology.

291. The different processing and drying characteristics of SP and CAS suggested that for regions where both raw materials were available for animal feeding, the gritting machine should be equipped with inter-changeable cutting blades for SP and CAS. Of the two commodities, SP proved to pose more utilisation problems in terms of digestibility and intakes, so that the griiting machine would focus on the processing of SP. This commodity also deserves priority attention in blade design due to the fact that chicks were observed to be able to cope with a wider range of CAS than of SP grit sizes. Whatever was successful with SP should also work well with CAS, but if efforts were made to optimise with CAS, there was a possiblity the product resulting from the same gritter when SP is processed may not be suitable. Overall, the findings indicated that the comb-cutter should be modified such that 40-60 per cent of the grits were of 4mm *x* 3mm *x* 2mm dimensions, with the remainder being smaller and some particles would emerge as fine particles. The finer particles would be consumed by the day-old chicks, which would then gradually consume the larger particles as they grew larger. Thus, The dimensions specified appeared optimal for combined SP and CAS in terms of meeting the nutritional requirements of chickens.

292. The desired specifications for grits was not considered possible with the existing design of the graters at MRS and PRTC. For example, to contain dustiness a clean cut on tubers and roots rather than a grating action might be more appropriate when designing the machine. It was, therefore, essential to design a gritting machine specially for the project. Since the development of a suitable gritting machine has reached the final stages, it is of vital importance that the specifications take account gender and safety considerations on height, weight, positions of various bars/handles. Socio-cultural factors as they relate to rural women eventually expected to operate the gritting machine, need to be considered in deciding whether the machine should be hand- or pedal-operated. The design of this machine should, therefore, be conducted with the participation of some of women groups in the field.

11.5.10.4.1 *Manual gritting machine prototype development during 1994-1997*

293. The first step taken in this project to developing a prototype manual cutting blade was to approach an engineering firm, CAIPCIG in Bamenda. The project work was discussed with the engineering firm CAIPCIG (in Bameda) who examined the grits and shreds produced by the TRS machine with a view to developing a suitable pilot cutting blade that would produce grits from SP and CAS that were about half the size of a maize grain. However, this firm did not have the necessary finances for the research required despite being offered a substantial sum from project funds as a top-up. Subsequently, the PRTC (the NGO participant in the on-farm trials) agreed to assist the project, this organisation having access to both engineering, technical and financial resources and having previous experience of developing agricultural implements for small-scale farmers.

294. By January 1996, PRTC used the basic design of the cassava graters (paragraph 266) to produce was a simple chipper which sliced SP and CAS into oblong 4 mm thickness chips, similar to those used in the NRI Phase 1 studies (Section 11.4.1., Appendix 14). The design of the machine did not pose any technical difficulties but the chips produced need to be ground further for use as mash feeds. Further, the rotating blade proved too heavy for manual operation, especially for women who were mostly expected to operate it.

295. PRTC modified this prototype by September 1996. For the second prototype, the engineer opted for a design in which four comb-type cutters were screwed onto the rotating disc at an

angleover a slit in the disc so that grits were produced. This machine had considerable potential for application as the grits could be sun-dried within a day. However, the design was still not suitable for producing the size of grits that chickens of all ages can consume wihout further grinding. The machine also still proved too heavy for on-farm operation by women. Further development of this machine was required

11.5.10.4.2 *Manual gritting machine prototype developed during 1997-1998*

296. LPP approved funds to finalise the developmeng of this manual gritting in February 1997. Steps were taken to ensure that there was genuine participation by women groups before the prototype is finalised. The technical problems of producing grits directly from fresh tubers and roots that upon sun-drying would be of a size that could be consumed by chickens were too great. After numerous trials, it was decided to develop a separate gritter (Pioneer gritter - see photographs) which would crush sun-dried SP and CAS chips into small particles suitable for chickens to consume.

297. The performance of the machine was evaluated also in terms of the ability of chicks of different ages to consume the gritted particles (Table 48). The results were considered satisfactory. Feeding trials will be conducted in the future using these grits to deterimine the long term potential of this method of producing feed and feeding it to chickens.

Table 48. Preliminary observations on the percentage of particles retained by various sieves of the manual prototype chipper and gritter machine products.

Sieve size (mm)	Percentage of particles retained Sweet potato	Cassava white	Observations
>6.30	4.69	2.81	Particles too large for adult chickens
>4.0 - ≤6.3	20.76	15.95	Particles fit for adult chickens
>3.15 - ≤4.0	13.72	16.28	Particles fit for adult chickens
>2.5 - ≤3.15	16.25	12.66	Particles fit for 5 day-old chicks
≤2.5	44.58	52.30	Paricles fit for day-old chicks

298. The protoype of the manual chipper and manual gritter had the NRI/ODA/IRZV logos. It will be kept at MRS and the design will be available for any person wishing to copy and producing tuber and root grits. It is expected that CAIPCIG may eventually become involved in the manaufacturing and marketing of this machine if sufficient demand is generated following the dissemination of project outputs.

12. PROJECT OUTPUTS

299. The project outputs were as follows.

12.1. *Cereal-free poultry rations*

12.1.1. *Sweet potato-based broiler and layer rations*

300. Some cereal-free SP-based ration was developed. These were more profitable than commercial rations. However, SP-based layer rations may only be suitable when egg production rate has fallen to about 50 per cent hen day.

12.1.2. *Cassava-based broiler and layer rations*

301. Numerous cereal-free CAS-based broiler chicken rations were developed that proved to be more profitable than the maize-based commercial ration in the production systems of small-scale resource-poor farmers in project field site. Also of significant benefit for resource-poor farmers was that cash outlay per day with these rations were generally one-third that with the commercial rations.

302. Whilst there remains the possiblity of improving these rations in terms of their production potential and profitability, the rations need to be promoted for adoption by appropriate dissemination. CAS has greater potential for use as poultry feed due to better chicken performance due to higher digestibility. Further, the dry matter of SP is lower than that of CAS generally, so that processing costs are lower with the former.

303. However, it should be appropriate at this stage to state that once optimal rations for different classes of poultry have been developed the figures need to be rounded up to make them farmer-friendly so that resource-poor farmers without access to weights and balances can use them on a routine basis. After rounding up the figures, the measures in weights should be changed to measures in the type of 'buckets' and 'scoops' that the particular user has access to. Such rounding up and conversion of weights to measures that the user can use is likely to lead to nutrient imbalances in the ration so that much care will be required to minimise these. However, this activity represents the final stage of adaptive research that the present project needs to implement when the results of the current research (Section 11.5.11) are available.

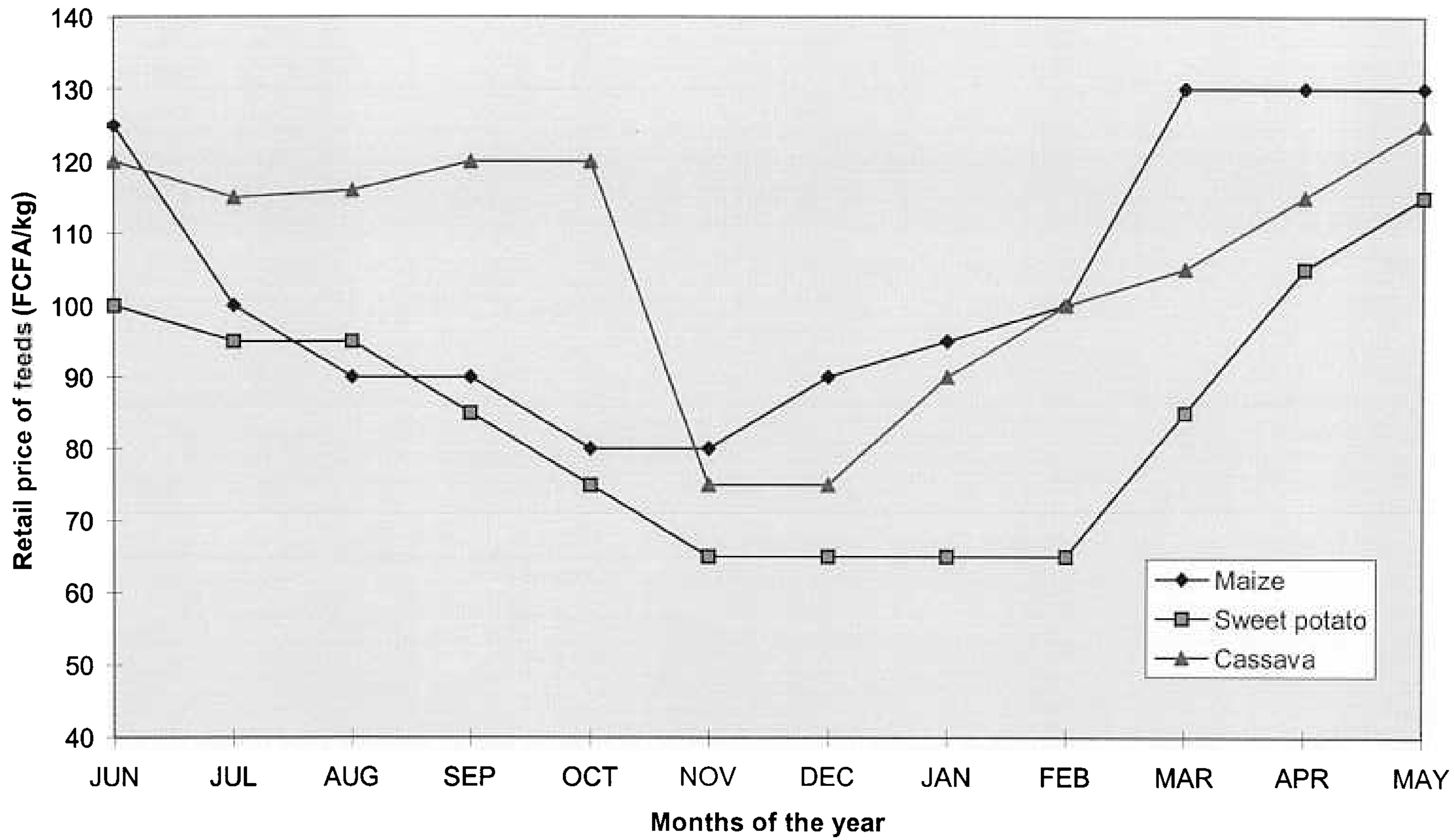
12.1.3. *Effect of price instability on project outputs*

304. This project commenced at a time of economic depression in Cameroon in 1993-1994 (Silverside, 1993) and the prices used in determinig the relevance of project research were based on those. Prices were more or less stable during the next two years at low levels, and the seasonal fluctuations were for SP, CAS and maize were followed during 1995 (Figure). The montlly fluctuations during the stable price period was studied and found to be consistent with the project concept of gritting, sun-drying and storing the tubers and roots in the dry season, which was not only technically most appropriate but also coincided with the time when the price advantage relative to maize was high.

305. However, during 1996-1997 large fluctuations were evident. For example, in 1994, WPK retailed in the rural areas at only 25 FCFA/kg but in 1997 the price increased to 125 FCFA/kg, reflecting an increase in demand for WPK. The recent increase in the general price level appears to be due to an economic recovery arising from the market liberalisation policies pursued by the government in recent years. IRZV researchers were concvinced that the WPK was unlikely to return to the old price, so the feeding trials designed for 1997 were based on the new price of this commodity.

306. Assessment of the outputs of the project must always be made with reference to relative prices of the major animal feed commodities (listed in Appendix 16.6). The project should aim to evaluate a range of rations which may be applicable under different price structure or to meet the different situations encountered by resource-poor production systems. Thus, Male Farmer B enquired whether he could use '*garri*' in poultry feeds because occasionally he is offered a large quantity of it at a knock down price that another ecnomic operator wished to dispose. Brewery dried grains and palm kernel meal from a industrial scale production were other items mentioned. Similarly, Male Farmer A enquired about optimal rations in down graded whole groundnuts and whole soyabeans could be similarly used. The essential point here is that in order to assist development the advice should be based on an approach that may be termed 'optimisation with options'. Small-scale poultry producers need a range of rations to suit different pricing situations commonly encountered in different seasons, so that they are able to respond to new prices by moving from one ration to the other. Currently, they may simply replace one ingredient with another which results in loss of production and a waste of resources.

Figure 2. Changes in the price of sweet potato tuber, cassava root and maize in the project field site region during 1995-1996 (on a dry matter basis).



12.2. *Tuber and root gritting machine*

307. The project concept is predicated on the development of a suitable equipment for red ucing fresh tubers and roots into particles sizes that can be sun-dried quickly under field conditions. A chipping machine was developed which is ready for transfer if it is decided to grind the sun-dried materials before incorporation into feeds. However, the project also developed a gritter to grit sun-dried CAS and SP chips. These produce grits that may be directly incorporated into feeds to reduce costs of feed production and improve poultry performance.

12.3. *Prevention of SP rotting losses*

308. Fresh SP tubers rot quickly, and rotting losses of up to 30 per cent of the harvested material is not uncommon with certain varieties. An important food and feed management consideration built into the project concept of chipping/shredding/gritting and then sun-drying SP is that these huge losses will also be prevented in addition to rendering the material suitable for use in poultry rations. The tuber and root storage feeding trial (paragraph) showed that there were no significant losses in the nutritive value of SP when gritted, sun-dried and stored for 6 months.

12.4. *Improving local agroprocessing and environmental problems*

309. The project rations were designed to maximise the use of local small-scale agroprocessing by-products and wastes. Traditional rural agroprocessing have come under stiff competition in recent decades from large-scale industrial processing, which because of economies of scale and new technology are efficient and can produce the primary product such as cooking oil cheaply. These industries are also able to realise high prices for their by-products because of the larger quantities generated at a single location on a regular basis. Adding value to oilseed by-products such as PPS and WPK by including it in the poultry rations will improve the financial viability of traditional processing. In the case of PPS, it also solves a major local environmental pollution proble, Similarly, the use of locally produced blood meal and bone meal from material generated in rural slaughter houses assists the disposal of these materials in a manner that minimises environmental pollution and improves the incomes of low income groups.

12.5. *Feed composition chart for project field site*

310. The development of a feed composition chart (Appendix 16.6) was deemed to be a necessary part of developing poultry rations. However, will have use in the western highlands of Cameroon and elsewhere with similar feed resources in assisting researchers to conduct other types of poultry ration developmental studies. If dissemination activities are undertaken to make the chart widely available and the method of using the chart is also shown through short courses in least-cost poultry ration formulation techniques, it will be of immense use to extension agents who would be able to train farmers in appropriate use of local feed resources.

12.6. *Institution building*

311. The project finances provided much needed appliances that will prove invaluable for other projects that may be undertaken at MRS in the future. The equipment purchased included numerous equipment relating to the poultry feeding facilities (troughs, brooding guards, etc). Funds were also used to rearrange the interior of the poultry houses so that these will assist in better design of any future studies involving feeding trials that are conducted. The TRS food processor sent from the UK will also assist in conducting experimental studies with many other local vegetables, including tubers and roots.

312. Above all, the benefits of the Optimix feed formulati on software package installed on MRS computer hardware represents the most useful component of institutional building. Since this was the first time that many staff had used such a package, it of this project. By demonstrating the use of this software package, the project manager provided training to MRS staff on the rationale of least-cost feed formulation. The training involved assessment of 'real life' examples of rations (for example, those shown in Tables 18, 19, 27-35, Appendix 16.7, Tables 1-6).

313. IRZV research team gained a great deal of experience during the project not only on poultry feeding and nutrition, but significantly on the intricacies of conducting adaptive research that is designed to increase the incomes of resource-poor farmers. This required an developing an awareness of the strengths and weakness of the target beneficiaries, and conducting interactive discussions with participating farmers. The project adopted a novel approach in poultry development with the focus on feed resource development through a mix of strategic and adaptive research by conducting feeding trials in controlled environment conditions, in on-station conditions and under farmer conditions in an iterative manner. IRZV researchers are now well-placed to take such project work forward after the completion of the project.

314. Effective transfer of knowledge in this area can only take place through adaptive research projects of the type implemented. The Director of IRZV has said that perhaps the greatest benefit of this project has been the transfer of knowledge from NRI to MRS. He writes further (letter dated 15 November 1996): 'it is very rewarding to realise that your exploratory visit some three years ago and subsequent discussions and understandings that followed have ended in this FTR (ie FTR for F0060) that bears with it a lot of hope for the small holder poultry farmer in Cameroon and why not, elsewhere. Yes, a lot of hope indeed given the prevailing situation characterised by extremely high competition for cereals for direct human consumption to the detriment of animal feeding. Ironically, the very population that *deprives* poultry of feed, needs affordable animal protein for its well being and an accessible source of income for alleviating poverty. This project, though disguised in its modesty has broken very fertile grounds in Cameroon that disposes of all ingredients of success for the development of peasant poultry production should the cereal-based feeding system find in it a viable substitute.

315. Thus, the project has opened a new dimension for the way forward on the optimisation of available feed resources in Cameroon. It helps to the people to help themselves to make most of their own natural resources. It is expected that in the future the researchers involved will disseminate the technical findings in journals, workshops and other scientific meetings, and promote the approach adopted in a project which has been a modest success.

13. CONTRIBUTION OF OUTPUTS TO DEVELOPMENT

13.1. *Poverty alleviation and nutrition of the poorer sector*

316. The outputs of the project contributes to poverty alleviation among the poorer sectors of the population by providing them with cheaper and more affordable poultry rations that reduce their dependence on commercial feeds. More poorer people will take up poultry rearing as an income generating activity since the rations designed are only suitable for this group. If the rations are adopted on a large scale it will also make it easier for poor people to consume more cereals the price of which will be reduced as a consequence of its replacement by SP and CAS. The price of poultry meat and eggs will also be reduced making it accessible to lower income groups to improve their nutrition and health.

13.2. *Livestock production*

317. The World Bank has set a goal of 4 per cent annual increase in food production in SSA to feed its growing population, improve nutrition, and eliminate food imports into the region. The LPP recognises the same targets for the supply of anuimal products. Thus, a priority area is to conduct research and technology transfer in ways of increasing the production of poultry products and improving the productivity of the poultry sector. The present project and other author's field experiences in SSA revealed that small-scale poultry production can play an important role in intensifying mixed farming systems, through the timely generation of cash for farmers, the optimal use of local feed resources, and the production of excreta which serves as (a) a high nutritional value dry season feed for ruminant livestock to supplement the otherwise low-nutritive value stovers and grasses that are available; (b) a fertiliser for crop cultivation or for horticulture. The main difficulty in assisting the small-scale sector is correctly assess their resources, constraints and opportunities and then to conduct the nutritional research that will lead to economically and environmentally sustainable mixed species livestock production system that are in harmony with a region's farming systems. The focus must be on reducing the dependence of the resource-poor poultry producer on commercial feeds by maximising the use of feed resources at his or her disposal. The development of socio-economically acceptable rations requires a combination of strategic and adaptive research on rural feed resources that vary according to agro-climatic zones, local agro-processing activities, and the varieties of crop plants cultivated.

318. The project has also demonstrated that it is possible to impr ove livestock production and productivity to generate income by resource-poor farmers and other low income groups in an environmentally conscious manner such as minimising the use of fossil fuel in poultry feed processing and preventing pollution (as with palm pit sediment). The approach, based as it was on optimising the use of local feed resources including traditional rural agroprocessing by-products and wastes, itself makes a contribution to development as a way forward for livestock developmental projects.

13.3. *Replacement of cereal component of livestock feeds*

319. Reducing the use of cereals in livestock feeds is an important aspect of food resource management in the future, due to fact that yield increases per hectare are no longer keeping pace with rising populations and unexploited cropland is also limited. Maize prices have continued to increase in the US (the world's largest exporter) with the result that the use of maize in the poultry industry will be limited (Hooge, 1996). There is, therefore, increasing pressure worldwide to use alternative raw materials recently identified as being one of 5 priority areas for research in poultry production (Williams, 1997).

320. The competition for maize between human food and livestock feed sectors is a major developmental issue globally, but for developing countries in particular because these are generally dependent on imports of this cereal. This project has developed cereal-free broiler chicken rations that have been demonstrated to be more profitable than the normally used maize-based rations in intensive poultry production system. If the rations are adopted on a large scale it will reduce the competition and make it easier for poor people to consume cereals. Similar concepts can be tried elsewhere, if not to completely eliminate the use of cereals to substantially reduce it.

13.4. *Feed technology: gritting and sundrying tubers and roots*

321. The contribution of the technology of gritting, sundrying and storing SP as animal feed was seen in the project area in late 1996-1997, when the price of maize rose so high that the local Ministry of Agriculture approached IRZV for advise on cereal-free rations feeds for all major classes

of livestock, including poultry, pigs, dairy cow and rabbits. The PRTC requested the second prototype gritting machine from IRZV, which was given after NRI was contacted for permission. PRTC produced mixed and sold animal feeds which livestock producers from up to 30 km away came to purchase.

322. The development of SP and CAS as poultry feeds using solar energy has cost and environmental adavantages over the alternative of using oven-dried maize. It should therefore be mentioned that a different situation exists in countries without a significant dry season (paragraphs). In Yaounde, ie South-East, the weather is very humid and hot compared with the highlands of Bamenda and it takes a day or two to acclimatise; this is necessary especially after arriving from 0 ^{o}C in Britain! In the highlands mountainous mid to high altitude agroclimatic zone, it is quite hot by mid-morning but dry heat, so no sweating takes place; the nights are cooler and air-conditioner is not necessary. As regards the project to convert root and tubers to poultry feeds, the Bamenda region is ideal from the climate point of view to add to the socio-economic and agronomic considerations. The preliminary trials showed that in January-February, the sphaghetti shaped sweet potato and cassave chips dried in one day if sparsely spread, the economic optimum. The technology will be more difficult to make it to work if it is conducted in the humid south-east, where even clothes take longer to dry compared with the Bamenda region (refer to deleterious effects of slow drying on nutritive value of sweet potato). This will apply to countries like Peru, that are also humid all year round.

