FINAL TECHNICAL REPORT

R5178 (A0315)

The use of tropical feeds in non-ruminant rations, with particular reference to poultry production

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Renewable Natural Resources Research Strategy: Livestock Production

NATURAL RESOURCES INSTITUTE
Overseas Development Administration

RNRRS FINAL TECHNICAL REPORT

THE USE OF TROPICAL FEEDS IN NON-RUMINANT RATIONS, WITH PARTICULAR REFERENCE TO POULTRY PRODUCTION

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PROJECT FUNDING DETAILS

Project title: The use of tropical feeds in non-ruminant rations, with particular reference to poultry production

Project Code: (R5178) A0315

NRD Programme: Livestock Production

Strategy Area: Livestock

Programme Manager (Institution): Natural Resources Institute, Central Avenue, Chatham Maritime, Kent, ME4 4TB, United Kingdom

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EXECUTIVE SUMMARY

1. A three-year project (cost £21,000) was established to enable the analysis, interpretation and dissemination of some of the research data collected at NRI between 1983 and 1990 from a research project entitled 'evaluation and improvement of the nutritional characteristics of unconventional and underutilised feed raw materials for use in non-ruminant livestock rations'. It had not been possible to conduct this work earlier because of problems related to the relocation of the NRI to Chatham, and the subsequent low priority accorded to poultry in ODA's 1988 RNRRS.

2. The objective of this project was to publish seven papers. By the end of the project period, six had appeared in print with a further two papers reaching the 'in press' stage. The value of some of the publications is reflected by the fact that findings were incorporated into an Adaptive Field Project in the Cameroon (F0004/F0060). Further, one of the concepts disseminated involves the integration of oilseed expelling with poultry production acitivities in developing countries. As a result of this publication, NRI has received several requests from NGOs working in sub-Saharan Africa for research and advisory support for their field activities. NRI has also received a steady flow of requests for reprints of the papers it has published on tropical poultry nutrition and production, and several requests for assistance in developing diet recipes for poultry production in developing countries.

3. It is recommended that a new three-year dissemination project be established to enable the writing of a further 15 scientific papers that are outstanding from previous research.

BACKGROUND

4. There is a need to improve the productivity of the poultry sector, measured in terms of meat and egg production, in less developed countries. Achieving improvement in poultry productivity will require, amongst other things, adequate nutrition of the bird. Research is needed to establish means for incorporating locally-available raw materials into poultry diets. This was the subject of experimental work conducted at NRI between 1983 and 1990 under the title 'evaluation and improvement of the nutritional characteristics of unconventional and underutilised feed raw materials for use in non-ruminant livestock rations' (Project A1489). However, this was later reduced to a very low level of activity in response to the change in emphasis recommended by the ODA's RNRRS-1988.

5. Although strategic research on poultry was brought to a low level of activity in 1990, a considerable number of experiments that had been conducted before 1990 had not been analysed, interpreted and disseminated. There were two reasons for this. First, and most important, the relocation of NRI from Culham to Chatham not only caused staffing difficulties, but in the three or four years leading up to relocation the Project Manager decided to concentrate effort on conducting as much practical work as possible before the Culham site closed down, under the assumption that dissemination could always be conducted through a future project. Second, poultry was accorded a low priority in the ODA's 1988 RNRRS. The new emphasis on ruminant production made it difficult to obtain funds for this work, with the consequence that, at the beginining of 1990, there were sufficient unpublished data to prepare approximately 30 scientific papers.

6. In order to disseminate some of those findings, a project was first established in 1990, under Problem Area Code A0029, with the allocation of five man months over a two-year period. Eight papers appeared in print during 1990 and 1991. With NRRD's change to Project funding, a new three-year project (1992-1995) was set up under Project Code R5178 (A0315) to continue this work, with a total allocation of three man months. This report summarises the results of activities in the latter project.

