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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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.

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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 mm*x*3 mm*x*2 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^{o}N and 9&16^{o}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.

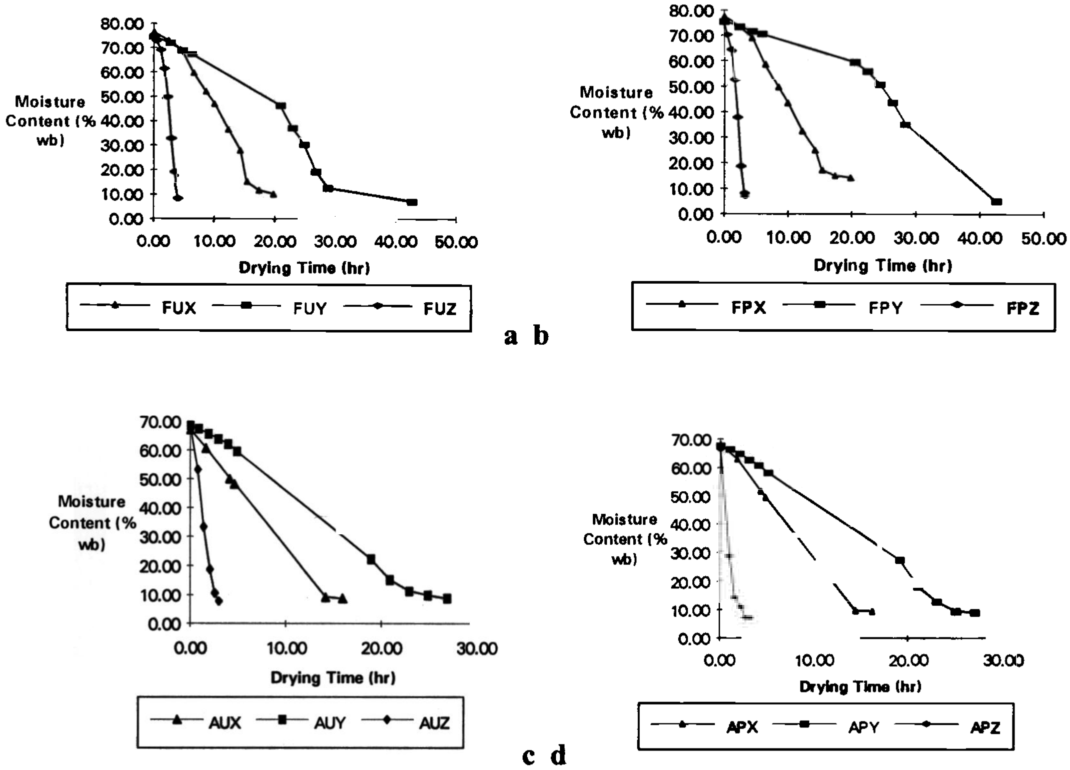
Table 2. Cultivars of sweet potato used in the NRI studies.

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 variety$x$processing 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 variety$x$drying 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: Bosbok			Carmel			Pooled SEM[1]	Significance (P=or<): 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^{o}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.