13.5. *Tubers and roots for large-scale animal feed production*

323. For commercial feed millers in economically well-developed countries the development sweet potato-based poultry feed could also consider the use of commercial enzymes and extrusion technology, two commonly used techniques for improving the nutritive value of high starch commodities. Unfortunately, however, feed compounders and institutions in developing countries are generally unable to conduct this type of research because of lack of suitable facilities and resources. In the production systems enzyme application to feed ingredients, such as galactosidases, xylanase, amylnase, protease, B-glucanase may be useful in cost effecting enhancing nutritional value

13.6. *Research methodology for livestock systems adaptive research*

324. During the course of implementation, a novel research methodology was also established for the development of poultry rations for small-scale producers through an interative process of strategic and adaptive research by conducting feeding trials in controlled environment conditions to establish feed potential; on-station feeding trials under researcher control for pre-testing of tentative rations, and finally, on-farm trials under farmer control to test the applicability of the rations developed. This approach could be applied in other concepts such as in agroforestry/livestock where tree leaves are considered as poultry feeds.

325. It should, therefore, aim to keep as many of the technical aspects as simple as possible drying within a day, starter-finisher). One of the considerations of the technology development is not to stick to the current stage of sun-dried cassava chips, otherwise the rich farmers will purchase it and the poor poultry farmers will be where they are, marginalised. Whilst, the purchase of large quantities of tubers and roots by large commercial poultry farmers will naturally benefit the crop farmers, it may not be sufficient to assist the small-scale poultry farmers working from within a mixed farming systems. John Ngwa said that the rich farmers will once again monopolise the process and the poor poultry farmer will remain in the same position, only worse if the cost of eggs in the market falls as a consequence of the new technology introduced.

326. Another problem is the variability in the composition of complementary feeds. CSC varied in crude protein content between 33 and 42 % lysine from 1.33-1.97 percent and free gossypol from

715-1350 mg/kg. It is within such 'unconventional' nature of feeds that on-farm feeding systems need to be developed.

327. Thus, the project technology must be developed specifically with these farmers in mind. To achieve this, it must be such that the it would be too much trouble for the rich poultry farmers to be interested in, or too risky for them given their high capital intensive operations of even imported feedstuffs and other elements. Risk: rich farmers may not be able to see egg production fall from 94 to 70 % if much money is tied in whereas the poor farmers with low input-output systems, and where poultry is only one of several enterprises they are involved in, included off-farm employment, they can take sudden falls, and in fact do as they look for cheaper feeds such as infested maize and palm kernel cake from traditional oil extraction methods. They have the time to go and collect small quantities of these from the villages, which the rich farmer will not be able to do. Palm pit sediment is another example. So the solution is to develop feeds simulataneously to blend some of these other cheap or discarded materials into root-crops based poultry diets specifically for these farmers, and which will not be of interest to the large commercial farmer: a separate small-scale poultry feed sector may be set up.CLM is easily dried and has potential interms of nutritive value and pigmentation for yolk colouring. It was therefore used in the rations, whilst SPLM was not so useful and discarded. It would serve as a better feed for rabbits and goats in the regions farming systems.

328. There is also the final stage adaptive research required when the figures of quantities of ingredients in rations need to be rounded up and converted to measures that resource-poor producedrs possess, such as buckets and containers (see paragraph 298).

329. Thus, the technology being developed must start by considering the resources, opportunities, constraints, and problems of the poor poultry farmer in relation to the demand for their products; these farmers need to be visited and discussed with. The ideal will be to work and develop technology that does not change their current way of lives, either for the crop farmer, the small-scale agroprocessor or the poultry farmer. However, if a technical optimum is found, it should be discussed with them. But far better to see the various ways in which the job is being done and see which is best for chickens then change the others. Same with poultry farmer: improve existing systems, not impose new ones. This way we optimise the use of their resources in relation to their goals and socio-cultural norms - sustainable management of their natural resources. This project ties up sweet potato, palm cultivation and chickens in this manner.

13.7. *Need for development of appropriate crop varieties identified*

330. Inadequate attention to food and feed utilisation aspects of the crop developmental activities of the IARC centres have frequently resulted in new high yeilding varieties of crops being introduced that have proven inappropriate in specific socio-economic environments. It was apparent that consideration of utilisation aspects was negligible in the breeding strategies that have been hitherto adopted for for sweet potato. In none of the countries visited by the author was there a discernible breeding strategy employed apart from the agronomic ones of high yields. It is common for new varieties to be first introduced and to conduct research on how to use the product on varieties that have passed the 'agronomic' test. This has led to varieties that did not meet consumer demand. This strategy is forced on the CGIAR's because they lack facilities for evaluating utilisation aspects, such as the nutritive value of feeds for human and livestock.

331. The case for integrated concepts for agricultural development, in particular for the 'push-pull approach' or 'production to consumption systems approach' (PCSA), is now widely recognised as the most appropriate basis for agricultural development. This project addresses a constraint in the PCSA chain as it affects some countries of sub-Saharan Africa, namely the underutilisation of root crops at the same time that cereals required for humans are imported for incorporation into poultry feeds as the major energy source. The project has demonstrated that greater attention needs to be paid to utilisation characteristics of tuber and root crops in breeding programmes.

332. The project has also highlighted the need for crop and livestock research to be developed in parallel. There is a need for greater emphasis on the utilisation characteristics of new cultivars for use as animal feeds before promoting new varieties of tubers and roots in developing countries.

333. Agronomic details are required on TIB1, TIB2, 1112, CIP No 193002.1 (AVRDC 5.018) and 490141.1 (RURB 15.004). Details should include foliage:tuber yield. the consideration is that for the purposes of this particular research project, it is OK to use the existing varieties, but if more digestible, easier to process and dry varieties were available that were not particularly prone to weevil (find out whether there is a correlation between weevil damage and trypsin inhibitors), given that storage losses will be brought to very low levels with this technology, it would be more appropriate to chose it. A separate basic research collaboration with CIP needs to be set up to monitor 6 kg sun-dried grated sweet potatoes in Peru to be sent to NRI for assessment as poultry feeds.

334. The adaptive research they then be modified by, for example, having the particular clones (AVRDC 5-018, CHGU 12-001 and CHGU 1-003) grown in Cameroon, Kenya or Uganda on a large scale. There is a need to select cultivars with thin or more digestible peels, a high dry matter content, and high dry matter digestibility when sun-dried, and texture that promotes high feed intakes by chicks.

13.8. *Need for esearch collaboration between livestock and crop research centres identified*

345. The CGIAR crop centres such as CIP, IITA and International Crop Research For the Semi-arid Tropics do not have the mandate to conduct livestock trials. It follows from the above discussion that this project has highlighted the need for research institutes involved in animal production such as NRI and IRZV to engage in on-going collaborative research with crop research insitutes to assist in the selection of varieties of crops (SP and CAS in the context of the present project) that are better suited to development as poultry feeds. A Chart of the type of research data on utilisation characteristics required is shown in Appendix 16.8. Such data requires consideration along with agronomic data before new varieties are introduced in developing countries.

14. PROJECT FOLLOW-UP ACTIVITIES

336. Limited dissemination has thus far been undertaken since the project is incomplete and lack of funds. Additionally, it is necessary to consider the next stage in the continuum from research to practical application in view of the progress made in the form of an agricultural project in the western highlands.

14.1. *Dissemination of project findings*

337. The following dissemination activities have been planned.

14.1.1. *Publications and Reports*

338. A scientific paper describing the processing and nutritional characteristics of two varieties of SP for poultry has been published (Panigrahi *et al*, 1996a), and a review paper on the use of cassava root for poultry production was presented at the *International Symposium on Tropical Tuber Crops*, 6-9 November 1993. Indian Society for Root Crops, Central Tuber Crops Research Institute, Sreekariyam, Thiruvananthapurum, India by the author of this report (Panigrahi, 1996). Sufficient research data has been collected from the feed developmental research undertaken in this project to write another 4-5 scientific papers.

14.1.2. *Regional Workshop*

339. Although Cameroon was not on the priority list of countries for the Livestock Production Programme, sub-component project F0060 was approved by ODA because of its global significance. It would, therefore, be appropriate to organise regional workshop to discuss the approach that has been adopted in the present project and to present its findings so as to encourage similar work to be undertaken by NARS in other West African countries.

14.1.3. *Design of leaflets and posters*

340. A poster for promoting the use of SP in poultry feeds has been developed for display at IRZV offices and those of extension agencies in Cameroon (Poster 1). It would be appropriate to design a similar one for cassava given that the potential for using cassava to replace maize in poultry diets has now been proven to be greater than that of sweet potato. The leaflet has been sent to CIP in Peru for wider dissemination in its Headquarters and through its regional offices throughout the developing world.

14.1.4. *Assisting animal feed millers*

341. A stakeholder system of integration comprising the processing of roots and tubers into grits, and their marketing to poultry producers or small-scale animal feed manufacturers will be required to promote the ration technology developed in this project. A system of production and utilisation is essential for large-scale adoption of cereal-free poultry rations. The private sector has an important role to play in promoting the concept of replacing cereals with maize. A distinction however should be made between three types of beneficiaries in terms of the ration characteristics that would be applicable for each. Large-scale producers are considerably more restricted in the rations and production methods they use than small-scale millers who in turn are more restricted than resource-poor farmers mixing their own feeds. Thus, each category requires a different type of assistance in agricultural projects. One of the on-farm project participants who owns a small animal feed shop was given rations that utilised materials such as brewery dried grains which may only be available intermittently (Appendix 16.8). Similarly, large-scale animal feed compounders need to be assisted with appropriate technology to convert tubers and roots to suit their production systems.

14.1.5. *Assisting NGOs*

342. PRTC and other local NGOs and Womens groups such as CAMWIDCO will be included in a agricultural project which will follow the research phase of the present project.

14.2. *Agricultural project*

343. There is a need to promote development in this area and take the concept from research to practical application. To maximise benefits of the project-developed technologies to the poorest farmers and other low income groups an approach is needed that brings together farmer groups and local NGOs in an agricultural project as four stakeholders: those cultivating tubers and roots, those processing the tubers and roots, those engaged in animal feed production, and those rearing chickens. Following the development of a suitable manual gritting machine, an agricultural project proposal for submission to aid agencies will be developed by NRI and IRZV in collaboration with CIP, and other local NGOs and government extension agencies working with poor farmers.

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APPENDICES

Appendix 16.1. The F0004 project concept note submitted under the 'Research Continuity Scheme'.

RESEARCH CONTINUITY SCHEME - CONCEPT NOTE

LIVESTOCK PRODUCTION PROGRAMME

The utilisation of sweet potato and cassava root meal in poultry diets

Alignment with Research Strategy

The proposed adaptive research aims to demonstrate that sweet potato and cassava root meals can be economically used at high dietary inclusion rates in the poultry production systems of certain developing countries. It merits priority rating 1 for cassava and 2 for sweet potato on commodities in the RNRRS. As the research concerns the cost effectiveness of providing essential nutrients to livestock using crops and their by-products, residues and wastes, it also merits priority 1 rating under Livestock Programme.

Relationship with earlier NRED-funded strategic research and NRI comparative advantage

The proposed work is a continuation of NRED-funded research at NRI during the 1980's. In that research, commodities were assessed to determine their maximum dietary inclusion rates, and the nutritional reasons for this limit. This is necessary to enable findings to be reliably adapted to the optimal inclusion rates appropriate to specific field situations. Strategic research on some root crops has reached a stage where field research is required to demonstrate the adaptation of experimental findings to specific local situations.

Root crops are one of several classes of tropical feeds (also oilseed cakes, animal wastes) evaluated under the programme, knowledge of this range of feeds is important when formulating least-cost poultry diets. This breadth of experience therefore places NRI in a unique position to conduct this adaptive research.

Geographical context of adaptive/field research

The research will be carried out in two stages: (i) country-specific adaptation trials for sweet potato, to be conducted in UK using raw materials relevant to Cameroon, and (ii) field trials for both commodities at the International Potato Centre (CIP) (Cameroon), which has a research programme on the development of root crops for livestock feeding. Collaboration with CIP will assist in the dissemination of findings, potentially leading to greater uptake in other countries and interest from other donors.

Outputs and Inputs

The project will

(i) demonstrate how appropriately-processed local varieties of sweet potato and cassava can be used in poultry diets at levels up to 500 g/kg,

(ii) evaluate the acceptability of root crops-based poultry diets among local small-scale poultry producers,

(iii) publish a paper to promote the concepts in other developing countries.

Summary of financial support requested from NRED funds

	Year 1	Year 2	Year 3
Personal Emoluments	32,620	23,790	11,010
Travel and Subsistence	0	11,000	4,500
Consumables	8,000	2,000	500
Other charges	0	1,000	500
Total	40,620	37,790	16,510

Applicability of results

Root crops are important resources for feeding livestock in many tropical developing countries, sweet potato and cassava being particularly versatile in their agronomic requirements, giving high yields in diverse climatic conditions. Whereas experimental results indicate that cassava root meal may be included in poultry diets at 500 g/kg without depression of production (NRI's recommendation), it suggests more caution in the case of sweet potato, limiting it to around 200 g/kg diet. Experience at NRI however indicates that the nutritive value of sweet potato may have been underestimated, partly due to inappropriate methodology being used in some of the reported studies: this has resulted in underutilisation of this resource. It is therefore pertinent to conduct adaptive research, using feeding techniques developed at NRI for cassava root meal, to demonstrate the high feeding value of sweet potato in poultry diets, and subsequently, to evaluate the acceptability to small-scale producers of including sweet potato or cassava in poultry diets.

The economic significance of the project lies in reducing the cost of poultry meat and egg production, and by replacing the cereal component of poultry diets with root crops, releasing the former for human consumption. The findings will be of interest to many poultry producers in African, Asian and Latin American countries where both cassava and sweet potato are available for feeding animals. The technique is likely to be immediately available and highly sustainable in view of the recent proliferation of high yielding varieties of sweet potato in developing countries.

Note: Following a prefeasibility study in 1994 to select a suitable project site, the structure of the project and budget were changed to incorporate a sub-component project for field activities (F0060) which was managed by IRZV as an Extra-Mural Contract.

Appendix 16.2. Memorandum of understanding signed by NRI and IRZV in 1992.

MEMORANDUM OF UNDERSTANDING

between

THE NATURAL RESOURCES INSTITUTE

hereinafter referred to as NRI with headquarters in Chatham, Kent, United Kingdom

and

THE INSTITUTE OF ANIMAL AND VETERINARY RESEARCH

hereinafter referred to as IRZV, with headquarters at Yaounde, B.P. 1457, Cameroon

PREAMBLE

Whereas NRI is a scientific agency of the UK Overseas Development Administration with a broad mandate for the improvement of agricultural production and other natural resources in developing countries, specifically in the area of pest management, resource assessment and farming systems, and food science and crop utilisation;

Whereas the IRZV is the Animal Research Institute of the Ministry of Scientific and Technical Research, responsible for all research in Animal Production in Cameroon, with a broad mandate for co-ordinating research in livestock farming systems, breeding/ selection, animal health, fisheries, and biodiversity conservation.

and

Whereas the NRI and the IRZV have common interest in improving live stock production and the utilisation of crop residues and agro-industrial by-products by livestock, and in meat science;

The two parties agree as follows:

Article I

The NRI and the IRZV, to achieve their common goals and to exploit complementarity of skills and expertise, will collaborate generally and exchange information in the areas of interest and mutual benefit stated in the Preamble. In particular, and as a basis for potential developments in other areas of interest, the parties agree to collaborate in the advancement of livestock production.

Article II

The Deputy Director of the NRI and the Head of Resource Assessment and Farming Systems Strategy Area, and the Director of the IRZV will determine the practical details of co-operation between the two organisations and, in general, to ensure the proper and effective implementation of this Memorandum of Understanding. Collaborative activities, current and potential, will be reviewed biennially by these individuals.

Article III

Each collaborative activity between the NRI and IRZV will be defined in a document, which will describe the objectives as well as the details of the responsibilities and activities of either party; this document will be signed by the representatives of the two parties named under Article II, and will be deemed to be an addendum to this Memorandum.

The on-going collaborative activities will be deemed to be covered under this agreement.

Article IV

This Memorandum of Understanding will become effective on the date of sig nature of both parties and will remain effective until either party gives notice to the other of its intention to terminate, provided such termination allows for the orderly completion of any collaborative project which may still be in the process of implementation, in which event the agreement shall stand terminated at the end of six months from the date of issue of such notice.

For the NATURAL RESOURCES INSTITUTE

______________________________ Date: ________________

For the INSTITUTE OF ANIMAL AND VETERINARY RESEARCH

______________________________ Date: ________________

Appendix 16.3. Poultry farm characterisation study: feed resources and poultry production systems in the mid and high altitude zone of Cameroon.

(Adapted from MRS Report No 13, August 1996 by Dr. R. T. Fomunyam, Dr. D. K. Poné, E. N. Ntumgia. The study was conducted at the start of the project's field activities to ensure that the feed developmental research fits into the agricultural systems in the project area).

Contents:

Abbreviations used:

AGROCAM	Agro-industrie du Cameroun
CCC	Complexe Chimique Camerounais
EEC	European Economic Community
EPA	Elevage Promotion Afrique
FONADER	Fonds National de Développement Rural
IPC	International Potato Centre
IRZV	Institute of Animal and Veterinary Research
KFBL	Kerosene Fuelled Bush Lamp
MESIRES	Ministry of Higher Education and Scientific Research
MINAGRI	Ministry of Agriculture
MINEPIA	Ministry of Livestock, Fisheries and Animal Industries
MINPAT	Ministry of Plan and Regional Development
MHAZ	Mid and High Altitude Zone
NRI	Natural Resources Institute
ONDAPB	Office Nationale de Développement de l'Aviculture et du Petit Bétail.
OPV	Veterinary Pharmaceutical Office
PRTC	Presbetarian Rural Training Centre
SAC	Société des Aviculteurs Camerounais
SCM	Société Camerounaise de Minoterie
SODECOTON	Société de Développement du Cotton

SODEPA	Livestock Development Corporation
SPC	Société des Provenderies du Cameroun
STV	Société de Transformation des Volailles

Introduction

The Republic of Cameroon has a population of 10.5 million people (Population Census, 1987) and covers an area of 475,000 km². Six major agro-ecological zones have been described as shown in Map 1: the Sahelian (Zone I), covering the Far North and North Provinces; the Sudano-Guinean Savanna (Zone II) of the Adamawa Province; the Mid and High Altitude Savanna (Zone III) of the West, North West and part of the South West Provinces; the Humid Forest (Zone IV) of South West and Littoral Provinces; the Sub-Humid Forest (Zone V) of Centre and South Provinces; and the Sub-Humid Savanna and Forest (Zone VI) of the East Province. Table 1 shows the principal characteristics of each zone.

The bread basket of the nation is Zone III, the Mid and High Altitude Zone (MHAZ) (Map 2). The major food crops in the zone (Table 2) are maize, banana and plantains, beans, cassava, Irish potatoes, sweet potatoes, cocoyams and yams. The major livestock (Table 3) are pigs, rabbits, chickens, cattle, sheep and goats. The farming system integrates crops and livestock. It has been estimated that an average farm in the zone has 26 cattle, 8 goats, 9 sheep, 3 pigs, and 13 chickens (MINAGRI, 1984). This zone in 1989/90 had 80 % of rabbits, 43 % of poultry, 40 % of pigs, 18 % cattle and horses, 17 % of sheep, and 12 % of goats in the total national livestock population. Within the zone itself, Donga Mantung division has the largest sheep population, while Menchum has the largest cattle stock. Goats and poultry are mostly found in Menoua division, while pigs and rabbits are intensively raised in Mifi division.

The MHAZ produced 59 % (1980-81), 37.7 % (1983-84), 47.2 % (1986-87) and 43 % (1989-90) of the national chicken population. Poultry is predominantly kept in Menoua and Mifi Divisions (West Province) while in the North West Province, they are found mostly in Mezam and Ndonga Mantung Divisions.

Poultry is estimated to yield about 13,000 tons of meat yearly. Annual poultry meat and egg consumption averaged 1.0 kg and 14 eggs of 50 g per capita. This means that each Cameroonian eats about 3 g of poultry meat and 2 g of fresh eggs daily. In 1984, meat and egg represented 1.38 % and 0.61 % of each urban household food budget (DSN, 1984). This figure is low and represents 12 % of the national annual per capita animal protein intake.

It was with this background that the feeding of chickens specifically energy sources in chicken diets was chosen for research in a collaborative study between the Natural Resources Institute (NRI) in the United Kingdom (UK), IRZV, IPC and extension ministries in Cameroon. This project fits well with IRZV's development goals aimed at increasing productivity in the poultry sector. In this regard an analysis of the poultry production business in the Western Highlands of Cameroon in particular and Cameroon in general has been undertaken.

Table 1. Economic and environmental indicators in the agro-ecological zones of Cameroon.