PROJECT OBJECTIVES

7. The project objectives as listed in the Project Summary Form are:
(1) To evaluate the use of tropical feeds in non-ruminant rations with reference to poultry;
(ii) To write scientific papers based on work carried out before 1990;
(iii) To publicise and disseminate findings.

8. The required project outputs were: Seven papers published by 1995.

RESEARCH ACTIVITES

9. This project involved desk work only. It involved the analysis of experimental data and the writing of articles for publication in scientific journals and presentation at conferences.

RESULTS:

10. Between 1992 and 1995, eight papers were written. The titles and abstracts of these are given here, with the full versions of only those that are still in the 'in press' stage given as corresponding Appendices:

1. Panigrahi, S. (1992) Effects of treating cottonseed meal with a solution of ferrous sulphate for the prevention of brown yolk discolouration. Animal Feed Science and Technology, 38: 89-103.

Abstract. The efficacy of detoxifying cottonseed meal (CSM) by treatment with ferrous sulphate heptahydrate (FSH) in solution or as a dry dietary ingredient was examined. In Experiment 1, Dekalb G-Link (DGL) hens were fed on a diet containing 300 g CSM/kg with iron treatment at 1470 mg iron/kg diet, and in Experiment 2, Hubbard Golden Comet (HGC) hens were fed on a similar diet treated with 1300 mg iron/kg.

Treatment of CSM with FSH in solution slightly depressed food intake and egg production initially, but the performance of hens gradually improved to that of non-CSM controls. Treatment with crystalline FSH lowered performance to a considerably greater degree without much sustained improvement. Both treatment methods were effective in preventing the gossypol-related brown yolk discolouration, although in Experiment 2, the solution method produced eggs of slightly better quality.

2. Panigrahi, S. (1992) Effects of different copra meals and amino acid supplementation on broiler chick growth. British Poultry Science, 33: 683-687.

Abstract. The effects of including two types of copra meals in nutritionally-balanced broiler chick diets were examined. A meal, screw press-expelled twice, and containing 75 g residual lipid/kg produced a lower growth rate than a meal pressed once to contain 220 g lipid/kg.

Chicks fed copra meal at 400 g/kg diet had a higher growth rate on a diet formulated to contain 12.4 g lysine/kg and 8.3 g methionine+cystine/kg than on a diet containing 13.5 and 9.0 g/kg of the respective amino acids. However, in a second experiment performance of chicks was unaffected when the low amino-acid, low-oil copra meal-based diet was supplemented with synthetic amino-acids.

3. Panigrahi, S. (1992) Energy deficit-induced behaviour changes in broiler chicks fed copra meal-based diets. Proceedings of the XIX World's Poultry Science Congress, 20-24 September, 1992, Amsterdam, The Netherlands; Volume 3, pp 503-507.

Abstract. Copra meal at 400 g/kg diet induced inquisitive and excited behaviour, and increased feed spillage and water intake in broiler chicks. When approached with a pencil these chicks became highly excited, jumping, vocalising and pecking the object vigorously. The behaviour patterns were negatively correlated with growth performance, and were elicited by an energy deficit. This was caused by copra meal's moderate digestibility and the chicks' inability to consume adequate food due to their limited gastro-intestinal capacity and the feed's bulkiness and high water-absorbing property. Addition of 0.4 MJ ME/kg to the diet improved the efficiency of food utilisation, food intake and growth rate, with concomitantly lower abnormal behaviour. Production and behaviour responses were similar for first pass and second pass screw-pressed copra meals.

4. Panigrahi, S., S. Phillips, Plumb, V.E. and Watson, A.J. (1992) Evaluation of the nutritive value of yellow rice in rats and broiler chicks. British Journal of Nutrition, 68: 573-582.

Abstract. Yellow discolouration often develops in rice kernels during post-harvest storage, due possibly to fungal activity. This study examined the changes in nutrient composition taking place during yellowing of rice, and the effects of feeding rats and broiler chicks on a moderately yellow rice at 600 g/kg diet.