Agro-ecological zones:	Sahel zone	Savanna zone II	Mid and High Altitude savanna zone III	Humid Forest zone IV	Sub-Humid Forest zone V	Sub-Humid Savanna and Forest zone VI	
Provinces:	Far North/ North	Adamawa	North West/West	South West/ Littoral	Central/ South	East	
Criteria:							**Total**
Altitude (m)	400-800	>1000	700-1900	0-800	<80	300-800	
Population density	Medium	Low	High	High	Medium	Low	
Rainfall (mm)	400-1000	1000-1500	1500-2500	>2500	1500-2500	1500-2500	
Land area (km²)	101,603	61,992	31,190	45,130	116,132	108,540	464,587
(%)	21.9	13.3	6.7	9.7	25.0	23.4	100.0
National parks and equivalent reserves (ha)	909,000		5,970	290,000	303,000	843,000	2,350,970
Climatic risks to agriculture	Very high	Low	Medium	Medium	Low	Very low	
Erosion/land degradation	Very high	Medium	High	Medium	Medium	Low	
Population	2,335,000	423,000	2,552,000	2,502,000	2,159,000	476,000	10,447,000
Population density (km²)	23.0[1]	6.7	81.8	55.4	18.6	4.4	22.5
Urbanisation (%)	14.0	22.6	22.4	60.8	37.9	24.0	30.3
Average gross income per farm FCFA	159,000	167,000	356,000	813,000	424,000	253,000	180,000
From:							
Export crops (%):	43.1	13.0	40.4	66.2	67.3	57.6	51.2
Food crops (%)	27.1	63.3	49.9	32.2	31.0	40.5	40.3
Livestock (%)	29.8	18.7	9.7	1.6	1.7	1.9	8.5
Livestock population (1986/87)							
Cattle	1,657,400	1,587,500	777,300	16,500	46,300	276,500	4,361,500
Sheep	1,362,600	139,000	406,000	34,200	166,300	250,000	2,358,100
Goats	1,507,300	84,900	695,000	56,000	307,100	267,200	2,917,500
Pigs	53,000	2,000	400,000	190,000	95,000	60,000	800,000
Poultry	1,867,000	194,000	3,054,000	2,393,000	6,014,000	478,000	14,000,000

1. Far North: Population density 95.1/Km², North population density 8.8/Km².Source: Cameroon Agricultural Sector Review, March 1989.

Table 2. Crop production in the MHAZ (tons).

Food crop	North West Province	West Province	MHAZ total	MHAZ as % of national
Maize	212,460	139,973	352,430	68.3
Banana	110,715	154,688	265,403	56.0
Plantains	168,275	128,809	297,084	73.2
Cocoyams	202,139	54,706	256,845	81.5
Cassava	124,696	106,049	230,745	59.3
Sweet potato	24,151	48,200	72,351	25.1
Yams	20,223	20,694	40,917	-
Irish potato	20,763	12,693	33,456	77.6
Beans	24,943	16,854	41,797	
Groundnuts(shelled)	15,191	13,963	29,154	33.0
Rice	2,378	5,164	7,542	69.5
Palm oil	12,343	6,567	18,910	43.0
Sugar cane	16,407	23,973	40,380	
Palm kernel	nd	23,091	23,091	

Notes: - nd: no data. Sources: MINAGRI: Annual reports, West Province; MINAGRI: Annual reports, North West Province.

Table 3: Livestock population in the MHAZ and their relative importance nation wide.

Division	Cattle	Sheep	Goats	Pigs	Poultry	Rabbits[1]	Horses
Bui	72,000	32,600	31,500	1,700	97,600	1,540	860
Donga-Mantung	148,300	86,000	18,700	2,300	145,000	1,320	760
Menchum	149,600	21,200	12,700	6,500	79,400	3,600	830
Mezam	72,100	16,500	18,500	7,800	310,750	5,545	480
Momo	30,500	8,600	10,400	11,400	68,150	1,000	276
North West Province	472,500	164,900	91,800	29,700	700,900	10,665	3,206
Bamboutos	18,662	8,203	9,399	16,481	126,320	266	256
Menoua	6,375	52,060	74,163	54,079	2,466,500	567	1,284
Mifi	3,818	21,856	30,625	130,274	602,912	13,860	16,835
Ndé	5,554	11,240	37,805	8,375	143,896	116	6,195
Noun	84,144	42,682	26,353	331	163,772	117	597
Upper-Nkam	1,067	8,290	7,599	13,738	121,550	1,115	939
West Province	119,620	144,331	185,944	223,278	3,624,950	16,041	26,106
MHAZ total	592,120	309,231	277,744	252,978	4,325,850	26,706	29,312
% of the nation total	18	17	12	40	43	80	

Sources: MINEPIA, Rapport annuel, Province Ouest: 1989/90; MINEPIA, Annual report, North West Province: 1989/90. 1 Heifer Project International report, 1990 (for NWP only)

2.0. Methodology

The survey on the characterization of poultry production systems was carried out in the MHAZ. One hundred and six (106) commercial poultry farms were surveyed and 102 poultry houses evaluated for management parameters. A clustering sampling technique was used to select six administrative divisions, three in each province taken separately, based on official statistics on poultry population. The Divisions were Mifi, Menoua and Bamboutos (West Province) and Mezam, Bui, and Donga Mantung (North-West Province).

Using a pre-tested questionnaire, data were gathered on farm age, production capacity, marketing, type and objective of production, and sources of funds. Because of inconsistent official data on the actual number of poultry farmers, a "snowball" sampling technique was implemented with the help of the first identified farmer in each administrative sub-Divisional unit. Visits were also made to government offices, feed mills, slaughter houses, local and major markets within the country for additional data.

A complementary description was provided using existing literature on poultry production under the traditional production system earlier reported in the North West Province of Cameroon by a multidisciplinary team of researchers. Because information herein did not reflect the entire nation, additional literature from other zones of Cameroon was included for comparative purposes.

3.0. Production systems

The MHAZ can be divided into two major farming systems based on land tenure and use pattern as described by Jahnke (1982) and this survey:

1. The extensive pasture-based livestock production system in which the major livestock are large and small ruminant animals, and a few monogastrics mostly chickens; and

2. The semi-intensive to intensive pastureless-based livestock production system in which the major livestock are monogastrics (pigs, poultry, and rabbits) and small ruminants.

Both systems have several minor variations from the above description.

3.1. The traditional poultry sector

This sector also known as the backyard or farmyard system and is characterized by chickens roaming around the farmyard, scavenging for themselves. Apart from containing 63% of the national flock population, the sector is managed (LSRP-Bambui, 1989) by 60% of the nation households. Flock size is small (6-50 birds) and 41% of households keep less than 5 birds (Table 4).

Table 4. Flock size characteristics for back-yard chicken population.

Flock sizes (number of birds)	Number of farms	Proportion (%)
< 5	54	41.2
6 - 20	30	22.9
21 - 50	32	24.4
> 50	15	11.5
Total	131	100.0

Source: LSRP-Bambui (1989).

3.1.1. Breeds and breeding management

(a) Breeds. Chickens found in the back yard are apparently crosses between local strains and introduced hybrids. Phenotypically, the chickens have white skin, red wattles and orange eyes. The plumage colour is of variable colours from a combination of red, white and black. Shanks are predominantly white and non-feathered. The legs have four toes. Sexual dimorphism favoured cocks for all body measurements except for beak length (Fotsa and Poné, 1988).

(b) Breeding management and performance. Farmers usually control breeding by introducing a cock to run with the hens or the hens get served by the cocks in the neighbourhood. Hens wean chicks at any time. A hen broods 3 to 4 times a year and produces 6-10 adult birds per year. Because of loose attention by the farmer, hatchability of all eggs brooded is always low. As shown in Table 5, the ratio of cockerels to pullets stands at 1:1 while at breeding age it declines to reach 1:3. Thus, few cocks are left in the backyard at breeding.

Chickens in this sector are characterized by small body sizes (1.2-2 kg), late maturity (10-12 months) (Table 6), low performance in egg number (80-140 eggs per year), small egg size (35-50 g) long laying pause (90-105 days), and a strong inclination to broodiness (18-28 days) (Douffissa, 1987; Fotsa and Poné, 1988; LSRP-Bambui, 1989).

Table 5. Structure of chicken population in Momo Division., North West Province.

Classes of chickens	Number of chickens	Proportion (%)
Cocks	510	16.2
Hens	1206	38.3
Cockerels	285	9.0
Pullets	338	10.7
Chicks	812	25.8
Total	3151	100.0

Source: LSRP-Bambui (1989).

Table 6. Age at first hatching of poultry in Momo division.

	Age range for first hatching (months)			
	<6	6-9	10-12	>12
Percentage of farms out of 19	15.8	31.6	52.6	0.0

Source: Adapted from LSRP-Bambui (1989).

3.1.2. Housing and housing management

Farmers do not generally provide a good poultry house for chickens. Chickens roam about the homestead with minimal attention from the owner. Douffissa (1987) reported that a raised slats housing system prevailed in the Adamawa Province of Cameroon. That house had a conic and thatched roof and the night floor density averaged 12 birds/m^2 (3-72 birds/m^2).

LSRP-Bambui (1989) reported that only 25 % of farmers practised a kind of confinement for chickens. Broody hens and their offsprings were confined for up to three months in the kitchen or in a separate barn, or along the house, while all classes of chickens were confined during cropping season, especially from March to May. Occasionally, chickens were confined and fattened for special cases such as emergency marketing, food and gifts, or for cultural activities.

3.1.3. Feed and feeding management

Apart from food obtained through scavenging, feed for birds particularly energy is often supplemented with household scraps particularly kitchen wastes and weeviled maize. Protein in the diets come from insects and herbage. Herbage and soil supply the minerals and vitamins in the diet. Even if the feed was balanced and adequate a lot of energy is spent scavenging for food.

3.1.4. Diseases

High pre-weaning mortalities (Table 7) i.e chicks survival up to 2-3 months was reported to vary from 30 to 60% (RRAS BUI, 1988). In the Adamawa Province of Cameroon, Douffissa (1987) reported that poultry farmers were loosing about one-third of their flock every year because of various chicken diseases such as Newcastle disease, pullorum and coccidiosis. It was also reported that night shades were of poor hygienic condition and frequently infested with lice. Mite infestation may also be a common problem.

Table 7. Distribution of mortality by age group of poultry in Momo Division.

		Age group		
	Still-birth	**Pre-weaned**	**Weaned**	**Breeders**
Mortality (as % of birds out of 485)	14.6	59.2	4.3	21.9

Source: Adapted from LSRP-Bambui (1989).

3.1.5. Socio-economics

3.1.5.1. Farmers' goals and objectives

Poultry under traditional or backyard system is part of the whole farming system. The goal is to ensure sustained food production and fulfil family needs such as food, clothing, medical care, school fees, and extended family problems.

3.1.5.2. Labour distribution and use

In the rural area (LSRP-Bambui, 1989), husbands contributed 36.4 % of the total labour input for livestock activities. 24.8 % of the labour supply came from children and 21.4 % from women and hired labour (19.2 %) (Table 8).

Family labour accounted for 80 % of the total labour input. Single species such as goats and poultry were managed by adults with 62.2 % and 81.4% of the labour devoted to them, respectively. Hired labour was employed mostly by farmers keeping cattle alone (72 %) or in association with sheep (20%) and to a lesser extent by farmers rearing poultry in association with pigs (10 %). Most of the labour from children was used for rearing goats alone (38 %) or goats and poultry combined (50 %). Livestock association in which pigs and poultry were combined were mostly handled by men (Table 8).

Table 8. Labour distribution according to poultry-livestock association in Momo Division.

Livestock associations	Number of farms	Husband	Farm labour (%) Wife	Children	Hired	
Single species:	176	26.1	24.4	19.3	30.2	
Cattle	68	13.2	7.4	7.4	72.0	
Goats	45	33.3	28.9	37.8	0.0	
Poultry	43	41.9	39.5	11.6	7.0	
Others	20	20.0	40.0	35.0	5.0	
Two species:	79	41.8	15.2	32.9	10.1	
Goats & pigs	16	37.5	25.0	31.2	6.3	
Goats & poultry	16	37.5	12.5	50.0	0.0	
Cattle & sheep	15	40.0	0.0	40.0	20.0	
Pigs & poultry	10	60.0	20.0	10.0	10.0	
Others	22	40.9	18.2	27.3	23.6	
Three species:	57	49.1	19.3	31.6	0.0	
Goats, pigs & poultry	37	51.4	18.9	29.7	0.0	
Others	20	45.0	20.0	35.0	0.0	
Four species:	6	50.0	33.3	16.7	0.0	
Sheep, goats, pigs & poultry		6	50.0	33.3	16.7	0.0
Total count	318	34.6	21.4	24.8	19.2	

Source: LSRP-Bambui (1989).

3.1.5.3. Marketing

Chickens are sold in the neighbourhood either at the farmers initiative or that of the neighbour. Thus, prices vary from 600 francs CFA for 500 g chick to 1500 FCFA for a hen or 2500 FCFA for a cock. Disposal of chickens is also prompted by other cultural activities such as arrival of a guest or birth of a child.

3.1.6. The future of the traditional sector

Despite the many set-backs of this sector of the poultry industry, farmers apparently make some gains or else the system would not continue to exist. It is suggested that a closer study be made with a view to making the system more efficient in terms of resources utilization.

Presently, the sector lives in harmony with the environment due to small flock sizes. Increased production will call for better resource utilization and protection of the environment. A pre-extension project has been initiated at IRZV Mankon to vaccinate chickens and supply feed to farmers in an attempt to reduce losses. A health package which involves vaccination of chickens against common contagious diseases and a feed package which supplies additional energy such as maize, tubers and banana/plantains are being evaluated. A second stage envisages a much improved housing and environmental systems. These improvement techniques are being introduced in a step by step method to minimize stress to the production system. The scope for significantly increasing the output and productivity of the traditional systems is however minimal.

3.2. The modern sector

This sector is characterized by intensive management practices in which housing, imported breeds, compound feeds, and drugs are introduced. Farmers objectives and know-how are related to size, production type, labour and marketing. Contrary to the traditional sector, the modern sector is well-encouraged by the government through establishment of government stations that supply subsidized inputs (MINPAT, VIth Plan, 1986-1991, p.89).

3.2.1. Breeds and breeding management

3.2.1.1. Type of chicken farms

Poné (1990) reported that in the MHAZ, 58% of poultry farmers kept layers, 32% kept broilers, and 10% were engaged in mixed operations with both broiler and laying hen flocks. The proportions of each type vary from one area to another and might be related to periods of the year (Table 9. For example, some farmers only produce broilers at peak demand periods.

3.2.1.2. Breeds

Three companies AGROCAM, SAC, SABEL and to a lesser extent IRZV, GILANN, and ONDAPB import parent stock chicks and/or hatchable eggs from major suppliers in the EEC (France, Belgium, Holland, Germany and United Kingdom), Middle-East (Israel) and USA. Some of the breeds recorded in the field are: Hybro, Jupiter, Derrich, Hubbard, Rhode Island Red, White Leghorn, Cornish, Lohmann, Hisex, ISA White and ISA Brown. The great variability in sources of day-old-chicks imported, also reflects variability in quality of chicks. AGROCAM (56%) and SAC (23%) are the major supplier of chicks.

Table 9. Proportions of broiler and layer farms (%) in different provinces of Cameroon.

Poultry farm type:	West Province[1]	MHAZ[2]	Centre and Littoral provinces[3]	Centre[4] Province
Broilers	47.8	31.7	37	4.3
Layers	21.6	58.4	3	61.4
Mixed (broiler and layers)	30.6	9.9	60	34.3

Source: 1.Djoukam and Téguia (1991); 2. Poné (1990) - unpublished data; 3. MINEPIA (1987) - registered farms. 4. Epo (1983).

There are fifteen hatcheries operating in the country with an annual total capacity of 20 millions chicks a year. However, between 1988 to 1991 only 4.7 million chicks were produced. Imports accounted for 1.4 million chicks during the same period (Crouail and Duault, 1991). In 1990/91, however, 7 million day-old-chicks consisting of 6.3 millions broiler chicks and 700,000 pullet chicks were sold (Table 10).

3.2.1.3. Breeding management

3.2.1.3.1. Flock sizes

The survey in the MHAZ showed that 87% and 44% of broiler and layer farms had flock sizes below 500 birds. The maximum flock size registered per farm was 8500 layers and 4800 broilers. On average, there were 295 broiler chickens per farm. For egg-type farms, pullets, cockerels and laying birds averaged 409, 24, and 832 birds per farm, respectively. As reported by Djoukam and Téguia (1991), there was a tendency for farmers to take poultry as a principal activity as flock sizes increased above 1000 birds, especially for those engaged in egg production (Table 11).

Table 10. Hatchery capacity and day-old-chick production and/or import (in thousands) in Cameroon.

Hatcheries	Financial year			Hatchery chicks
	1988/89	1989/90	1990/91	production capacity
AGROCAM	1,963	2,698	2,892	6,240
SAC (AZANGUE)	nd	nd	1,520	3,780
GILANN (KADJI)	nd	nd	300	2,000
ONDAPB Douala	710	402	159	2,000
ONDAPB Yaoundé	644	391	188	2,000
ONDAPB Muyuka	nd	nd	54	300
ONDAPB Kounden	44	116	131	200
SABEL Yaoundé	nd	nd	nd	3,000
Monastery Mbengwi	nd	nd	nd	156
IRZV	10	6	4	220
Others	600	500	700	nd
Total production	3,971	4,113	5,948	19,896
Total imports	1,521	1,725	1,057	
Total chicks available	5,492	5,838	7,005	
Imports of hatchable eggs[1]	842	1,124	2,000	

Notes: 1. Hatchable eggs are imported during peak day-old-chicks demand periods (October-November); nd: not determined; Sources: Crouail and Duault (1991); Batimba and Mewoand (1992); IRZ Mankon (1988).

Table 11. Comparison of type of chicken and flock size on farms where farmers keep poultry as a principal activity.

Farm flock size (birds)	Type of production (% given in brackets) Broilers only	Layers only	Broilers & layers	Total
<500	1 (8.33)	-	-	1 (8.3)
501-1000	1 (8.33)	1 (8.33)	-	2 (16.7)
1001-2500	-	3 (25.0)	-	3 (25.0)
>2500	-	5 (41.7)	1 (8.3)	6 (50.0)
Total	2 (16.7)	9 (75.0)	1 (8.3)	12 (100)

Source: Djoukam and Téguia, 1991

3.2.2. Houses and housing systems

A total of 252 poultry buildings were identified on 92 poultry farms. 40% of the surveyed houses were used for broiler production and 60% for egg production. 59% of broiler houses were used for separate building activities such as brooding (38%) and growing (21%), and 41% of them were used in all-in-all-out practice. For the pullet houses, 53% were used for growing-laying activities (Table 12).

Table 12. Distribution of housing systems according to management activities.

Management activities	Number of buildings	%	Overall
Broiler houses	100	100.0	39.7
Brooding only	38	38.0	
Brooding-growing	41	41.0	
Growing only	21	21.0	
Pullet houses	152	100.0	60.3
Brooding-growing	3	2.0	
Growing-laying	80	52.6	
Laying only	6	4.0	
Brooding-growing-laying	63	41.4	
Total	252	-	100.0

Source: Adapted from Poné (1993).

Three types of housing systems were identified based on flooring systems: deep litter, raised slats, and battery caging. 79% of the floors were of the deep litter system (Table 13). 77% of farmers conceived and designed their poultry houses, while about 17% did so using available poultry manuals (Table 14).

Table 13. Frequency distribution of housing systems according to floor type.

Floor type	Number of houses	Percentage
Deep litter system	199	79.0
Raised bamboo slats system	49	19.4
Battery caging system	4	1.6
Total	252	100.0

Source: Poné (1993)

Table 14. Poultry house designer, as percentages of surveyed respondents.

Designer	Number of farmers	Percentage
Poultry farmer conception	78	76.5
Poultry farmer using manuals	17	16.6
Poultry specialist	7	6.9
Total	102	100.0

Source: Poné (1993)

Table 15 shows that 49.5% of poultry houses were less than five years, 37.6% were between 5 to 10 years, and 12% 10 years and older. The raised bamboo floor house was newer in design than the deep litter house, with 95% versus 85% of the houses being less than 11 years old.

Table 15. Age distribution (%) of poultry houses according to floor and chicken types.

	Number of houses	Age of poultry house (years) <5	5-10	>10
***Floor type*:**				
Deep litter	80	50.0 (40)[1]	35.0 (28)	15.0 (12)
Raised slats	19	52.6 (10)	42.1 (8)	1.0 (1)
Caging	2	0 (0)	100 (2)	0 (0)
***Chicken type*:**				
Broilers	38	52.6 (20)	29.0 (11)	18.4 (7)
Pullet (grow-lay)	63	47.6 (30)	42.9 (27)	9.5 (6)
Total	101	50	38	13
Percentage of total	-	49.5	37.6	12.9

***Notes*:** 1.Number of observation per cell. ***Source*:** Poné (1993)

3.2.2.1. Level of farm equipment

Forty five percent of the farms were fenced or protected from outsiders. The level of mechanization was very low. Out of 106 farms, 23% used a farm transport vehicle and 9.4% had quarantine facilities. Battery cage units were found in one farm while 3 farms had feed mill facilities. One farm each had a small hatchery unit, a processing plant unit, a freezing/cooling room, a feed bin, and automatic feeders (Table 16).

Most production units lacked diagnostic laboratories and egg grading machines. Ten farms had stand-by generators, 32 had water pumps, 17 used automatic drinker systems, 31 and 11 farms possessed electrical and gas brooding equipments, respectively. 18 farms hired someone to debeak their chickens with an electric debeaker, 15 and 12 farms had reception and sale offices, respectively. Four farms had manual disinfectant pump/sprayer (Table 16).

3.2.2.2. Construction materials

Sun-dried mud blocks (51 %) and raffia bamboo (47 %) were the most popular materials used on the wall of poultry houses (Poné, 1993). Few walls of the deep litter system were plastered half way inside. Epo (1983) reported that 58.6 % of all poultry houses floors were cemented while 41.4 % were not, but Poné (1993) reported that over 70 % of the deep litter floor were cemented.

Eucalyptus poles (68.6 %) and sawed wood (65.7 %) were used for roof frames. Corrugated zinc sheets (93.1 %) and transparent zinc sheets (10.8 %) were common roof covers. Dried grass/hay (Hyparrhenia spp. and Imperata cylindrica) and wood shavings were the most important floor litter materials and represented 34.9 %, 29.7 %, and 24.4 % of all cases, respectively (Poné, 1993).

Table 16. Level of surveyed farm equipment

Type of equipment	Frequency (number of farms)	Percentage (out of 106 farms)
Sweeping broom	101	95.3
Manual feeders	100	94.3
Manual drinkers	97	91.5
Spade	89	84.0
Bush lamp brooder	74	69.8
Wheel barrow	67	63.2
Scrubbing hand brushes	65	61.3
Waste disposal procedure	63	59.4
Hover for brooding	59	55.7
Fork	54	50.9
Water pit/wells	54	50.9
Pushing truck/scales/rake	50	47.2
Fencing	48	45.3
Electric brooder	31	29.2
Water tank	28	26.4
Knife for debeaking	27	25.4
Farm transport vehicle	24	22.6
Water pump	22	20.8
Automatic drinkers	17	16.0
Reception office	15	14.2
Sales office	12	11.3
Gas brooder	11	10.4
Quarantine house	10	9.4
Standby generator	10	9.4
Feed mill	3	2.8
Other equipment	2	1.9

Source: Poné (1990)

3.2.2.3. House size

The shape of the buildings was rectangular averaging 93.2 m^2 per house and 255.2 m^2 per farm in size, respectively. Each farm had an average of 3 poultry buildings. Table 17 shows the scale of floor area in poultry houses. 41.7 % of them had floor areas less than 50 m^2. Epo (1983) reported that poultry farms around Yaoundé were sufficiently big in sizes with about 79 % falling between 250 and 500 $m^2$of floor space. However, he pointed out that only about 58 % of the surfaces were occupied by chickens. Reasons for these non utilization of space attributed to lack of day-old-chicks when needed, broiler marketing difficulties, inadequate funds, and longer quarantine periods.

Table 17. **Frequency distribution of poultry house floor area (m^2).**

Classes (m^2)	Number of houses	Percentage
<50	105	41.7
50-99	54	21.4
100-149	41	16.3
150-199	31	12.3
200-249	10	4.0
250-300	5	2.0
>300	6	2.4
Total	252	100.0

Source: Poné (1993)

3.2.2.4. Routine management practices

Farm morning activities included flock observation, feed and watering, carcass removal, cleaning and egg collection. In the afternoon, flock observation, feeding/watering and egg collection were routinely achieved. Culling, herbage supply, and other activities were practised in few farms (Poné, 1990). The percentage of farmers who carried out these activities daily were: flock observation (27.5%), feeding and watering (26.7%), egg collection (16.4%), and to a lesser extent carcass removal (12.2%) and cleaning of appliances (7.7%) (Poné, 1990).

3.2.2.4.1. Brooding management

Partial house brooding was practised by 91% of the farmers. Kerosene fuelled bush lamps (KFBL) and electricity were used as fuel source during brooding by 71% and 29% of the farms, respectively. Charcoal or wood burning was used to complement kerosene lantern or electricity (Table 18). No farm was found using radiant gas brooding technique although some possessed the equipment. Hovers were used in 61% of cases at a height of 0.83 m. This technique was similar for all house flooring type (Poné, 1993). Epo (1993) reported that 73% of the farms used KFBL as energy for brooding chicks.

Table 18. Brooding management according to floor type and energy sources.

Practice	Count	(%)	House floor type	
			Deep litter	Raised bamboo
***Brooding*:**				
Partial	21	91.3	90.0 (18)[1]	100.0 (3)
Whole house	2	8.7	10.0 (2)	0.0 (0)
***Energy source*:**				
Kerosene	17	70.8	71.4 (15)	66.7 (2)
Electricity	7	29.2	28.6 (6)	33.3 (1)
Wood or charcoal	1	4.2	4.8 (1)	0 (0)

Notes: 1. Number of observation for each cell unit. ***Source***: Poné (1993)

Two-thirds of broiler farmers brooded chicks for three weeks and one-third did so for a period of four weeks. Pullet chicks and chicks from mixed operations were brooded for 4 weeks in 70% and 50% of the farms, respectively (Poné, 1990).

3.2.2.4.2. Debeaking practises

Debeaking was not done on broiler farms, however, 80% and 90% of the layer and mixed operations debeaked their chickens, respectively. 40% of farmers practising debeaking did so for the second time when pullets were 20 weeks old. The first debeaking was done at 12 weeks of pullets age (Table 19).

3.2.2.4.3. Record keeping

Out of 106 farmers interviewed, 81 %, 70 %, 69 %, 68 %, and 64 % of them kept records on mortalities, vaccination, feed intake/purchase, sales and expenses, and culled out birds, respectively. Half of these farmers kept no written records but remembered facts vividly. Lighting time table, temperature, and body weight were recorded only by 14, 7, and 4 farmers. Out of 69 farms keeping egg type flocks, 48 (70 %) kept records on egg production. Humidity was not measured at all in all farms surveyed (Poné, 1990).

Table 19. Frequency of farms practising debeaking, expressed as percentages of counts.

Farm type	Count	First debeaking Birds age (weeks)	Second debeaking (%)	Birds age (weeks)
Layer	47	11.4	38.3	19.6
Mixed (boiler & layer)	9	13.4	55.6	20.4
Average:		11.7	41	19.7

Source: Poné (1990)

3.2.3. Feed and feeding management

3.2.3.1. Feedstuffs and feed sources

(a) Feedstuffs. Table 20 shows the major feedstuffs produced in the MHAZ compared to national totals. Apparently, the Zone is not self-sufficient in cereal and tubers, but sufficient in bananas and plantains production and has a good potential for pasture production. Crop in excess of or not fit for human consumption is used for animal feed. Most often there is open competition in the market between buyers of feedstuffs for animal feed and the buyers for human feed. Table 20 also shows the extraction rates for estimation from total crop produced of feedstuff quantities for animal feeds. Maize, the principal energy source for chicken feed is seasonal and in short supply (Fomunyam *et al.*, 1990). It is also of low lysine content. The main protein source is cotton seed meal produced from the cottonseed oil mills of Northern Cameroon. Palm kernel cake and soya bean meal (mostly imported) is also used. In an analysis of crop by-products for animal feed in the North West Province, Fomunyam *et al.* (1990) found that about 52,000 tons of these were available yearly. Matching available nutrients to livestock population and needs, the authors reported a deficit in both total dry matter and crude protein (Table 21).

Table 20. Production of major foods and agro-processing by-products in MHAZ (tons).

Crop & by-products	North West Province	West Provinces	MHAZ total	MHAZ as % of national
Maize	10,623	6,998	17,621	68.3
Banana	11,071	15,468	26,539	56.0
Plantains	25,340	19,321	44,661	73.4
Cocoyams	20,213	5,470	25,683	81.5
Cassava	62,348	53,024	115,372	59.3
Sweet potato	24,151	48,200	72,351	25.1
Yams	nd	nd	nd	nd
Irish potato	1,038	639	1,677	77.8
Beans	nd	nd	nd	nd
Groundnut cake	8,051	7,400	15,451	33.0
Rice bran	356	774	1,130	69.5
Palm oil sludge	3,114	1,841	4,955	45.1
Sugar cane molasses	2,132	3,116	5,248	nd
Palm kernel meal	nd	4,618	nd	nd

Notes: ND: No data. ***Source***: MINAGRI/DPAO/SPESAO, Annual reports, West/North West Provinces (1989/90). Fomunyam *et al.* (1990).

Table 21. Balance sheet of livestock nutrient needs from crop by-product feed in the North West Province (*1000 tons).

Descriptions	Dry matter	Crude protein
Livestock nutrients requirements	1,893.0	149.5
Nutrients available from food and cash crop by-products	226.9	40.3
Nutrient deficit	1 666.1	109.2
Self-sufficiency rate (%)[1]	12.0	26.9

Notes: 1. Obtained as ratio of available by-products to animal nutrient requirements. ***Source***: Fomunyam *et al.* (1990).

(b) Feed mills and feed dealers. Three feed manufacturers and suppliers (SPC, SAC, NUTRICAM) produce most of the livestock feed. 53,000 tons of poultry feed is sold annually. Feed is also sold by smaller commercial companies and by owners of private mills. A dozen farmers own small mills for private use and occasionally sell feed in excess of use upon demand for which data was not readily available.

Most mills operate at 30-45% capacity (Table 22). The types of feed produced and sold as mash are for broiler starters and finishers, pullet starters, growers, and layers. Protein premixes at 5%, 10%, 20%, and 40% concentrations do exist both for broilers and layers. Farmers need only add an energy source, usually maize as specified by manufacturers, to obtain a complete mash for the type and class of chickens. This sometimes leaves room for adulteration.

(c) Feeding systems. Djoukam and Téguia (1991) reported that 95% of poultry farmers used commercial feed while 5% used home made feed. They also found that 77% of home made feed users kept more than 2500 birds while 15% of them kept less than 500 birds (Table 23). This last category of farmers might not be well armed to prepare balanced chicken diets. Feed is fed free choice in wooden or plastic feeders while water is given in plastic containers. Both feed and water are given once a day.

Table 22. Trends in annual animal feed production by local feed mills (tons).

	1988/89	1989/90	1990/91	Feedmill Capacity
SPC (AGROCAM)	19,540	15,654	15,600	30,000
SADE	1,747	425	nd	6,000
EPA (AZANGUE)	9,000	10,000	10,400	12,000
NUTRICAM (ADER)	2,400	2,400	6,000	14,400
ONDAPB	3,485	2,411	1,544	28,000
CACIR Yaounde	nd	nd	nd	3,000
MONASTERY-Mbwengwi	nd	nd	1,300	4,500
RTC Mfonta	nd	nd	900	1,400
Lapinière	nd	nd	nd	19,000
IRZV	287	298	273	6,000
Other feed mills	14,000	20,000	20,000	56,000
Totals	50,459	51,188	60,017	181,300

Notes: nd :no data. ***Sources***: IRZV Mankon (1988);Crouail and Duault (1991); Batimba and Mewoand (1992).

Table 23. Users of home made feed grouped according to flock sizes.

Farm flock size (number of birds)	Number of farms	Percentages
<500	2	15.4
501-1000	0	0
1001-2500	1	7.7
>2500	10	76.9
Total	13	100

Source: Djoukam and Téguia, 1991

(d) Chemical composition and feed standards. Tables 24 and 25 provide results of preliminary analyses of selected feedstuffs. The energy values were not be determined because of a burnt out galvanometer of the bomb calorimeter. Similarly, the amino acid analyser is temporary out of order. Analyses are carried out according to A.O.A.C. (1975). Routine analysis of these feedstuffs and feeds both at preparation and storage is the basis for the establishment of feedstuffs and feed standards at National Biochemistry Laboratory (NBL) Mankon.

Most feed manufacturers have no quality control facilities. No strict control on the quality of feedstuffs and feed is carried. There are no dates of manufacture or of expiration of commercially sold feed. Labels only carry minimum information. Size, shape, colour, and writings on the labels is at the discretion of feed manufacturers.

Table 24. Proximate composition (%) of common poultry feeds

Feedstuffs	Dry matter	Crude protein	Crude fat	Crude fibre	Ash	PDM
Maize	89.4	8.2	4.7	2.7	1.3	
Rice bran	89.9	6.4	4.7	19.4	15.4	
Wheat bran	91.6	16.7	6.6	8.6	4.6	
Brewers' grains	90.4	27.9	7.7	15.4	3.5	
Palm cake	90.8	12.7	18.9	21.1	3.4	
Peanut cake	91.9	41.8	12.0	7.6	5.0	
Cotton seed cake, pelleted	90.5	33.4	3.3	8.6	7.3	
Cotton seed cake, unpelleted	94.1	52.5	6.7	5.1	7.2	
Fishmeal	90.5	61.3	4.4	0.7	22.1	
Blood meal	92.4	81.7	0.2	-	4.4	
Oyster shells	99.8	0	0.0	0.0	99.4	
Sweet potato tuber, T1B1	92.5	1.2	0.3	nd	4.0	28.1
Sweet potato tuber, T1B2	92.0	1.3	0.2	nd	3.0	25.2
Sweet potato tuber, 1112	97.5	1.4	0.4	nd	3.5	29.4
Cassava root, 79152	90.0	1.5	0.5	nd	3.0	36.8
Cassava root, 7621	92.5	1.5	trace	nd	3.5	45.8
Cassava root, 79307/8	91.4	1.5	trace	nd	4.0	33.9
Cassava root, local red	92.3	1.3	trace	nd	4.0	42.5
Cassava root, local white	95.7	1.4	trace	nd	5.0	40.6

Notes: PDM - Partial dry matter of roots (as a percentage of fresh root and tuber). nd = not determined. ***Source***: NBL Mankon (1994).

Table 25. Chemical composition of selected livestock feed.

Commercial feeds	Dry matter	Ash	Organic matter	Crude protein	Crude fat	Crude fibre	NFE
Poultry starter mash	91.2	12.9	78.3	18.0	7.6	5.5	47.2
Poultry grower mash	91.2	9.2	82.0	13.0	5.6	5.9	57.5
Poultry layer mash	91.0	9.2	81.7	16.8	7.3	5.4	52.3
Pig creep mash	91.6	6.3	85.2	21.2	8.2	4.4	51.5
Pig grower mash	91.6	7.6	84.0	17.8	6.6	5.9	53.7
Rabbit all mash	90.3	8.7	83.6	19.3	7.0	7.9	49.4
Goat feed	91.6	6.4	85.2	17.8	5.0	8.3	54.1

Source: NBL (1994).

(e) Feedstuffs and feed marketing. Maize which constitutes 50-65 % of chicken feed remains in short supply and the seasonality of its production often compels feed manufacturers to resort to importation. Tables 26 and 27 give export and production data for some commonly used feedstuffs.

Imported feedstuffs are mostly protein and vitamin and mineral premixes. On average, 10,000 tons of soybean meal worth 1.6 million FCFA and 720 tons of premixes worth 144 millions FCFA are imported annually (Crouail and Duault, 1991). In 1990, Cameroon spent 400 million FCFA of foreign exchange earnings for import of calcium carbonate needed as calcium supplement (Duplaix, 1990).

It is rather difficult to understand why livestock feed preparations use imported soybean meal, given there are local producers of this meal. Furthermore, substitutes have been proposed by IRZV researchers. For instance, cotton seed cake can be used efficiently at levels up to 30% in the diets for broiler and laying chickens (Poné et al., 1986 and 1987) and up to 7.5% in breeders diets (Dongmo *et al.*, 1987). Yet, about 20 tons of cotton seed cake were exported in 1989. Poné and Dongmo (1990) reported that at 4% dietary level, sun-dried leucaena leaf meal was acceptable egg yolk colourant. Recently, Téguia et al. (1992) reported that at 3% dietary levels, chicken egg shells, snail shells and oyster shells were comparable to imported calcium carbonate for egg production and egg quality of laying hens.

Current market prices for poultry feedstuffs and poultry rations as per classes of chickens are provided in Table 28. Because of the devaluation of the FCFA, this sector is quite fluid and prices are continuously on the rise.

Table 26. Trends in imports and exports of poultry feedstuffs in Cameroon (tons).

Year	**1988**	**1989**	**1990**
***Imports*:**			
Maize	4,368	10,910	9,795
Soyabean meal	418	1,049	3,806
Premixes	2,930	5,008	5,975
***Exports*:**			
Palm kernel cake	2,714	4,353	nd
Cotton seed cake	nd	19,699	nd
Various cereal brans	5,778	1,228	nd

Notes: nd:-no data. ***Source***: Syndicat des Acconiers (1990).

Table 27. Meat processing by-products production and prices at SODEPA (tons).

By-products	**FCFA/kg**	**1989/90**			**1990/91**		
		Douala	**Yaounde**	**Total**	**Douala**	**Yaounde**	**Total**
Blood meal	230	7,235	49,073	56,310	nd	43,043	43,043
Meat and bone meal	230	2,090	3,740	5,830	6,600	2,331	8,930
'Cornillons'	100	11,400	7,173	18,570	nd	49	49
Fishmeal	250	4,096	274	4,370	10,090	360	10,450

Notes: nd - no data. ***Source***: SODEPA activity report.

Table 28. Prices of feedstuffs in Cameroon before and after currency devaluation in 1991 (FCFA/kg).

Feedstuffs	Before devaluation	After devaluation
Maize	70-100	140-160
Sweet potato tuber (DM)	40-50	75-80
Cassava root (DM)	30-40	60-75
Soya bean meal	160-200	300
Cotton seed cake	60-80	120
Palm kernel cake	35	55
Wheat bran	45	50
Bone meal	30-35	55-60
Oyster sea shells	35-50	70-80
Salt	66	122
Fish meal	600	800
Palm oil sludge	20	50
Rice bran	35	60
Palm oil	120	300
Blood meal	300	550
Vitamin mineral premix	14,000	26,000
Commercial chicken feeds:		
Broiler starter	136	180
Broiler finisher	132	160
Layer starter chick	127	165
Layer grower chick	115	145
Laying hen	124	160

Source: Local markets in Bamenda.

3.2.4. Health and health management

3.2.4.1 Observed poultry diseases

Most tropical viral, bacterial and parasitic diseases are enzootic in the area. Epo (1983) reported that coccidiosis (32.9 %), chronic respiratory disease (20 %), and diarrhoea (12.9 %) were the principal disease problems/symptoms encountered by poultry farmers. The same author pointed out that 56 % of the farmers had the tendency to diagnose and prescribe medicine for their chickens without prior consultation of a specialist. Furthermore, farmers tended to adulterate feed inevitably leading to nutritional imbalances and consequent health problems. Disposal of dead carcasses on the farm remains a critical problem. Farmers suggested that an analysis and revamping of the drug delivery system be carried out.

3.2.4.2. Health management

(a) Use of disinfectant foot bath. One-fifth of surveyed poultry houses had a disinfectant foot bath at their entrance as a disease preventive measure. Of these, houses with layers (27 %) were more protected than those with broilers (18 %) (Poné, 1993).

(b) Deworming practises. Only 19 % of broiler farms were reported (Poné, 1990) to practise de-worming as compared with 78 % and 70 % of layer and mixed operations, respectively. As shown in Table 29, de-worming was done only once for broilers and at least twice in laying flocks. Broilers were de-wormed by 5 weeks of age. Pullets were first de-wormed at 13 weeks of age. 41 % of laying flocks already de-wormed at 13 weeks old were de-wormed the second time just before point-of-lay (19 weeks old).

(c) Quarantine period between two crops of chickens. The quarantine period between two consecutive flocks/crops in the same building varied from a minimum of two weeks to a maximum of 26 weeks. Reasons for these differences were lack of day-old-chicks, poor marketing, frequent disease incidence, lack of finances, and above all poor management planning (Poné, 1990).

Table 29. Frequency distribution of farms practising de-worming according to farm type, expressed as percentages of counts.

Farm type	Number of farms	First de-worming Birds age (weeks)	Second de-worming (%)	Birds age (weeks)
Broiler	6	5.3	0.0	
Layer	46	13.0	43.5	18.8
Mixed (broiler & layer)	7	13.5	28.6	22.0
Average:		12.2	40.7	19.0

Source: Poné (1990)

3.2.5. Meat and egg technology

3.2.5.1. Processing

Meat processing is not well organized in the poultry industry in Cameroon. Some work on frozen, de-hydrated, smoked chickens as well as on carcass characterization have been carried at IRZV (Imélé, 1989, unpublished data; Poné *et al.*, 1985), and some private companies (Table 30).

Another type of processing occurs through mobile cafeteria. Here eggs are boiled and sold at 75-100 FCFA a piece with hot pepper sauce. When fried with oil, an egg sells for 100-150 FCFA including other spices and charges for services rendered.

Table 30. Carcass yield of broiler chickens produced in Cameroon.

Characteristics	Broilers[1]	%	Broilers[2]	%
Birds age (weeks)	8	-	12	
Liveweight (g)	1,500	100	2090	100
Dressed weight (g)	1,200	80	1722	82.4
Ready to cook weight (g)	975	65	1398	66.9
Gizzard weight (g)	30	2	37.6	1.8
Leg weight (g)	60	4	nd	nd
Liver weight (g)	30	2	29.3	1.4
Head and neck weight (g)	7.5	0.5	nd	nd
Abdominal fat pad weight (g)	nd	nd	8.6	0.4
Heart weight (g)	nd	nd	117	5.6

Notes: nd - no data. 1. (STV) Société de Transformation de Volailles, Douala, 1990. 2. Poné *et al.* (1985).

3.2.5.2. Quality standards and control

Laws do exist but are not well controlled due to unorganized markets. Egg quality (Haugh units) which is high at farm gate (82.6 - 90.4; Poné, 1993) will quickly deteriorate by the time consumers buy them due to poor storage facilities during transportation from farm to market. Eggs are stored at room temperature, and the further they travel from farms, the more unstable the egg contents become, due to poor road infrastructure, unadapted transportation containers, and environmental stress (heat, high relative humidity, dust).