Nitrogen content was found to be higher in rice grains that had become more yellow, only part of the increase being in non-protein nitrogen. However, relative to crude protein the concentrations of lysine, methionine, cysteine and arginine were lower. There were no significant differences between white and yellow rice in the food intake, weight gain and efficiency of food utilisation (EFU) of rats and chicks when diets were formulated to contain similar nutrient concentrations, or the same basal ingredient composition. Diet-pelleting increased food intake and weight gain in both animal species, but reduced dry matter and energy digestibility in rats. Effects on nutrient retention in chicks were variable. Relative liver weights of rats and chicks and relative pancreas weights of chicks were unaffected by yellow rice. However, chicks fed on mash had a larger pancreas, on average, than those fed on pellets.

Thus, whilst the nutrient composition of rice is altered during yellowing a moderately yellow rice is unlikely to produce major adverse effects when fed to rats and broiler chicks.

5. Panigrahi, S., Rickard, J., O'Brien G.M. and Gay, C. (1992) Effects of different rates of drying cassava root on its toxicity to broiler chicks. British Poultry Science, 33: 1025-1042.

Abstract. The effects of drying cassava root at different rates on its composition and toxicity to broiler chicks were examined. Unpeeled roots from a high-cyanide cultivar of cassava were chipped and sun-dried to a moisture content below 100 g/kg over 24 hours for fast-dried meal (FD), or 48 to 72 hours for slow-dried meal (SD). The meals were incorporated in semi-synthetic diets at 250 and 500 g/kg and fed to day-old broiler chicks as mash or pellets in separate experiments.

The two drying rates produced meals with similar concentrations of polyphenols but different concentrations of cyanogens; the latter being 38 and 482 mg total cyanide/kg for SD and FD, respectively. The linamarin, acetonecyanohydrin or total cyanide content measurements of pelleted diets were highly correlated.

Growth rates of chicks fed on SD-based diets were significantly higher than those of chicks fed on FD-based diets. Compared with a control diet, weight gain of chicks fed the 500 g FD/kg diet (containing 258 mg total cyanide/kg) was 77% lower, although performance also appeared to be reduced at 142 mg total cyanide/kg.

The ratio of water:food intake of chicks was higher in FD than in SD groups, and this was reflected in the high water content of excreta. There was increased bile excretion, the chloretic effect increasing with the cyanogen content of diet. Pancreas weights were lower in FD than in SD groups in experiment one (mash diets) but not in experiment two (pelleted diets). There was a significant interaction between drying method and level of cassava inclusion on liver weight in experiment two but not in experiment one. There were no effects on the mortality rate.

Pelleting of diets generated high temperatures but did not significantly alter the cyanogen concentration or the growth performance of chicks.

Thus, slower rates of drying cassava roots produce meals with lower cyanogen concentration that are, consequently, less toxic to broiler chicks. Cassava root meal of less than 40 mg total cyanide/kg can be fed to broiler chicks at 500 g/kg without any adverse effects.

6. Panigrahi, S. and Plumb, V.E. (1995) Effects on dietary phosphorus of treating cottonseed meal with crystalline ferrous sulphate for the prevention of brown yolk discolouration. British Poultry Science (in print).

Abstract. Two experiments were carried out to examine whether the adverse effects on laying hen performance of treating cottonseed meal (CSM) with crystalline ferrous sulphate heptahydrate (FSH) for the prevention of brown yolk discolouration, was due to iron reducing the availability of dietary phosphorus. Two batches of CSM, with different free gossypol and cyclopropenoid fatty acid contents, were treated with FSH at a 4:1 weight ratio of iron to free gossypol, and fed to hens at 300 g/kg diet with or without supplementation with sodium dihydrogen phosphate (SHP).
FSH treatment of CSM reduced food intake and egg production. Although performance was improved by supplementing the FSH-treated CSM diets with SHP, it was still poorer than that achieved by hens fed a non-CSM control diet.