3.2.6. Socio-economics factors

3.2.6.1. Socio-cultural activities

3.2.6.1.1. Farmer's goals

Table 31 shows that for most broiler farmers poultry was kept essentially for manure (37.7 %) and as a source of income (22.1 %). Family food had the same ranking, as employment needs (13 %). Keeping broilers as a hobby was contemplated by 13% of respondents. The use of farm for research and/or exhibits was reported in one case only.

The major reasons for keeping laying birds were as a source of income (32 %), the use of manure (31.4 %), as a job (18 %), hobby (7 %), and as family food (5.8 %). Research/teaching/demonstration as reason for keeping layers was carried out by 4.5 % of farmers. In mixed farming operations, financial gains (29.6 %), manure (25.9 %), hobby (22.2 %), employment (14.8 %), and research/exhibition (3.7 %) or food for the family (3.7 %) were recorded. Although farmers kept chickens, Table 32 shows that in 44.8 % of cases, crop farming was the major occupation of interviewed farmers. Only 2 % of them were engaged in the poultry business, principally those have been to school. Civil servants represented 21 %, skilled workers (mason, carpenters, craftsmen) amounted to 15 %. Petit traders (11.4 %), religious staff (2.9 %) and traditional chiefs (3 %) were the occupations of the other farmers.

Table 31. Farmer's objectives for keeping chickens according to farm type, expressed as percentages of counts.

Farm type	Number of farmers	Producer objectives in rearing chickens					
		Income	Hobby	Research and exhibition	Use of manure	Food	Job
Broiler	77	22.1	13.0	1.3	37.7	13.0	13.0
Layer	156	32.0	7.0	4.5	31.4	5.8	18.0
Mixed (broiler & layer)	27	29.6	22.2	3.7	25.9	3.7	14.8
Total:	260	28.9	10.4	3.5	32.7	7.7	16.2

Source: Poné (1990)

3.2.6.1.2. Sex and age of farmers

Men represented 75 % of the surveyed population. More than half of the broiler farms were handled by women while men managed 89 % of the layer enterprises (Table 33). This trend was also reported by Djoukam and Téguia (1990).

Table 32. Level of education and major occupation of interviewed poultry farmers expressed as percentages of total counts.

Level of education	Number of farmers	Civil servant	Crop farmer	Religious staff	Petit-traders	Retired staff	Skilled worker	Local chief	Poultry farmer
None	12	0	66.7	0	16.7	0	8.3	8.3	0
Primary	52	1.9	55.8	0	13.5	0	25.0	1.9	1.9
Secondary and higher	36	33.3	25.0	8.3	8.3	13.9	5.6	2.8	2.8
Vocational	5	60.0	20.0	0	0	20.0	0	0	0
Total:	105	15.2	44.8	2.9	11.4	5.7	15.2	2.9	.9

Younger (<20 years old) farmers represented only 1.0 % of the surveyed population. The active age groups 20 to 39 years old represented 44 % of respondents. However, farmers below 40 years old represented 56 %, 41 % and 40 % for broiler, layer and mixed operations, respectively (Table 33). 86 % of the respondents were 30 years and above with 67 % of them between 30 and 50 years old.

A trend towards aged farming population could be associated although not exclusively to land acquisition/inheritance problems. 54 % of the land used for crop and livestock production in the North West Province (Momo division) were reported to be inherited while only 13 % were purchased (LSRP-Bambui, 1989).

Table 33. Age and sex of chicken producers (as percentages of counts) according to farm type.

Farm type	Count	Sex		Count	Age (years)				
		Male	Female		<20	20-29	30-39	40-49	>50
Broiler	31	48.4	51.6	32	0.0	28.1	28.1	34.4	9.4
Layer	55	89.1	10.9	54	1.9	5.6	33.3	24.1	35.1
Mixed (broiler & layer)	10	80.0	20.0	10	0	10.0	30.0	50.0	10.0
Total	96	75.0	25.0	96	1.0	13.1	31.3	31.3	23.3

Source: Poné (1990).

3.2.6.1.3. Level of eduction of poultry producers.
The surveyed group had a literacy (reading and writing English or french) of 88 %. Illiteracy rates averaged 9 % and 17 % in broiler and layer operations, respectively (Table 34). A further analysis of the data showed that those who never attended school fell within the ages of 40 and 50 years.

3.2.6.1.4. Farm age and registration status
As shown in Table 35, 76 % of the farms were ten (10) years old. Twice as many broiler than layer farms (19 % vs. 9 %) were below one year old. Broiler operations were younger with 97 % being less than 11 years old compared to 63 % for layer operations. 88 % of the farms were not in the government extension office register and might be a serious concern for the organization of farmers.

3.2.6.1.5. Farm labour use

Table 36 shows that 4 % of the farms used hired workers only. One fifth of the farms employed paid poultry attendants and 79 % of the farms used exclusively family work force. In Table 37, average poultry paid worker earned 19,000 FCFA a month. This is close to the minimum wage of 21,000 FCFA paid to unskilled labourers. Higher wages of about 29,000 FCFA were paid to workers on laying birds farms, probably due to the intense nature of work involved and the substantial flock size of 410 birds/farm compared to 294 birds per broiler farm. However, salary varied from 10,000 FCFA to 40,000 FCFA. The highest reported wage was that for technicians.

Table 34. Percentage formal educational level of farmers according to farm type.

Farm type	No schooling	Primary school	Secondary school	High school	Technical training	College/ University
Broiler	9.4	46.9	12.5	12.5	6.2	12.5
Layer	16.7	53.7	14.8	3.7	0	11.1
Mixed (broiler & layer)	0	45.5	27.2	9.[illegible]	18.2	0.0
Total	11.8	50.0	15.7	7.8	4.9	9.8

Source:Poné (1990).

Table 35. Percentage poultry farms age and registration status according to farm type.

Farm type	Age (years)				Registration status	
	<1	1-3	4-10	>10	Yes	No
Broiler	18.8	37.5	40.6	3.1	3.1	86.9
Layer	8.8	7.5	36.8	36.8	12.5	87.5
Mixed (broiler & layer)	20.0	30.0	30.0	20.0	30.0	70.0
Total	12.6	26.2	36.9	24.3	11.8	88.2

Source: Poné (1990).

3.2.6.2. Economic activities

3.2.6.2.1. Sources of financing

Djoukam and Téguia (1991) reported that over 85 % of funding for intensive poultry farming was from private funds (family income or loan from village/family groups ("Djangui"). This trend was consistent whether the activity was a principal or secondary job, or male- or female-run (Table 38).

Table 36. Labour characteristics in poultry farms according to farm type.

Farm type	Number of farms	Hired only	Spouse & children	Owner only	Owner and family	Owner and hired	Owner, family and hired
Broiler	32	3.1	0	12.5	68.8	12.5	3.1
Layers	59	5.1	3.4	8.5	69.4	5.1	8.5
Mixed (broiler & layer)	10	0	0	0	60.0	10.0	30.0
Total	101	4.0	2.0	8.9	68.3	7.9	8.9

Source: Poné (1990).

Table 37. Average monthly payment (x 1000 CFA francs) for hired poultry attendants in poultry farms according to farm type.

Farm type	Count	Wage	Range
Broiler	6	15.8	10-30
Layers	1	29.3	10-40
Mixed (broiler & layer)	4	13.0	10-20
Total	21	19.1	10-40

Source: Poné (1990).

3.2.6.2.2. Marketing

Most broilers are sold life and unweighed. However, data gathered showed life broilers weighing from 1.5 kg to 1.8 kg selling at 1500 to 1900 FCFA (1000 FCFA/kg live weight). Eggs are not graded and sold from 800 to 1500 FCFA per 30 eggs. Spent hens are sold during high demand periods at 1500 to 1800 FCFA per head, or 1000 FCFA/kg live weight. Maintenance cost due to piecemeal sales of broilers is 30 FCFA per bird per day after 8 weeks of production. This cost could be minimized provided studies on chicken meat technology are intensified.

Presently, small scale producers carry 5 to 30 broiler chickens in baskets to village markets weekly. To clear a flock of 500 birds it takes about 2 to 6 weeks. In an attempt to reduce these costs or extra charges farmers start sales at 6 weeks of birds age, when bigger birds weigh 1.2 to 1.4 kg. Culls are used for home consumption or sold at discount rates.

Table 38. Source of funding of intensive poultry operations and their relative importance (%) for farmers keeping poultry.

Sources of funding	Relative importance			
	Principal job	Secondary job	Female-run activity	Overall study
Personal funds only	31.2	42.5	45.5	41.5
Personal funding and "Djangui"	43.8	44.8	42.4	44.0
Personal funds and "Farmer's bank" like FONADER	12.5	9.1	9.	10.0
Personal funds and commercial banks	12.5	3.6	3.0	4.5

Source: Adapted from Djoukam and Téguia (1991).

Table 39. Places of sale for poultry products.

Places	Number of farmers	Proportion (%)
Farm-gate	10	13.9
Middle persons	27	37.5
Restaurants/shops/bakeries	18	25.0
Butchers	2	2.8
Market	15	20.8
Total	72	100

Source: Epo (1983).

Epo (1983) reported that most of the poultry products sales (37.5 %) were done by middle-persons (Table 39). Apparently, these economic intermediaries were thought to make most of the profits. However, recent evidence suggest that because of traffic frauds and also slow delivery services, those agents do not get it all. Consumers are the ones paying for extra charges incurred. Eggs bought at 40 FCFA a piece at farm gate sell at 45-55 FCFA each in urban markets.

(a) Market prices and type of products. Tables 40 shows prices of poultry and other meat sold in Bamenda. Locally produced day-old-chicks and hatchable eggs are sold at prices given in Table 41. Retailer prices are above farm gate prices by about 100-150 FCFA for one broiler and 5-10 FCFA for an egg (Table 42).

(b) Priority uses of farm revenue. In 50 % of the answers (Table 43), revenue was being re-invested into the poultry business. 42 % of respondents used money for family living, while investment in another business or other activities was listed by 5.6 % and 2.8 % of the respondents, respectively. This trend was consistent with farm types.

Table 40. Market prices FCFA/kg (carcass weight) of various meat sold at Bamenda/North West Province - Cameroon, before and six months after devaluation of FCFA.

Meat type	Before devaluation	After devaluation
Chicken	800	1,250
Pork	800	1,000
Beef	600	1,000
Rabbit	1,000	1,000
Egg (one)	40	50
Mutton	1,000	1,200
Goat	1,000	1,200
Fish:		
Mackerel	400	550
Barre	450	750

Table 41. Current market prices (FCFA) of day-old-chicks and hatchable eggs.

Institutions	Broiler		Layer		Breeds
	chicks	eggs	chicks	eggs	
ONDAPB-Kounden	340	nd	490	nd	Arco, Hybro
SPC/AGROCAM	350	180	640	nd	Lohmann
EPA	325	nd	700	nd	Arnak, Indian river
IRZV	250	50	500	50	Lohmann and crosses
SABEL	300	nd	nd	nd	nd
Monastery-Mbengwi	nd	nd	nd	100	Rhode Island Red
WAN Poultry-Bamenda	nd	nd	250	nd	Crosses

Note: nd - no data

Table 42. Farm-gate and market prices of poultry products in selected towns in March 1994.

Type of products	Yaounde		Douala		Bafoussam		Bamenda	
	Farm gate	Market	Farm gate	Market	Farm gate	Market	Farm gate	Market
Broiler chicken (FCFA/kg)	900	1,050	870	1,000	800	950	950	1,000
Spent hens (FCFA/kg)	700	,000	600	800	500	600	700	900
Table eggs (FCFA/egg)	38	50	35	40	30	35	35	41

(c) Cost-effectiveness of poultry farms. Vancoppenoble (1991) suggested that egg-type enterprise was uneconomical with a flock size below 500 hens/pullets while broiler operations were profitable with a flock of 500 chicks. IRZV (1990) showed that small scale intensive poultry units are profitable at 100 hens operation or 100 broilers operation after two, or one and a half years.

Broiler operations are more profitable than layer operations because of three factors: low investment cost on housing, day-old-chicks, quick turn over rate (4.5 times a year for broiler and only 0.7 times for layer). However, small scale broiler farmers tend to loose much of the profit and even part of their capital when marketing is not immediate. The presence of organized production and marketing systems will certainly make the business more cost effective. Table 44 shows estimated production costs before and after devaluation of the CFA francs. The key question is, can the poultry farmer survive?

Table 43. Priority uses of farm revenue according to farm type, in percentages of counts.

Farm type	Count	Use of farm revenue			
		Family living	Re-invest into same business	Use in another business	Others
Broiler	49	38.8	57.1	4.1	0
Layer	110	43.6	47.3	6.4	2.7
Mixed (broiler & layer)	21	42.9	42.9	4.7	9.5
Total	180	42.2	49.4	5.6	2.8

Source:Poné (1990)

(d) Sustainability of production. Farmers encountered some form of setbacks upon opening their operations. This happened when the farm activities were interrupted for at least once during the life span of the enterprise. Two third (67 %) of those farms which were closed at least once did so within the period of four years (Table 45). 36 % of farmers experienced such failure due mostly to inadequate funds and disease outbreaks. Marketing difficulties and lack of day-old-chicks contributed to setbacks for 11 % and 7 % of cases, respectively. Other reasons (11 % of all cases) were listed as quarantine measures, transition to build a separate poultry house out of living quarters, fire disaster, or investment into another business (Table 46).

Table 44. Distribution of production cost (FCFA) items for broiler operations before and six months after FCFA devaluation.

Items	After devaluation		Before devaluation			
	FCFA	% cost items	FCFA	% cost items[1]	FCFA	% cost items[2]
Number of chicks	2,000		2,000		8 000	
Mortality rate (%)	3.5	-	3.5	-	10.81	
Day-old-chicks	25.0	25.1	250	26.2	247	25.2
Feed & water	810	62.6	560	58.6	647	66.07
Medication	32	2.5	30	3.1	43	4.4
Sanitation	16	1.2	10	1.1	28	2.8
Labour	30	2.3	30	3.1	nd	nd
Brooding & energy	10	1.0[a]	10	1.1	7	0.73[b]
Housing depreciation	40	3.0	40	4.2	nd	nd
Other costs	30	2.3	25	2.6	7	0.74
Total	1,293	100	955	100	979	100
Liveweight price (FCFA/kg)	808	-	560	-	612	

Notes: nd: not determined. Source: 1. Poné (1992) in the MHAZ; 2. Batimba and Mewoand (1992) at Douala-Cameroon; a. Kerosene fuelled bush lamp; b. Stove using wood shavings and fire wood.

Inadequate funds (42.9 %) and disease outbreaks (28.6 %) ranked highest in broiler operations while the opposite was noticed in layer operations which had 47.8 % and 21.7 % of the cases, respectively. Marketing was a problem for broilers than for layer operations (14.3 % vs. 8.7 %). Inadequate funds contributed to about 50 % of drop out rates (Table 46). Bankruptcy is usually the results of many factors e.g. disease outbreaks, high mortalities and poor cash flow system. The fact that 36 % of the farms have been out of production at least once calls for further understanding of this situation.

Table 45. Time elapsed from creation to first shutdown of poultry farms, expressed as percentages of counts.

Farm type	Number of farms	Years in activity until shutdown occurred 1	2	3	4	>4
Broiler	11	0	27.3	18.1	27.3	27.3
Layer	22	13.6	18.2	18.2	9.1	40.9
Mixed (broiler & layer)	2	0	50.0	50.0	0	0
Total	35	18.5	23.1	18.0	2.8	33.3

Source: Adapted from Poné (1990).

Table 46. Proportion of poultry farms having interrupted their activities at least once and reasons attributed to that, expressed as percentages of counts.

Farm type	Interrupted at least once		Reasons for shutting down					
	Number of farms	Yes	Number of farms	Inadequate funds	Disease outbreak	Marketing	Lack of day -old-chicks	Other reasons
Broiler	32	34.4	14	42.9	28.6	14.3	0	14.3
Layer	55	36.4	23	21.7	47.8	8.7	8.7	13.
Mixed (broiler & layer)	10	20.0	2	100	0	0	0	
Dropped out farmers	3	100	6	50.0	16.7	16.7	16.7	
Total	100	36.0	45	35.5	35.6	11	6.7	11.

Source: Poné (1990)

3.2.7. Environmental constraints

It was assumed that rearing chickens in town or around city dwellings creates conflicts or complaints from neighbours. This was not the case as 96 % of the respondents rejected the hypothesis. On the other hand, 60 % of the poultry farms faced environmental constraints (Table 47) associated with one or combinations of problems such as cats eating chicks (25.6 %), theft (24.2 %), cat and theft cases combined (22.6 %), stray animals (9.7 %), theft and stray animals combined (9.7 %), cats and stray animals combined (6.4 %), and cats, theft, and stray animals combined (1.6 %).

3.2.7. The future of the modern sector

This sector like the traditional sector has developed very well without government interference. What needs to be done is for farmers to organize themselves so as to disentangle the bottlenecks in this business namely supply of chicks, feed, drugs, processing and marketing. The development of appropriate poultry ration technology for different groups of producers in accordance with their resources and constraints and objectives, which are related to the other agricultural and employment activities they are engaged in, is crucial to the the development of this sector. The project concept makes a major thrust into this area, which has been hitherto ignored by livestock planners.

Table 47. Environmental constraints reported as problems in surveyed areas.

Constraints	Count	Proportion (%)
(1) Cats eating chicks	16	25.8
(2) Theft cases	15	24.2
(3) Stray animals	6	9.7
(1) & (2)	14	22.6
(1) & (3)	4	6.4
(2) & (3)	6	9.7
(1), (2) & (3)		1.6
Total	62	100

Source: Poné (1990)

4.0. Conclusion

Poultry is the one protein source likely to supply the much needed meat at a cheaper price to satisfy the rapidly growing Cameroon population in general and specifically the urban population as well as revamp the rural economy. The short production cycle of the chicken, low investment and family developed technology and the fact that chicken meat unlike pork has no cultural barrier, makes this animal species worth re-evaluating in the Cameroon context.

A 'chicken policy' is required for efficient chicken production. The main objectives of the policy should be:

(a) ***To ensure adequate day-old-chicks***. Research institutions and the farmers are the principal actors in the development of adapted breeding stock as well as the establishment of guidelines on any imports of breeding stock into the country.

(b) ***To ensure efficient management of inputs***. Farmers should take the lead to organize themselves and the input-output supply of the poultry business needs. Government policy should liberalize all sales and purchases as well as effect measures against traffic fraud. Research results on standards of all goods is necessary.

(c) ***To establish efficient marketing systems***. Farmers should organize their marketing, although government policy on the protection of local production is very necessary. Research must supply information to keep production costs low.

(d) ***To establish an efficient management information system***. All actors in the business should establish an information circulation system for the benefit of all stakeholders as has been done for coffee production. A forum should be established for exchange of ideas at all levels of production.

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Appendix 16.4. Feed samples prepared in Mankon Research Station for use in NRI Phase 2 experiments.

Sample Number	Sample Preparation Date	NRI Phase 2 feeding Trial No/Date	Sample description	First on-station testing date[1]	First on-farm testing date
1.	Feb 1995	1/May 1995	Maize (local)	Mar 1995	Feb 1996
2.	Feb 1995	1/May 1995	Sweet potato TIB1 shreds	Mar 1995	-
3.	Feb 1995	1/May 1995	Sweet potato TIB2 shreds	Mar 1995	-
4.	Feb 1995	1/May 1995	Sweet potato 1112 shreds	Mar 1995	Feb 1996
5.	Feb 1995	1/May 1995	Cassava Red shreds	Mar 1995	-
6.	Feb 1995	1/May 1995	Cassava White (CASWht) shreds	Mar 1995	Feb 1996
7.	Mar 1995	2/Jul 1995	SPTIB1-5%PPS	-	-
8.	Mar 1995	2/Jul 1995	SPTIB1-10%PPS	-	-
9.	Mar 1995		SPTIB1-15%PPS	-	-
10.	Mar 1995	2/Jul 1995	SPTIB1-20%PPS	-	-
11.	Mar 1995	2/Jul 1995	SPTIB1-25%PPS		-
12.	Mar 1995	2/Jul 1995	CASWht-5%PPS	Oct 1995	Feb 1996
13.	Mar 1995	2/Jul 1995	CASWht-10%PPS	Oct 1995	Feb 1996
14.	Mar 1995		CASWht-15%PPS	Oct 1995	Feb 1996
15.	Mar 1995	2/Jul 1995	CASWht-20%PPS	Oct 1995	Feb 1996
16.	Mar 1995	2/Jul 1995	CASWht-25%PPS	Oct 1995	Feb 1996
17.	Mar 1995	3/Jul 1995	SPTIB1-5%WPK	Oct 1995	Feb 1996
18.	Mar 1995	3/Jul 1995	SPTIB1-10%WPK	Oct 1995	Feb 1996
19.	Mar 1995	3/Jul 1995	SPTIB1-15%WPK	Oct 1995	Feb 1996
20.	Mar 1995	3/Jul 1995	SPTIB1-20%WPK	Oct 1995	Feb 1996
21	Mar 1995	3/Jul 1995	SPTIB1-25%WPK	Oct 1995	Feb 1996

(continued next page)

Feed samples prepared in Mankon Research Station for use in NRI Phase 2 experiments.

22.	Jun 1995	-	SPTIB1-5%PKC	-	-
23.	Jun 1995	-	SPTIB1-10%PKC	-	-
24.	Jun 1995	-	SPTIB1-15%PKC	-	-
25.	Jun 1995	-	SPTIB1-20%PKC	-	-
26.	Jun 1995	-	SPTIB1-25%PKC	-	-
27.	Jun 1995	4/Oct 1995	CASWht-5%PKC	-	-
28.	Jun 1995	4/Oct 1995	CASWht-10%PKC	-	-
29.	Jun 1995	-	CASWht-15%PKC	-	-
30.	Jun 1995	4/Oct 1995	CASWht-20%PKC	-	-
31.	Jun 1995	4/Oct 1995	CASWht-25%PKC	-	-
32.	Jun 1995	4/Oct 1995	CASWht-5%WPK	Oct 1995	Feb 1996
33	Jun 1995	4/Oct 1995	CASWht-10%WPK	Oct 1995	Feb 1996
34.	Jun 1995	-	CASWht-15%WPK	Oct 1995	Feb 1996
35.	Jun 1995	4/Oct 1995	CASWht-20%WPK	Oct 1995	Feb 1996
36.	Jun 1995	4/Oct 1995	CASWht-25%WPK	Oct 1995	Feb 1996
37.	Sep 1995	5/Apr 1996	SP1112-fermented 24 hrs	-	-
38.	Sep 1995	5/Apr 1996	SP1112-fermented 48 hrs	Mar 1997	-
39.	Sep 1995	5/Apr 1996	SP1112-fermented 72 hrs	-	-
40.	Sep 1995	5/Apr 1996	CASWht-fermented 24 hrs	-	-
41.	Sep 1995	5/Apr 1996	CASWht-fermented 48 hrs	Mar 1997	-
42.	Sep 1995	5/Apr 1996	CASWht-fermented 72 hrs	NS	NS
43.	Sep 1995	6/Apr 1996	SP1112-25% SPLM	NS	NS
44.	Sep 1995	6/Apr 1996	SP1112-50% SPLM	NS	NS
45.	Sep 1995	6/Apr 1996	CASWht-25% CLM	Mar 1997	-
46.	Sep 1995	6/Apr 1996	CASWht-50% CLM	Mar 1997	-

Note: PPS palm pit sediment, PKC traditionally-processed palm kernel cake; WPK whole palm kernels; SPLM sweet potato leaf and vine meal; CLM cassava leaf meal. - broiler trials were not conducted on these samples. 1. The first time the feed mixture concept was tested in field feeding trials. - NS feed mixture rejected as 'not suitable'. Percentage incorporation rates refer to sun-dried material.

Appendix 16.5. Composition of feed samples from the project field site, on an as received basis (%).

	Dry matter	Moisture	Crude protein	Ether extract	Crude fibre	Ash	Calcium	Phos-phorus	Salt	Lysine	Methionine + cystine	AME (MJ/kg)	Price/kg (FCFA)	Format No
Roots and Tubers:														
Maize - (White)	93.65	6.35	7.64	4.35	1.75	1.19	0.01	0.25	0.01	0.31	0.66	13.98	157	1000
Sweet potato TIB1(SPTIB1)	96.67	3.33	3.98	1.07	2.63	3.06	0.11	0.12	0.02	0.20	0.17	12.03	106	1001
Sweet potato TIB2	93.86	6.14	5.07	0.79	2.58	3.28	0.01	0.11	0.01	0.26	0.26	11.69	106	1002
Sweet potato 1112 (SP1112)	93.15	6.85	4.54	0.39	2.55	2.95	0.07	0.08	0.02	0.22	0.25	11.69	106	1003/1150
Cassava root red	94.27	5.73	3.28	0.81	3.09	2.04	0.08	0.07	0.01	0.12	0.23	15.37	65	1004
Cassava root white (CASWht)	93.78	6.22	2.11	0.37	2.25	1.93	0.06	0.07	0.02	0.10	0.08	15.57	63	1005/1152
Feed mixtures:														
SPTIB1-5%Palm pit sediment (PPS)	89.55	10.45	4.32	2.24	2.07	2.87	0.11	0.14	0.14	0.22	0.23	11.47	105	1006
SPTIB1-10%PPS	89.68	10.32	4.39	4.16	2.06	2.82	0.10	0.13	0.13	0.21	0.22	11.81	105	1007
SPTIB1-15%PPS	90.19	9.81	4.21	5.86	2.33	2.71	0.10	0.12	0.12	0.19	0.25	12.20	105	1008
SPTIB1-20%PPS	89.62	10.38	4.39	7.75	2.20	2.70	0.11	0.12	0.13	0.22	0.26	12.45	104	1009
SPTIB1-25%PPS	89.65	10.35	4.43	9.49	2.06	2.72	0.10	0.12	0.12	0.19	0.25	12.78	104	1010
CASWht-5%PPS	89.47	10.53	2.10	0.94	2.46	1.87	0.07	0.09	0.05	0.10	0.10	14.93	62	1011
CASWht-10%PPS	89.39	10.61	2.19	1.90	2.32	1.88	0.08	0.06	0.02	0.11	0.11	14.98	62	1012
CASWht-15%PPS	89.6	10.4	2.24	3.86	1.84	1.90	0.07	0.06	0.03	0.11	0.12	15.09	62	1013
CASWht-20%PPS	89.61	10.39	2.40	5.47	2.13	1.95	0.06	0.06	[illegible]	0.12	0.12	15.16	61	1014
CASWht-25%PPS	89.7	10.3	2.44	7.10	2.21	2.06	0.07	0.06	0.03	0.13	0.14	15.25	61	1015
SPTIB1-5%Whole palm kernels (WPK)	87.77	12.23	4.38	2.83	1.99	2.80	0.09	0.13	0.13	0.17	0.25	11.11		1016
SPTIB1-10%WPK	88.15	11.85	4.69	4.70	2.15	2.74	0.10	0.14	0.13	0.19	0.22	11.33		1017
SPTIB1-15%WPK	87.78	12.22	4.92	6.36	2.29	2.72	0.10	0.15	0.13	0.19	0.22	11.47		1018
SPTIB1-20%WPK	87.21	12.79	5.13	7.57	2.49	2.70	0.10	0.16	0.13	0.20	0.24	11.57		1019
SPTIB1-25%WPK	88.53	11.47	5.50	10.13	2.71	2.59	0.10	0.15	0.13	0.22	0.23	11.92		1020

Composition of feed samples from the project field site in Cameroon, on an as received basis (%) - continued.

	Dry matter	Moisture	Crude protein	Ether extract	Crude fibre	Ash	Calcium	Phos-phorus	Salt	Lysine	Methionine + cystine	AME (MJ/kg)	Price/kg (FCFA)	Format No
Feed mixtures:														
SPTIB1-5%Palm kernel cake (PKC)	87.77	11.04	4.13	2.39	2.66	2.68	0.09	0.11	0.15	0.20	0.20	11.13		1021
SPTIB1-10%PKC	88.15	10.97	4.80	4.15	3.09	2.61	0.08	0.12	0.14	0.21	0.21	11.19		1022
SPTIB1-15%PKC	87.78	10.77	4.91	5.99	3.16	2.48	0.08	0.12	0.13	0.22	0.22	11.27		1023
SPTIB1-20%PKC	87.21	11.57	5.23	7.19	3.64	2.40	0.10	0.13	0.13	0.23	0.24	11.23		1024
SPTIB1-25%PKC	88.53	12.02	5.23	8.09	4.28	2.45	0.10	0.13	0.12	0.24	0.25	11.23		1025
CASWht-5%PKC	89.47	9.11	2.64	1.72	2.45	1.74	0.05	0.07	0.02	0.12	0.11	14.95		1026
CASWht-10%PKC	89.39	8.84	3.19	3.25	2.64	1.78	0.05	0.08	0.02	0.13	0.13	14.87		1027
CASWht-15%PKC	89.6	9.1	3.30	4.69	2.84	1.68	0.05	0.09	0.02	0.14	0.14	14.69		1028
CASWht-20%PKC	89.61	9.41	3.69	6.93	3.30	1.70	0.05	0.10	0.02	0.14	0.14	14.51		1029
CASWht-25%PKC	89.7	9.01	3.97	8.30	4.27	1.66	0.05	0.10	0.02	0.15	0.16	14.44		1030
CASWht-5%WKP	89.47	8.9	2.62	2.41	2.57	1.94	0.06	0.07	0.02	0.11	0.11	15.12		1031
CASWht-10%WKP	89.39	8.73	2.90	4.90	2.73	1.84	0.06	0.09	0.02	0.13	0.11	15.14		1032
CASWht-15%WPK	89.6	8.5	3.42	6.66	2.74	1.83	0.06	0.10	0.03	0.13	0.13	15.18		1033
CASWht-20%WPK	89.61	8.39	3.39	8.79	2.75	1.86	0.06	0.11	0.03	0.13	0.13	15.19		1034
CASWht-25%WPK	89.7	8.59	3.14	12.04	3.821	1.96	0.07	0.14	0.04	0.13	0.13	15.16		1035
SP1112-25% SP leaf meal	87.91	12.09	6.41	1.19	5.91	4.61	0.22	0.11	0.22	0.33	0.28	9.30	82	1042
SP1112-50% SP leaf meal	88.79	11.21	11.46	1.43	10.36	7.66	0.43	0.16	0.25	0.56	0.34	8.05	65	1043
CASWht-25% CAS leaf meal	86.63	13.37	7.94	1.07	4.81	2.50	0.24	0.09	0.02	0.47	0.35	12.31	48	1044
CASWht-50% CAS leaf meal	88.58	11.42	19.49	3.02	9.1	3.89	0.53	0.18	0.04	1.05	0.62	10.46	42	1045

Composition of feed samples from the project field site, on an as received basis (%) - continued

	Dry matter	Moisture	Crude protein	Ether extract	Crude fibre	Ash	Calcium	Phos-phorus	Salt	Lysine	Methionine + cystine	AME (MJ/kg)	Price/kg (FCFA)	Format No
Other local feeds (1994):														
Palm fruit fibre	89.93	10.07	6.83	23.14	25.68	8.78	0.40	0.06	0.01	-	-	9.89	0	1111
Infested maize (J.Ngwa)	92.41	7.59	9.95	3.07	3.04	1.64	0.01	0.30	0.01	0.34	0.58	12.01	0	1112
Wheat feed(Mbengwi)	90.59	9.41	16.80	4.13	5.74	4.03	0.08	0.78	0.01	0.63	0.90	9.56	0	1113
Roasted palm kernels	95.99	4.01	17.27	32.77	27.34	3.36	0.23	0.58	0.01	-	-	-	0	-
Fishmeal (MRS)	91.43	8.57	68.19	4.14	0.26	18.56	4.43	3.05	2.05	4.68	5.06	11.89	600	1114
Meat meal (Mbenbwi)	96.58	3.42	56.61	14.97	2.39	16.83	5.11	2.53	1.43	3.11	1.67	10.00	0	1115
Palm kernels (fruit boiled)	91.99	8.01	10.05	42.85	14.17	1.66	0.10	0.32	0	0.36	0.65	15.10	70	1118
Palm kernel cake (J.Ngwa)	91.21	8.79	13.50	27.89	15	1.97	0.16	0.38	0.01	0.57	1.04	12.33	70	1119
Dried brewers grains	92.5	7.5	21.09	1.63	14.87	6.95	0.37	0.62	0.23	0.60	1.10	9.94	0	1116
Palm pit sediment (direct pit)	80.91	19.09	5.97	40.78	6.85	12.82	0.92	0.06	0.07	0.30	0.43	17.51	6	1117
Blood meal	89.6	10.4	84.64	0.42	0.61	4.00	0.55	0.42	0.59	7.05	1.07	11.40	250	1100
Bone meal	99.4	0.6	2.30	0.13	0.10	96.93	30.52	12.58	0.08	0.28	0.15	0	75	1101
Bone meal - 1997	97.49	2.51	2.92	0.01	0.01	93.52	35.98	15.62	0.20	0.20	0.10	0	75	1104
Cottonseed cake	91.41	8.59	51.30	6.80	7.50	7.10	0.31	1.27	0.08	1.76	1.10	8.51	100	1102
Broken rice with chaff added	91.71	8.29	8.69	8.71	20.20	13.73	0.13	1.12	0.14	0.59	0.30	7.35	50	1099
Rice bran without chaff	91	9	12.70	13.70	11.60	11.62	0.07	1.54	0.10	0.65	0.37	11.50	75	1097
Oyster shell	99.73	0.27	0.80	0	0	97.69	34.01	0.26	0.35	0	0	0	80	1103
Palm Oil	100	0	0	100	0	0	0	0	0	0	0	33.45	550	1154
Palm kernel meal (commercial)	91.6	8.4	18.70	7.60	8.24	5.22	0.36	0.60	0.04	0.88	0.38	8.34	70	1121
Soyabean meal	90	10	44.10	1.40	7.02	6.48	0.27	0.61	0.13	2.78	1.29	9.27	400	1098
Lysine-Hcl	92.5	7.5	92.50	0	0	0	0	0	0	78.00	0	0	5000	503
Methionine	95	5	57.00	0	0	0	0	0	0	0	95.00	0	5000	504
Salt	97	3	0	0	0	97.00	0	0	97.00	0	0	0	165	502
Vitamin-mineral premix	95	5	0	0	0	61.75	0	0	0	0	0	0	23750	520
Ferrous sulphate	95	5	0	0	0	95.00	0	0	0	0	0	0	5300	

Composition of feed samples from the project field site, on an as received basis (%) - continued

	Dry matter	Moisture	Crude protein	Ether extract	Crude fibre	Ash	Calcium	Phos-phorus	Salt	Lysine	Methionine + cystine	AME (MJ/kg)	Price/kg (FCFA)	Format No
Solid-state fermented roots & tubers:														
SP1112 fermented 24 hrs	88.25	11.75	2.82	0.33	2.89	2.28	0.06	0.08	0.19	0.17	0.14	10.72	106	1036
SP1112 fermented 48 hrs	85.93	14.07	3.13	0.47	3.15	2.40	0.06	0.09	0.21	0.18	0.12	10.57	106	1037
SP1112 fermented 72 hrs	88.64	11.36	2.90	0.19	2.87	2.38	0.05	0.08	0.20	0.16	0.11	10.68	106	1038
CasWht fermented 24 hrs	86.4	13.6	2.35	0.29	2.94	1.98	0.08	0.06	0.02	0.14	0.10	14.08	62	1039
CasWht fermented 48 hrs	82.55	17.45	2.24	0.28	2.65	1.51	0.07	0.04	0.02	0.12	0.08	13.13	62	1040
CasWht fermented 72 hrs	80.37	19.63	1.96	0.44	2.53	1.74	0.07	0.05	0.02	0.10	0.08	12.05	62	1041
Means estimated from feed mixtures:														
Mean PPS	88.1	11.9	6.81	33.73	1.23	2.07	0.11	0.16	0.54	0.24	0.63	16.67	10	1048
Mean WPK*	90	10	10.35	43.12	3.09	1.97	0.11	0.31	0.07	0.27	0.39	14.87	20*	1049
Mean PKC	90.1	9.9	12.46	31.97	8.57	0.70	0	0.20	1.17	0.45	0.65	12.33	16	1050
Mean SP leaf meal	78.31	21.69	13.90	2.72	15.37	10.02	0.64	0.19	0.57	0.71	0.38	4.17	25	1046
Mean CAS leaf meal	74.28	25.72	26.61	3.77	12.31	4.49	0.76	0.20	0.03	1.52	0.98	5.22	25	1047
SP1112 fermented 48hrs	93.15	6.85	4.54	0.39	2.55	2.95	0.07	0.08	0.02	0.22	0.25	11.46	106	1151
CasWht fermented 48hrs	93.78	6.22	2.59	0.38	2.785	2.457	0.08	0.07	0.02	0.10	0.16	14.91	60	1153

* Note: retail price for third years feeding trials increased to 125 FCFA/kg. Format Raw material no in NRI's Feed Formulation software package.

Appendix 16.6. Composition of the diets in the variety evaluation and dried tuber and root shreds storage feeding trials on-station.

Table 1. Composition of the broiler starter diets (% unless otherwise stated).

	Control maize A	Sweet potato TIB1 B	Sweet potato 1112 C	Cassava White D	Cassava Red E	Sweet potato-TIB1-CSC/Fe F	Cassava White-CSC/Fe G	Sweet potato TIB1-CSC H
Fishmeal	8.99	10.00	10.00	5.97	6.13	2.43	6.65	2.42
Oyster shells	0.64	0.08	0	0	0	0.55	0.58	0.56
Bone meal	0	0.29	0.32	1.15	1.16	1.05	0.28	1.05
Blood meal	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50
Soyabean meal	16.98	16.11	18.17	32.49	31.83	0	0	0
Salt	0.23	0.21	0.21	0.23	0.23	0.29	0.25	0.29
Methionine	0.39	0.36	0.43	0.46	0.46	0.49	0.57	0.49
Palm oil	0	5.00	5.00	5.70	5.70	5.30	4.96	5.26
Palm kernel cake	5.00	11.77	13.07	0.39	1.94	0	0	0
Rice bran	1.89	0	0.17	0	0	0	0	0
Vitamin-mineral premix	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Cottonseed cake	0	0	0	0	0	25.00	25.00	25.00
Lysine	0.16	0.06	0.03	0	0	0.65	0.51	0.65
Maize	62.22	12.62	9.10	10.11	9.05	20.68	17.64	20.78
Cassava - Red	0	0	0	0	40.00	0	0	0
Cassava - White	0	0	0	40.00	0	0	40.00	0
Sweet potato TIB1	0	40.00	0	0	0	40.00	0	40.00
Sweet potato TIB2	0	0	0	0	0	0	0	0
Sweet potato 1112	0	0	40.00	0	0	0	0	0
Ferrous sulphate heptahydrate	0	0	0	0	0	0.06	0.06	0
Total	100	100	100	100	100	100	100	100

Notes: The composition of Fav'solforte premix (made by Velta Animal Health) for administration in water used in the on-station trials supplied (per kg of powder): vitamin A 20,000,000 IU; vitamin D3 - 5,000,000 IU; vitamin E - 10g; vitamin B1 - 2g; vitamin B2 - 4.6g; vitamin B6 - 2.5g; vitamin B12 - 0.025g; vitamin C - 25 g; nicotinamide - 25 g; vitamin K3 - 3g; biotin - 11 g; folic acid - 0.5g; calcium pantothenate - 7.5g; methionine - 10g; lysine - 5g; zinc sulphate - 15g; ferrous sulphate - 15g; manganese sulphate - 15g; sodium chloride - 15g; copper sulphate - 2g.

Table 2. Calculated analyses of the broiler starter diets (% unless otherwise stated). Cost excludes vit-min premix cost.

	Control maize A	Sweet potato TIB1 B	Sweet potato 1112 C	Cassava White D	Cassava Red E	Sweet potato TIB1-CSC/Fe F	Cassava White-CSC/Fe G	Sweet potato TIB1-CSC H
As intended:								
Crude protein	22.00	22.00	22.00	22.00	22.00	22.00	22.00	22.00
AME (MJ/kg)	12.25	12.25	12.25	12.25	12.25	12.25	12.25	12.25
Calcium	1.12	1.12	1.12	1.16	1.17	1.12	1.12	1.12
Phosphorus	0.60	0.60	0.60	0.60	0.60	0.65	0.65	0.65
Lysine	1.42	1.42	1.42	1.44	1.44	1.42	1.42	1.42
Methionine+cystine	1.08	1.08	1.08	1.08	1.08	1.08	1.08	1.08
Salt	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40
Cost (FCFA/kg)	245	237	243	259	258	215	207	211
As achieved:								
Crude protein	21.81	21.01	22.17	22.68	22.99	20.08	22.19	20.08
AME (MJ/kg)	12.21	12.27	12.16	12.45	12.31	12.26	12.42	12.26
Calcium	0.70	0.70	0.68	0.75	0.77	0.75	0.70	0.75
Phosphorus	0.60	0.60	0.60	0.59	0.60	0.63	0.64	0.63
Lysine	1.32	1.32	1.38	1.44	1.45	0.88	1.03	0.88
Methionine+cystine	1.51	1.28	1.39	1.32	1.34	1.10	1.36	1.10
Salt	0.46	0.46	0.46	0.41	0.41	0.38	0.43	0.38
Cost (FCFA/kg)	243	240	245	262	262	188	186	184

Table 3. Composition of the broiler finisher diets (% unless otherwise stated).

	Control maize A	Sweet potato TIB1 B	Sweet potato 1112 C	Cassava White D	Cassava Red E	Sweet potato TIB1-CSC/Fe F	Cassava White-CSC/Fe G	Sweet potato TIB1-CSC H
Fishmeal	7.23	9.99	10.00	9.76	10.00	0.77	2.51	0.41
Oyster shells	0	0.10	0	0	0.06	0.12	0.03	0.11
Bone meal	0.63	0	0.07	0.64	0.50	1.45	1.19	1.52
Blood meal	2.45	2.45	0.85	0	0.11	0.60	2.45	0.86
Soyabean meal	10.96	12.09	17.75	23.56	21.52	0	0	0
Salt	0.26	0.2	0.21	0.22	0.22	0.32	0.29	0.32
Methionine	0.14	0.07	0.11	0.03	0.05	0.09	0.21	0.10
Palm oil	1.50	7.00	6.95	6.20	7.00	7.15	7.11	7.15
Palm kernel cake	8.66	0	0.42	2.52	8.08	0	0	0
Rice bran	0.71	12.16	10.93	0	0	0	0	0
Vitamin-mineral premix	1.00	1.00	1.00	00	1.00	1.00	1.00	1.00
Cottonseed cake	0	0	0	0	0	25.00	25.00	25.00
Lysine	0.20	0	0	0	0	0.31	0.16	0.31
Maize	66.26	14.94	11.71	16.07	11.46	23.13	19.99	23.22
Cassava - Red	0	0	0	0	40.00	0	0	0
Cassava - White	0	0	0	40.00	0	0	40.00	0
Sweet potato TIB1	0	40.00	0	0	0	40.00	0	40.00
Sweet potato TIB2	0	0	0	0	0	0	0	0
Sweet potato 1112	0	0	40.00	0	0	0	0	0
Ferrous sulphate heptahydrate	0	0	0	0	0	0.06	0.06	0
Total	100	100	100	100	100	100	100	100

Table 4. Calculated analyses of broiler finisher diets (% unless otherwise stated). Cost excludes vit-min premix cost.