Brown yolk discolouration was prevented by treatment of CSM with FSH. Additional phosphorus did not produce any significant effects on brown colour development in yolks, indicating that the bioavailable gossypol content of diets had not been altered. However, chemical analyses showed an apparent increase in the free gossypol content of diets with the inclusion of SHP, suggesting that the assay method gives misleading results.

7. Panigrahi, S. (1995) The potential for small-scale oilseed expelling in conjunction with poultry production in developing countries. World's Poultry Science Journal, Vol 50 (July 1995 issue): 1-6.

This paper combined the results of UK-based research (Stage one 1 in the Strategy, see para 11-16), with NRI's experiences in transferring poultry feed technology to the field (Stages two and three in the Strategy). The full paper is given in Appendix 4.

Abstract. Small-scale oil expelling is a natural component of agricultural systems in the poorer African and Asian countries. This paper relates to the work of the NRI and the assistance it has given to the installation and operation of small-scale oilseed expellers in a number of countries, including Zambia, Gambia and Sudan. A concept of integrated agricultural development is outlined comprising oilseed cultivation, small-scale expelling and poultry production. Consideration is given to differences in nutritive value of the oilseed meals produced, oilseed processing technology and the need for interdisciplinary research, coupled with co-ordinated strategies, in order to maximise the impact on farming communities which have desperately few resources.

8. Panigrahi, S. (1995) A review of the potential for using cassava root meal in poultry diets. Proceedings of a the International Symposium on Tropical Tuber Crops (ISOTUC) 6-9 November 1993. Abstracts published by Indian Society for Root Crops, Central Tuber Crops Research Institute, Sreekariyam, Thiruvananthapurum, India (in print).

Abstract. An investigation was conducted to reassess the potential for using cassava root meal in poultry diets. The results confirm that slow rates of drying a high-cyanide variety of cassava roots produce meals of lower cyanogen content which are consequently less toxic to poultry.

Low-cyanide cassava root meals may be incorporated in nutritionally-balanced poultry diets at between 500 and 600 g/kg without any reduction in weight gain or egg production. Whereas a dietary cyanide content in excess of 100 mg/kg diet appears to adversely affect broiler performance, laying hens may be affected by levels as low as 25 mg total cyanide/kg diet. This difference in susceptibility may, however, reflect the different dietary methionine requirements of the two species.

Whilst methionine supplementation of a high-cyanide cassava root meal improved poultry meat and egg production, it did not overcome the toxicity, whilst inorganic sulphur did not improve performance.

The cyanide content of cassava root meal in poultry diets produces an increase in bile excretion and watery excreta, both effects being reduced by supplementation of the diet with methionine.

CONTRIBUTION OF NRI'S POULTRY PROJECTS TO LIVESTOCK DEVELOPMENT

(a) Wider developmental objective

11. Existing trends in *per capita* income and population growth rates indicate a meat deficit in sub-Saharan Africa (SSA) by the year 2000 that will be three and half times as large as the level in 1990 (IFPRI Report 49,1985). As current concerns on the productivity of the rangeland increases, and more of it is taken up by crop cultivation, it appears increasingly likely that greater reliance will be placed on poultry production from the high potential zones to meet this shortage in livestock products. However, the same IFPRI study also predicted a deficit in egg production for SSA. Thus, a priority area in the original Livestock Programme was to conduct research and technology transfer on ways of increasing the production of poultry products and improving the productivity of the poultry sector in SSA. Subsequently, the new Livestock Production Programme also considered it appropriate to fund an adaptive field project entitled, 'the use of sweet potato and cassava in poultry diets' (F0004/F0060) in Cameroon.