	Control maize A	Sweet potato TIB1 B	Sweet potato 1112 C	Cassava White D	Cassava Red E	Sweet potato-TIB1-CSC/Fe F	Cassava White-CSC/Fe G	Sweet potato TIB1-CSC H
***As intended*:**								
Crude protein	19.00	19.00	19.00	19.00	19.00	19.00	19.00	19.00
AME (MJ/kg)	12.75	12.75	12.75	12.75	12.75	12.75	12.75	12.75
Calcium	1.00	1.00	1.0	1.17	1.17	1.00	1.00	1.00
Phosphorus	0.61	0.61	0.61	0.61	0.60	0.65	0.65	0.65
Lysine	1.23	1.23	1.23	1.23	1.23	0.95	0.95	0.95
Methionine+cystine	0.75	0.75	0.75	0.65	0.65	0.65	0.65	0.65
Salt	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40
Cost (FCFA/kg)	218	216	231	227	225	178	166	174
***As achieved*:**								
Crude protein	18.67	18.05	19.17	19.81	20.14	17.30	19.32	17.29
AME (MJ/kg)	12.70	12.78	12.66	12.94	12.81	12.78	12.95	12.78
Calcium	0.59	0.58	0.56	0.73	0.74	0.64	0.61	0.65
Phosphorus	0.61	0.61	0.61	0.60	0.60	0.63	0.63	0.63
Lysine	1.10	1.18	1.21	1.23	1.23	0.68	0.84	0.68
Methionine+cystine	1.14	0.96	1.06	1.01	1.03	0.63	0.83	0.63
Salt	0.44	0.46	0.46	0.45	0.46	0.36	0.38	0.36
Cost (FCFA/kg)	213	221	235	231	229	168	162	165

Table 5. Composition of the layer diets (% unless otherwise stated).

	Control maize A	Sweet potato TIB1 B	Sweet potato TIB2 C	Sweet potato 1112 D	Cassava White E	Cassava Red F	Cassava White - CSMFe G
Fishmeal	2.19	6.00	6.50	6.50	6.50	6.50	2.94
Oyster shells	6.63	6.06	5.98	5.97	5.96	5.92	6.23
Bone meal	1.97	1.89	1.78	1.83	1.83	1.90	2.09
Blood meal	0.62	0.26	0	0	0.62	0.55	0
Soyabean meal	18.00	16.55	17.97	18.39	23.73	23.82	0
Salt	0.29	0.23	0.23	0.23	0.22	0.22	0.27
Methionine	0.23	0.14	0.18	0.21	0.26	0.26	0.39
Palm oil	0	3.50	3.65	3.65	4.50	4.20	6.25
Palm kernel cake	5.08	1.83	0.80	4.94	0	0.11	0
Rice bran	0	0	0	0	0	0	0
Vitamin- mineral premix	1.00	1.00	00	.00	1.00	1.00	1.00
Cottonseed cake	0	0	0	0	0	0	25.00
Lysine	0.16	0	0	0	0	0	0.42
Maize	63.83	12.54	11.91	7.28	5.38	5.52	4.89
Cassava - Red	0	0	0	0	0	50.00	0
Cassava - White	0	0	0	0	50.00	0	50.27
Sweet potato TIB1	0	50.00	0	0	0	0	0
Sweet potato TIB2	0	0	50.00	0	0	0	0
Sweet potato 1112	0	0	0	50.00	0	0	0
Ferrous sulphate heptahydrate	0	0	0	0	0	0	0.25
Total	100	100	100	100	100	100	100

Table 6. Calculated analyses of the layer diets (% unless otherwise stated). Cost excludes vit-min premix cost.

	Control maize A	Sweet potato TIB1 B	Sweet potato TIB2 C	Sweet potato 1112 D	Cassava White E	Cassava Red F	Cassava White-CSMFe G
***As intended*:**							
Crude protein	16.50	16.50	16.50	16.50	16.50	16.50	16.50
AME (MJ/kg)	11.40	11.40	11.40	11.40	11.40	11.40	11.40
Calcium	3.40	3.40	3.40	3.40	3.40	3.40	3.40
Phosphorus	0.65	0.65	0.65	0.65	0.65	0.65	0.75
Lysine	0.98	0.98	0.98	1.01	1.09	1.08	0.98
Methionine+cystine	0.76	0.76	0.76	0.76	0.76	0.76	0.76
Salt	0.40	0.40	0.40	0.40	0.40	0.40	0.40
Cost (FCFA/kg)	211	201	201	208	210	211	180
***As achieved*:**							
Crude protein	16.01	15.07	16.14	16.50	17.37	17.72	16.82
AME (MJ/kg)	11.36	11.44	11.44	11.30	11.64	11.48	11.63
Calcium	3.02	3.01	2.96	2.98	2.98	2.99	3.00
Phosphorus	0.64	0.64	0.64	0.65	0.64	0.65	0.73
Lysine	0.89	0.92	0.98	1.00	1.08	1.09	0.65
Methionine+cystine	1.01	0.83	0.95	0.96	1.01	1.04	0.91
Salt	0.39	0.40	0.41	0.42	0.41	0.41	0.38
Cost (FCFA/kg)	209	208	214	213	213	215	162

Appendix 16.7. Data required for evaluating the processing characteristics of tubers and roots when considering their development into poultry feeds in different agro-climatic zones.

TRS[1] Plate combination or other process used	Throughput time for 100 kg of fresh	Drying time (hrs[2])	Particle size (Mean+sd) (mm*mm)	Ease of crumbing in hand (score 0-5) tuber	Clumpiness after drying (score 0-5)	Dustiness after grinding through 3 mm screen	Potential for direct feeding to layers (score 0-5)	Estimated cost of processing 1 kg of dry tuber (FCFA)	Other comments on feed texture
Sweet potato variety:									
A									
B									
C									
D									
E									
Cassava variety:									
A									
B									
C									
D									
E									

Note:s 1. Dito Sama Crypto Peerless Food Processor. 2. Time taken to dry to below 10% moisture. Detailed notes on temperature variation during the day while the chips are drying, spreading density (eg 4 kg of fresh material/sq m); if it takes longer than a day, was it brought and spread indoors. (Lack of time precluded these studies but it is shown here for guidance if the technology is considered elsewhere).

Appendix 16.8. Advice given to Test Farmer 'Male B' following the first on-farm trials to assist the development of small-scale commercial sweet potato tuber and cassava root-based poultry rations in the project area.

To
Mr Wilfred Fai
ETS FAI WILFRED M.
P.O. Box 337
BAMENDA
NORTH WEST PROVINCE
CAMEROON

21 January 1997

Dear Mr Fai

ENQUIRY ON ROOT-CROPS-BASED RATIONS FOR POULTRY AND PIGS

1. I apologise for this long delay in replying to your letter. The reason was that we were still completing our analysis of experimental results from the feeding trials conducted at Mankon, and I did not wish to provide you with ration formulae before we were satisfied with the data obtained.

2. Please find herewith some tentative broiler, and laying hen diets. I say 'tentative' for two reasons. Firstly, I have had to guess at the prices of feeds. Please, therefore, complete Table 1 with up-to-date prices of all the raw materials on the list, and of others available to you that I may have missed. Secondly, and perhaps more importantly, you will appreciate that giving the rations is not the end of the matter. We need to work together for at least a year or more to develop the rations that will meet with your objectives and constraints over the whole year. Due to the natural variability in the quality, nutrient composition and prices of feeds in different seasons, the best way forward is for me to suggest some rations to begin with. You may produce these and try them out with some small-scale poultry producers, keeping a good record of the performance of chickens in terms of feed consumption and weight gain of broilers and feed consumption and egg production of layers. If you then let me have the results together with your comments on how good (or bad!) the rations proved to be and what you would like to see included in or excluded from it (depending on availability of various feeds), I will modify the rations to improve them. This is what large feed manufacturers do to retain the confidence of their customers.

3. I have also given the calculated chemical composition of the diets for your information. However, these are guesstimates based on my previous experience in the region. Ideally, we need to analyse all the raw materials that you will use, but this is impractical and we do not have the funds for such a thorough approach. This should also point out a limitation of providing you rations from the UK. Nevertheless, if we work together we should develop good rations in the longer term.

4. Please take particular note of the prices that I have used to calculate the rations. It is especially important to point out that I have assumed that a vitamin and mineral package will be given to chickens in the water supply in accordance with standard practices in the region (please check with your customers). If on the other hand you add vitamins and mineral to the ration at a fixed rate, the composition of the ration will change in proportion (please advise on your requirements).

5. I have given you some options with each of the rations so that you may appreciate what is possible and how the cost changes with different alternatives. You will have to decide from poultry production records whether a particular option is worth your while pursuing (for example, the palm pit sediment option). If you would like particular raw materials to be included that is not already in the ration, please let me know their prices and the quantities available in different seasons.

6. For cassava root and sweet potato tuber you need to have these grated (as in garri, but with slightly larger particles) and then sun-dried. The chickens will prefer to eat small particles rather than ground meals. However, if grating is not possible, chipping and sun-drying within a day to below 12 per cent moisture, followed by grinding is a good alternative. If palm pit sediment from traditional pits is available, these should be added to the dried cassava grits or chips and sun-dried to below 12 per cent moisture. Palm pit sediment will be especially useful for broiler diets. However, it may be too much trouble for you (?), being labour-intensive. You will also need to provide me with a price that includes the cost of preparing it.

7. For broilers, I would strongly recommend that you suggest to small-scale poultry producers that it is a waste of time using starter and finisher feeds. The broiler rations I have given have been specially formulated to yield equally good production. Having two diets does nothing major for production overall, but increases the cost of producing the ration, and therefore, the price charged to the customer.

8. For egg production, a particular concern may be egg yolk quality. If the acceptability of yolk colour is poor, the ration will have to be suitably modified using a natural pigment source, such as cassava leaf meal. You will need to follow this up with an egg producer initially and find out what the customers of eggs say about egg quality. I will then advise on how a cheap pigment source may be added to the ration.

9. Please take particular note that the rations suggested are very specific in the ingredients they contain. The rations are designed such that you cannot leave out any ingredient or add more or less of it. They may appear similar but even slight changes to the 'wrong' ingredient could markedly affect the nutrient content and result in poor chicken production. If you have sudden problems in the availability of a particular feed, you must move on to a different formulae altogether. This is another reason that we need to work together. Please write to me about the problems of availability you face from time to time so that I may suggest alternative formulae for different bird types in these situations.

10. ***Palm oil sludge***. You should be able to make substantial savings on production cost if you obtain palm oil sludge, the waste from purification in commercial palm oil production. Like palm pit sediment, it is best to dry the sludge on to dried cassava or sweet potato meals in the proportions given by a ration. The sludge must be fresh and must not have been lying around for more than a week when you come to mixing the rations. The rations with palm pit sludge as an ingredient must also be sold off within 2 weeks, and farmers purchasing it must use it up within 2 months. If you wish to follow this option and produce rations that include palm oil sludge please let me have details of how it is produced in the factory, the quantities available to you and, of course, the price (in Table 1).

11. You may find some of the rations have too many ingredients but this is unavoidable if you wish to reduce the cost (done by avoiding high-cost maize). I have not yet formulated the pig grower diet that you requested, but will do so after you have examined the poultry rations and given me your comments on them and the up-to-date feed prices.

12. ***Quality of feed ingredients***. I should also point out that while these rations may appear cheap compared with commercial rations, you need to pay attention to the quality of several of the raw materials that you are buying. You need to be more careful than the large-scale animal feed compounder because your raw materials are what we describe as 'unconventional'. I have marked the ones on which you need to pay most attention in the Tables. For these ingredients, you will need to monitor the production process from time to time. For the blood meal you will need to inform the producer that the temperature at which blood is boiled is not allowed to rise very high. The oyster shells must be the 'burned' type from Limbe. Use of brewer's spent grains could save a great deal of money but the material has to be collected fast off the production process, drained quickly, and dried within 3-4 days. You should then get excellent results. I would even suggest that you need to employ someone to make trips to the brewery for this material on a regular basis and dry it for you.

13. *Mixing feeds*. It is essential to get a very good blend when preparing poultry feeds. An attempt should be made to obtain a homogenous mixture even if very basic 'bucket' or 'floor & shovel' methods of mixing are employed. This can be achieved by adopting a step-by-step approach. Ingredients that are included in the ration in the smallest quantity (e.g. blood meal, fishmeal, bone meal, oyster shells, salt, etc.) must first be accurately weighed (a sensitive weighing balance is needed by a small-scale manufacturer of animal feeds!) and hand-mixed in a bucket, ensuring that there is no loss by wind blowing any feed particles away. Other ingredients should then be added to this (e.g. palm oil) and the blending continued. This mixture should then be transferred to a larger drum, or better still, a cement mixer if this is available. The mixture is therefore bulked-up gradually. The largest ingredient (cassava root, or sweet potato tuber) should be added last of all, and it is at this stage that floor mixing may be employed. Absence of colour patches or streaks in the mixture is used at each stage as a guide to how well the ration is being blended. In this regard, the white colour of cassava root or sweet potato tuber is particularly helpful.

14. Another important hint is to avoid the temptation to make a single very large batch of a ration that you hope will last for 3 months or longer, particularly when there are ingredients such as palm pit sediment, palm oil sludge and palm oil. I would suggest mixing small quantities every 3-4 weeks using fresh feeds as these are procured. This may increase your production cost because of extra labour requirements, but the customers of feeds will be more satisfied with the poultry production that results. Smaller quantities are also easier to blend. The minimum batch size will depend on the weighing balances you have. If you have an electronic 2 kg balance, you may mix small batches of 25 kg on a regular basis with very good poultry production results.

15. If you decide to follow my recommendations, I would be grateful if you would let me know the prices at which you start selling each of the ration and how this price changes with time as you begin to get the reactions of the poultry producers buying the feeds. A record of the prices charged will give me clues on how the different rations may be modified in the longer term, if you continue to seek NRI's advice in this matter.

16. I hope the information provided here is useful. I look forward to your reply as soon as possible. I am keen to know of your plans for developing the small-scale animal feed production and sale, as I believe that small-scale animal feed enterprises could play an important role in agricultural development in a way that will assist local small-scale, resource poor farmers.

Yours sincerely

Dr S. Panigrahi
Natural Resources Management Department

Table 1. Prices of animal feeds for a small-scale animal feed retailer in Cameroon [Mr Wilfred Fai, Box 337, Bamenda, North West Province, Cameroon] - Mr Fai to fill the Chart with up-to-date prices of feeds.

	Mid-dry season		Mid-wet season	
	Wholesale (FCFA/kg)	**Retail (FCFA/kg)**	**Wholesale (FCFA/kg)**	**Retail (FCFA/kg)**
***Feed raw materials*:**				
Sweet potato tuber, chipped, dried & ground	75	85		
Cassava roots, chipped, dried & ground	55	65		
Maize	110	120		
Fishmeal (good quality)	500	600		
Soyabean meal	340	360		
Cottonseed meal	72	86		
Palm kernel meal	30	50		
Blood meal	250	400		
Palm oil	400	500		
Wheat bran	50	60		
Rice bran with chaff	36	50		
Rice bran without chaff	60	80		
Brewer's dried grains[1]	35	50		
Bone meal	40	50		
Oyster shells (Limbe burned)	50	80		
Palm pit sediment (good quality)[2]	10	20		
Cassava leaf meal (good quality)	25	40		
Salt	30	40		
Palm oil sludge[3]				
Vitamin mineral premix				
Commercial rations (without premix):				
Broiler starter ration				
Broiler finisher ration				
Layer chick starter				
Layer chick grower ration				
Laying hen ration				
Pig grower ration				

***Notes*:** 1. All procurement costs (including for processing and transporting feeds) costs must be included in the wholesale prices.

1. This must be collected and dried very quickly after it is released by the brewery.
2. Mix wet palm pit sediment with sun-dried cassava root (or sweet potato) grits or chips as follows: (i) Determine the approximate dry matter (DM) content of a sample of drained PPS. (ii) Assuming a dry matter content for sun-dried cassava of 90 per cent, calculate the weights of drained palm pit sediment and sun-dried cassava to obtain the ratio in the ration as fed. (iii) Prepare the necessary quantity of the wet palm pit sediment-cassava mixture and sun-dry to below 12 per cent moisture content. (iv). Grind the dried palm pit sediment-cassava mixture, if necessary.
3. This must be freshly produced. It is best to dry it on to cassava root or sweet potato tuber meals in the proportions given for a ration.

Table 2. Cassava root-based broiler rations for a small-scale animal feed manufacturer in Bamenda (diets to be fed from 0-8 weeks).

Ingredients (kg):	*Fai Broiler A (0-8 weeks)*	*Fai Broiler B (0-8 weeks)*	*Fai Broiler C (0-8 weeks)*	*Fai Broiler D (0-8 weeks)*
Ingredients (kg):				
Salt	0.127	0.152	0.135	0.144
Palm pit sediment[1,2]	5.000	5.000	-	-
Rice bran - no chaff	-	0.432	12.212	10.916
Soyabean meal	10.704	14.560	9.260	10.350
Blood meal[2]	2.000	2.000	2.000	2.000
Bone meal	0.768	1.132	-	-
Cottonseed meal	10.000	10.000	11.000	11.000
Oyster shells[2]	1.135	1.092	1.838	1.936
Fishmeal[2]	9.615	7.281	10.074	9.179
[illegible]	10.946	-	3.481	-
[illegible]	-	10.000	-	4.475
[illegible]	49.705	48.351	50.000	50.000
[illegible]	(in water)	(in water)	(in water)	(in water)
[illegible]	100	100	100	100
[illegible]	128.6	129.9	131.5	130.6
Analyses (% calculated):				
Crude protein	21.80	22.00	21.80	21.80
[illegible]	1.20	1.20	1.20	1.20
[illegible]	0.70	0.70	0.76	0.73
[illegible]	0.40	0.40	0.40	0.40
Metabolisable energy (MJ/kg)	12.70	12.70	12.70	12.70
Lysine	1.22	1.19	1.22	1.20
Methionine+cystine	0.91	0.91	0.91	0.91

Notes: 1. Mix wet palm pit sediment with sun-dried cassava root grits or chips as follows: (i) Determine the approximate dry matter (DM) content of a sample of drained PPS. (ii) Assuming a dry matter content for sun-dried cassava of 90 per cent, calculate the weights of drained palm pit sediment and sun-dried cassava to obtain the ratio in the ration as fed (e.g. 5 kg: 49.70 5 kg for Broiler Diet A). (iii) Prepare the necessary quantity of the wet palm pit sediment-cassava mixture and sun-dry to below 12 per cent moisture content. (iv). Grind the dried palm pit sediment-cassava mixture (if necessary) for blending in the ration.

2. These must be good quality feeds.

3. This must be collected and dried very quickly after it is released by the brewery.

4. Chipped (or gritted), sun-dried, and ground if necessary.

5. It is assumed that the required vitamins and minerals will be provided in the drinking water.

6. Least-cost diet formulations on the basis of wholesale prices in Table 1.

Table 3. Cassava root-based layer chick starter (to be fed from 0-8 weeks) and grower (to be fed from 8-16 weeks) rations for a small-scale animal feed manufacturer in Bamenda.

	Fai Layer Chick Starter (0-8 weeks) A	*Fai Layer Chick Starter (0-8 weeks) B*	*Fai Layer Chick Grower (8-16 weeks) A*	*Fai Layer Chick Grower (8-16 weeks) B*
Ingredients (kg):				
Salt	0.251	0.257	0.298	0.257
Palm pit sediment	5.000	-	4.261	-
Rice bran - no chaff	15.000	15.000	19.379	19.944
Soyabean meal	4.347	3.186	-	-
Blood meal[2]	2.000	2.000	0.786	0.448
Bone meal	0.786	0.621	0.701	-
	7.000	7.000	7.000	7.000
	1.696	1.721	2.000	2.560
	4.311	5.365	2.549	3.161
	15.000	15.000	20.000	20.000
	15.000	15.000	15.000	15.000
	29.609	34.850	28.026	31.630
	(in water)	(in water)	(in water)	(in water)
	100	100	100	100
Cost per kg (FCFA)[6]	83.1	86.8	59.8	63.9
Analyses (% calculated):				
Crude protein	19.15	19.15	16.41	16.40
	1.20	1.20	1.20	1.20
	0.80	0.80	0.80	0.73
	0.45	0.45	0.45	0.40
Metabolisable energy (MJ/kg)	11.65	11.65	11.45	11.40
Lysine	0.95	0.96	0.73	0.73
Methionine+cystine	0.73	0.75	0.60	0.61

Notes: 1. Mix wet palm pit sediment with sun-dried cassava root grits or chips as follows: (i) Determine the approximate dry matter (DM) content of a sample of drained PPS. (ii) Assuming a dry matter content for sun-dried cassava of 90 per cent, calculate the weights of drained palm pit sediment and sun-dried cassava to obtain the ratio in the ration as fed (e.g. 5 kg: 29.609 kg for Chick Diet A). (iii) Prepare the necessary quantity of the wet palm pit sediment-cassava mixture, and sun-dry to below 12 per cent moisture. (iv). Grind the dried palm pit sediment-cassava mixture (if necessary) for blending in the ration.
2. These must be good quality feeds.
3. This must be collected and dried very quickly after it is released by the brewery.
4. Chipped (or gritted), sun-dried, and ground if necessary.
5. It is assumed that the required vitamins and minerals will be provided in the drinking water.
6. Least-cost diet formulations on the basis of wholesale prices in Table 1.

Table 4. Cassava root-based laying hen rations for a small-scale animal feed manufacturer in Bamenda (diets to be fed from 16 weeks to the end of laying period).

	Fai Laying hen (16 weeks-) A	*Fai Laying hen (16 weeks-) B*	*Fai Laying hen (16 weeks-) C*	*Fai Laying hen (16 weeks-) D*
***Ingredients (kg)*:**				
Salt	0.187	0.156	0.200	0.171
Palm pit sediment[1]	5.000	5.000	-	-
Rice bran - no chaff	0.709	-	-	1.975
Soyabean meal	13.727	9.908	13.932	10.560
Bone meal	1.811	1.347	1.803	1.157
Cottonseed meal	7.000	7.000	7.000	7.000
Oyster shells[2]	9.108	9.150	9.323	9.593
Fishmeal[2]	4.448	7.572	5.277	7.980
[illegible] meal	-	14.789	-	11.564
[illegible]	15.000	-	13.151	-
[illegible]	43.010	45.077	49.314	50.000
[illegible]	(in water)	(in water)	(in water)	(in water)
[illegible]	100	100	100	100
[illegible]	109.1	111.4	115.9	118.3
***Analyses (% calculated)*:**				
Crude protein	17.50	17.50	17.50	17.50
Calcium	4.00	4.00	4.10	4.10
Phosphorus	0.70	0.70	0.70	0.70
Salt	0.40	0.40	0.40	0.40
Metabolisable energy (MJ/kg)	11.50	11.50	11.50	11.50
Lysine	0.87	0.94	0.89	0.96
Methionine+cystine	0.75	0.75	0.75	0.75

Notes: 1. Mix wet palm pit sediment with sun-dried cassava root grits or chips as follows: (i) Determine the approximate dry matter (DM) content of a sample of drained PPS. (ii) Assuming a dry matter content for sun-dried cassava of 90 per cent, calculate the weights of drained palm pit sediment and sun-dried cassava to obtain the ratio in the ration as fed (e.g. 5 kg: 43.01 kg for Layer Diet A). (iii) Prepare the necessary quantity of the wet palm pit sediment-cassava root mixture and sun-dry to below 12 per cent moisture content. (iv). Grind the dried palm pit sediment-cassava mixture (if necessary) for blending in the ration.
2. These must be good quality feeds.
3. This must be collected and dried very quickly after it is released by the brewery.
4. Chipped (or gritted), sun-dried, and ground if necessary.
5. It is assumed that the required vitamins and minerals will be provided in the drinking water.
6. Least-cost diet formulations on the basis of wholesale prices in Table 1.

Table 5. Sweet potato tuber-based broiler rations for a small-scale animal feed manufacturer in Bamenda (diets to be fed from 0-8 weeks).

Ingredients (kg):	*Fai Broiler A (0-8 weeks)*	*Fai Broiler B (0-8 weeks)*	*Fai Broiler C (0-8 weeks)*	*Fai Broiler D (0-8 weeks)*
Ingredients (kg):				
Salt	0.151	0.142	0.165	0.158
Palm pit sediment[1,2]	5.000	5.000	-	-
Rice bran - no chaff	-	-	0.426	1.211
Soyabean meal	12.807	11.732	12.579	11.832
Blood meal[2]	2.000	2.000	2.000	2.000
Bone meal	1.219	1.071	1.090	0.915
Cottonseed meal	11.000	11.000	11.000	11.000
Oyster shells[2]	0.986	1.015	1.021	1.112
Fishmeal[2]	8.047	8.922	8.819	9.410
Palm kernel meal	-	4.048	-	2.362
Brewer's dried grains[3]	4.215	-	2.900	-
Sweet potato tuber[4]	40.000	40.000	40.000	40.000
	9.575	10.070	15.000	15.000
	5.000	5.000	5.000	5.000
	(in water)	(in water)	(in water)	(in water)
	100	100	100	100
***Cost per kg (FCFA)*[6]**	154.9	155.6	160.2	160.8
Analyses (% calculated):				
Crude protein	21.80	21.80	21.80	21.80
Calcium	1.20	1.20	1.20	1.20
	0.70	0.70	0.70	0.70
	0.40	0.40	0.40	0.40
Metabolisable energy (MJ/kg)	12.40	12.40	12.40	12.40
Lysine	1.21	1.23	1.22	1.24
Methionine+cystine	0.91	0.91	0.91	0.91

Notes: 1. Mix wet palm pit sediment with sun-dried sweet potato tuber grits or chips as follows: (i) Determine the approximate dry matter (DM) content of a sample of drained PPS. (ii) Assuming a dry matter content for sun-dried sweet potato of 90 per cent, calculate the weights of drained palm pit sediment and sun-dried sweet potato tuber to obtain the ratio in the ration as fed (e.g. 5 kg: 40 kg for Broiler Diet A). (iii) Prepare the necessary quantity of the wet palm pit sediment-sweet potato tuber mixture and sun-dry to below 12 per cent moisture content. (iv). Grind the dried palm pit sediment-sweet potato tuber mixture (if necessary) for blending in the ration.

2. These must be good quality feeds.
3. This must be collected and dried very quickly after it is released by the brewery.
4. Chipped (or gritted), sun-dried, and ground if necessary.
5. It is assumed that the required vitamins and minerals will be provided in the drinking water.
6. Least-cost diet formulations on the basis of wholesale prices in Table 1.

Table 6. Sweet potato tuber-based layer chick starter (to be fed from 0-8 weeks) rations for a small-scale animal feed manufacturer in Bamenda.

	Fai Layer Chick Starter (0-8 weeks) A	*Fai Layer Chick Starter (0-8 weeks) B*	*Fai Layer Chick Starter (0-8 weeks) C*	*Fai Layer Chick Starter (0-8 weeks)) D*
***Ingredients (kg)*:**				
Salt	0.203	0.191	0.176	0.202
Palm pit sediment[1]	5.000	5.000	-	-
Rice bran - no chaff	-	-	-	-
	10.923	12.293	2.691	10.342
	2.000	0.095	2.000	0.053
	1.967	1.442	1.216	1.231
	7.000	7.000	7.000	7.000
Oyster shells[2]	0.697	0.870	0.972	0.945
Fishmeal[2]	4.455	7.108	7.272	7.938
Palm kernel meal	-	15.016	10.193	18.296
	16.955	-	18.000	-
	40.000	40.000	40.000	40.000
	8.800	7.985	6.480	9.993
	2.000	3.000	4.000	4.000
	(in water)	(in water)	(in water)	(in water)
	100	100	100	100
Cost per kg (FCFA)[6]	119.9	135.0	115.5	138.0
***Analyses (% calculated)*:**				
Crude protein	19.15	19.15	19.15	19.14
	1.20	1.20	1.20	1.20
	0.70	0.70	0.70	0.70
	0.40	0.40	0.40	0.40
Metabolisable energy (MJ/kg)	11.60	11.60	11.60	11.60
Lysine	0.99	1.05	0.98	1.05
Methionine+cystine	0.80	0.80	0.85	0.80

Notes: 1. Mix wet palm pit sediment with sun-dried sweet potato tuber grits or chips as follows: (i) Determine the approximate dry matter (DM) content of a sample of drained PPS. (ii) Assuming a dry matter content for sun-dried sweet potato tuber of 90 per cent, calculate the weights of drained palm pit sediment and sun-dried sweet potato tuber to obtain the ratio in the ration as fed (e.g. 5 kg: 40 kg for Chick Diet A). (iii) Prepare the necessary quantity of the wet palm pit sediment-sweet potato tuber mixture, and sun-dry to below 12 per cent moisture. (iv). Grind the dried palm pit sediment-sweet potato tuber mixture (if necessary) for blending in the ration.

2. These must be good quality feeds.
3. This must be collected and dried very quickly after it is released by the brewery.
4. Chipped (or gritted), sun-dried, and ground if necessary.
5. It is assumed that the required vitamins and minerals will be provided in the drinking water.
6. Least-cost diet formulations on the basis of wholesale prices in Table 1.

Table 7. Sweet potato tuber-based layer chick grower (to be fed from 8-16 weeks) rations for a small-scale animal feed manufacturer in Bamenda.

	Fai Layer Chick Grower (8-16 weeks) A	*Fai Layer Chick Grower (8-16 weeks) B*	*Fai Layer Chick Grower (8-16 weeks) C*	*Fai Layer Chick Grower (8-16 weeks) D*
Ingredients (kg):				
Salt	0.214	0.207	0.223	0.226
Palm pit sediment[1]	5.000	5.000	-	-
Rice bran - no chaff	4.245	17.338	16.836	11.253
Blood meal[2]	2.000	2.000	2.000	2.000
Bone meal	1.370	0.407	0.163	0.839
Cottonseed meal	7.000	7.000	7.000	7.000
Oyster shells[2]	1.067	2.239	2.182	1.687
Fishmeal[2]	5.813	3.504	6.142	4.786
Palm kernel meal	23.291	-	15.454	7.209
Brewer's dried grains[3]	-	21.397	-	15.000
Sweet potato tuber[4]	30.000	30.000	30.000	30.000
Cassava root	20.000	10.908	20.000	20.000
Palm oil	-	-	-	-
	(in water)	(in water)	(in water)	(in water)
	100	100	100	100
Cost per kg (FCFA)[6]	83.7	75.8	90.2	82.8
Analyses (% calculated):				
Crude protein	16.40	16.40	16.40	16.40
	1.20	1.20	1.20	1.20
	0.70	0.70	0.70	0.70
	0.40	0.40	0.40	0.40
Metabolisable energy (MJ/kg)	11.40	11.40	11.40	11.40
Lysine	0.87	0.76	0.88	0.80
Methionine+cystine	0.64	0.70	0.64	0.68

Notes: 1. Mix wet palm pit sediment with sun-dried sweet potato tuber grits or chips as follows: (i) Determine the approximate dry matter (DM) content of a sample of drained PPS. (ii) Assuming a dry matter content for sun-dried sweet potato tuber of 90 per cent, calculate the weights of drained palm pit sediment and sun-dried sweet potato tuber to obtain the ratio in the ration as fed (e.g. 5 kg: 40 kg for Chick Diet A). (iii) Prepare the necessary quantity of the wet palm pit sediment-sweet potato tuber mixture, and sun-dry to below 12 per cent moisture. (iv). Grind the dried palm pit sediment-sweet potato tuber mixture (if necessary) for blending in the ration.
2. These must be good quality feeds.
3. This must be collected and dried very quickly after it is released by the brewery.
4. Chipped (or gritted), sun-dried, and ground if necessary.
5. It is assumed that the required vitamins and minerals will be provided in the drinking water.
6. Least-cost diet formulations on the basis of wholesale prices in Table 1.

Table 8. Sweet potato tuber-based laying hen rations for a small-scale animal feed manufacturer in Bamenda (diets to be fed from 16 weeks to the end of laying period).

	Fai Laying hen (16 weeks-) A	*Fai Laying hen (16 weeks-) B*	*Fai Laying hen (16 weeks-) C*	*Fai Laying hen (16 weeks-) D*
Ingredients (kg):				
Salt	0.083	0.077	0.088	0.094
Palm pit sediment[1]	5.000	5.000	-	-
Rice bran - no chaff	5.224	5.941	10.785	9.721
Soyabean meal	6.803	6.120	4.362	4.989
Bone meal	0.573	0.414	0.267	0.337
	7.000	7.000	7.000	7.000
	9.852	9.935	10.000	10.000
	10.814	11.354	12.000	11.407
	-	2.159	2.498	-
	2.651	-	-	3.452
	30.000	30.000	30.000	30.000
	20.000	20.000	20.000	20.000
	2.000	2.000	3.000	3.000
	(in water)	(in water)	(in water)	(in water)
	100	100	100	100
Cost per kg (FCFA)[6]	133.4	133.9	137.7	136.7
Analyses (% calculated):				
Crude protein	17.50	17.50	17.50	17.50
	4.10	4.10	4.10	4.10
	0.70	0.70	0.76	0.74
	0.40	0.40	0.40	0.40
Metabolisable energy (MJ/kg)	11.50	11.50	11.50	11.50
Lysine	0.97	0.98	0.99	0.97
Methionine+cystine	0.90	0.90	0.90	0.90

Notes: 1. Mix wet palm pit sediment with sun-dried sweet potato tuber grits or chips as follows: (i) Determine the approximate dry matter (DM) content of a sample of drained PPS. (ii) Assuming a dry matter content for sun-dried sweet potato tuber of 90 per cent, calculate the weights of drained palm pit sediment and sun-dried sweet potato tuber to obtain the ratio in the ration as fed (e.g. 5 kg: 30 kg for Layer Diet A). (iii) Prepare the necessary quantity of the wet palm pit sediment-sweet potato tuber mixture and sun-dry to below 12 per cent moisture content. (iv). Grind the dried palm pit sediment-sweet potato tuber mixture (if necessary) for blending in the ration.

2. These must be good quality feeds.

3. This must be collected and dried very quickly after it is released by the brewery.

4. Chipped (or gritted), sun-dried, and ground if necessary.

5. It is assumed that the required vitamins and minerals will be provided in the drinking water.

6. Least-cost diet formulations on the basis of wholesale prices in Table 1

Appendix 16.9.Photographic records of project-developed manual tuber and root chipping gritting machines. (IRAD document reproduced in full).

MANUAL PROTOTYPE MACHINE

for

PROCESSING ROOT TUBERS

To be used in

CHICKEN FEED

Constructed by R T C Mfonta for

ODA - NRI - IRZV

Institute of Agricultural Research
for Development (IRAD)
Mankon Research Station
September 1997

Plate 1 (above) Logo on machines

Plate 2: Full view of chipper from the back (reference farmer's position).

(a) fly wheel, (b) chipper
(c) chute
(d) chipped product (there is a guard to protect chips from scattering, removed for the picture).

Plate 3:
Front view showing
chipper

Plate 4: Left view
showing chute that
holds tubers or
roots.

Plate 5:
Right view showing flywheel to reduce labour force applied by operator.

Plate 6:
Top view of chipper.

Plate 7:
Top view showing mechanism that operates chipper.

Plate 8:
Front view of Pioneer chipper - operators complained this needed a lot of energy to operate.

Plate 9:
Back view of
Pioneer
chipper
showing
blades.

Plate 10:
Right view of
Pioneer chipper
showing
operating arm.

Plate 11:
Top and left view of pioneer chipper.
Closer view of blades and chute.

Plate 12:
Female A operating machine.
Machine at starting position for processing [illegible]kg of cassava white (cw) or sweet potato (sp).

Plate 13:
Female A at
acceleration
position.

Plate 14:
Female A at
levelling
position.

Plate 15: Female A at position to apply force. Processed 5kg of tubers:ap; 48 seconds; cw, 1 minute.

Plate 16: Female B processed 5kg ast sp, 1min. 36 secs. ; cw 1min. 16 secs.

Plate 17:
Female C
sp. 43 secs.,
cw, 1min.
Feeding of
sp in chute.

Plate 18:
close up of
feeding of
cassava
into chute.

Plate 19:
Male A
Time:
sp 1 min. 8 secs.
cw 1 min.

Plate 20:
Male B
sp 52 secs.
cw 49 secs.

Plate 21: chipped sweet potato

Plate 22: Close-up of chipped sweet potato

Thickness 2-3 mm. Size variable according to tuber size.

Plate 23: chipped cassava white tubers.

PLate 24: Close up of chipped cassava white tubers. Thickness: 2-3 mm.

Plate 25:
Left view
of prototype
gritter.
(a) fly wheel
(b) chute.

Plate 26:
Right view of
gritter
showing fly
wheel.

Plate 27:
Front view
showing the
gritting box.

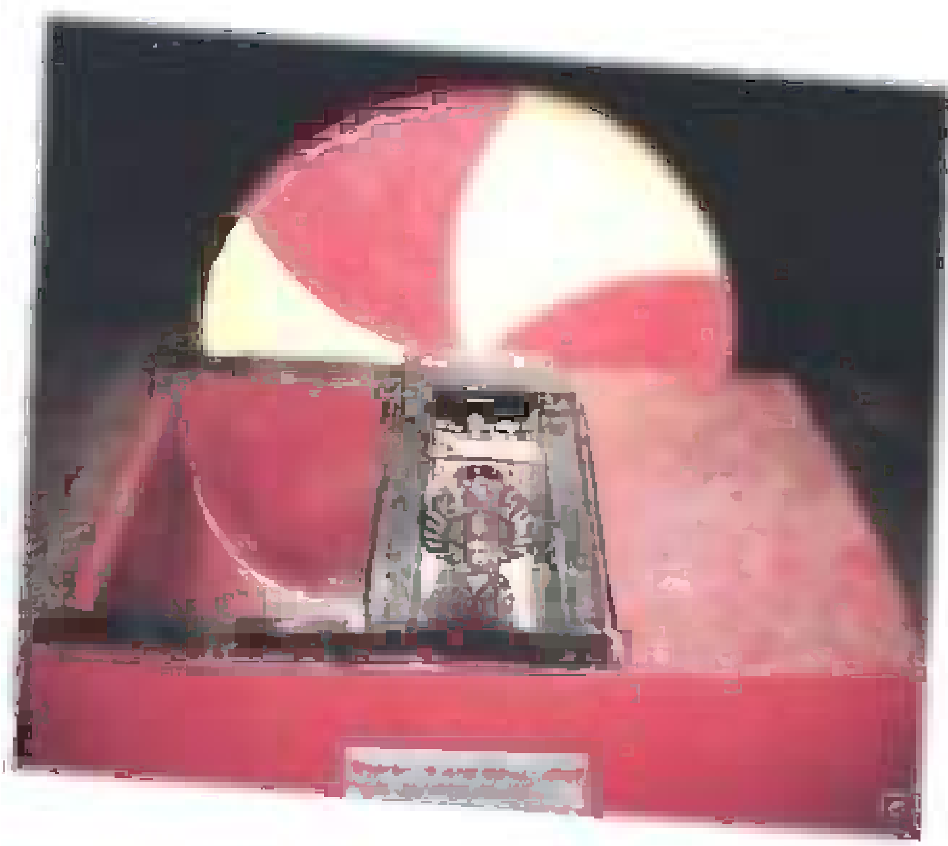

Plate 28:
Top view of
prototype
gritter
showing
bearings.

Plate 29: Left view of pioneer gritter. (a) gritting box. (b) chute to hold material. (c) sieve (d) operating arm.

Plate 30: Right view of pioneer griitter.

Plate 31:
Front view of
pioneer
gritter.

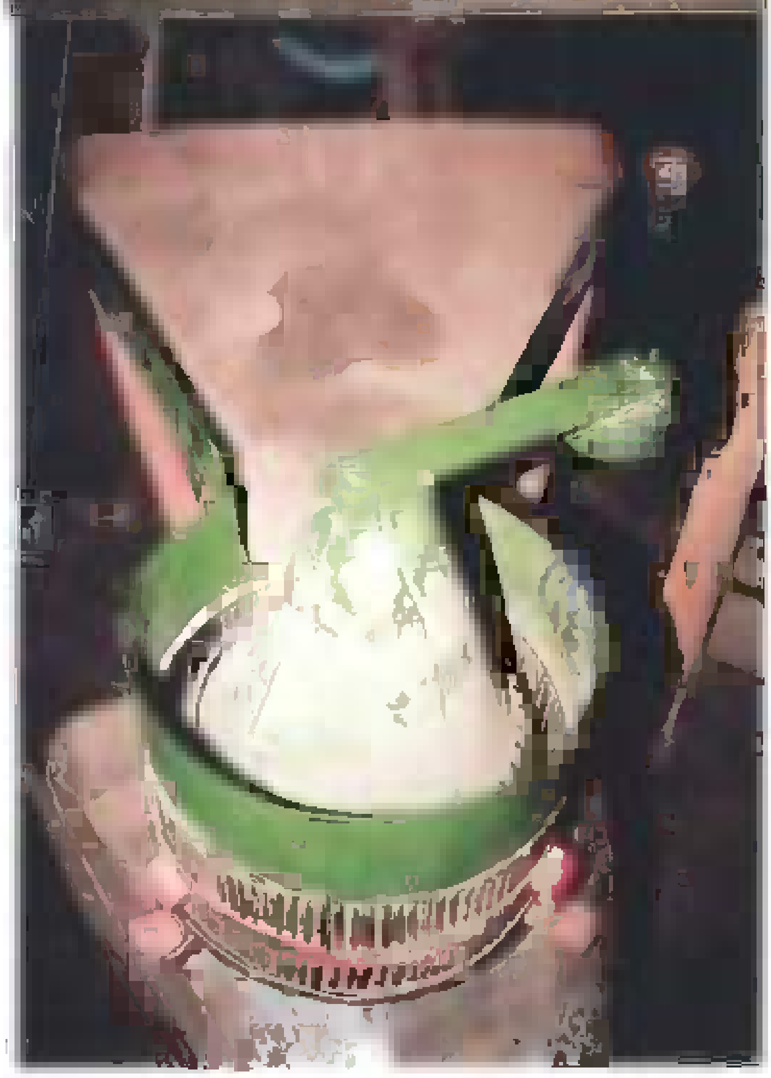

Plate 32:
Top view of
pioneer
gritter.