12. Since feed represents between 60-70 percent of the cost of commercial poultry production, improvements can be achieved most effectively by utilising locally-available feed resources optimally, and using technologies that reduce the cost of poultry rations. NRI has also oriented its poultry programme to meeting the needs and constraints of the small-scale poultry sector in the rural areas and small towns of SSA. These are producers who generally keep their birds in confinement (ie, not the purely backyard system), and for whom poultry keeping may be only one of a number of low-income generating activites, including crop cultivation. This decision concerning the appropriate target beneficiaries was taken for sociological reasons, and because of the fact that this sector holds considerable potential for achieving improvements in poultry productivity in ways that benefit the wider local agricultural system: the production system would utlilise substantial quantities of local agro-processing by-products.

13. NRI's research strategy for poultry feed development comprised a three-stage approach. In Stage one, the objective was to evaluate and improve the nutritive value of tropical raw materials under controlled-conditions so that the potential of a feed could first be accurately determined. For this purpose, special controlled-environment poultry houses were constructed in Culham, Oxfordshire, and subsequently, in Chatham, Kent. These enabled external factors that are known to affect poultry performance (disease, temperature, humidity) to be excluded from feed evaluation. Only the test ingredients were imported from developing countries, with all complementary dietary ingredients being obtained in the UK. All feed ingredients were checked for quality before feeding trials were conducted (eg mycotoxin-contaminated feeds were rejected). These measures were all designed to reduce background variability in the responses of poultry to the test diets, so that the potential of any diet technology developed was known with confidence before any field work was undertaken. Many tropical materials contain toxic principles (e.g. cyanide in cassava roots, gossypol in cottonseeds) for which simple methods of detoxification were developed and their efficacy tested. The facilities enabled reliable assessment of the nutritive value of tropical feeds at very high dietary inclusion rates

where the maximum financial and economic benefits could be attained. To give some examples, copra cake was successfully fed to broilers at 50% and to layers at 40% of the diet (published), while cottonseed cake and palm kernel cake were tested at 50 and 70% of poultry diets, respectively (unpublished).

14. The second step was to conduct adaptive field research to test these findings under field conditions.This was done by on-station and on-farm feeding trials which used only local feed ingredients. In the conduct of the on-station feeding trials (Stage two), environment controls were released but researcher-control retained. This stage also allowed the technology to be demonstrated to scientists in NARS, who need to be convinced before they can promote it among farmers. Finally, for Stage three, on-farm trials were planned, for which much more simple diet recipes were to be developed for testing in the facilities of the target poultry producers under their own control. If, during Stages two and three, particular field conditions were encountered that called for a major change in the diet recipe, feed development research would be continued with small quantities of feeds being sent to the UK for further testing under controlled-environment conditions. Thus, the development of diet recipes and their transfer to the target groups was considered to represent an iterative process of adaptive research. It must be mentioned that the full strategy is being implemented for the first time in the current Adaptive Research Initiative Project, 'the use of sweet potato and cassava meals in poultry diets' in Cameroon (F0004/F0060).

15. If the above stages are completed successfully, the approach should lead to the formulation of simple diet recipes that (a) consist of no more than five locally-available feed ingredients (plus a premix), thereby keeping the ingredients that need to be transported into a region to a minimum; and (b) are appropriate to the circumstances of small-scale poultry producers. Depending on the variability in the availability and prices of local feeds, and the objectives of the target group, different recipes may be developed for different seasons.

(b) Field application.

16. There is much demand from small-scale producers in rural and peri-urban areas of small towns for diet recipes based on the use of locally-available feeds. During 1994, NRI received two requests for diet recipes from officials in (a) the Local Government Service Commission in Onwerri (Nigeria), and (b) the Estate Extension Service Trust in Malawi. Additionally, since 1991, the NGO Intermediate Technology Development Group-Zimbabwe has sought such advice in relation to oilcakes produced by a small expeller. Advisory support was also provided to the NGO, The Anglican Training College, Farafenni, The Gambia, on utilisation of groundnut cake expelled from a small-scale oil expeller. This project ended in 1992. More recently, in response to the presentation of a developmental concept in a workshop in Arusha, Tanzania (Appendix 4) the NGO, Appropriate Technology International, requested NRI to provide technical support on the utilisation of oilcakes from ram presses in Zimbabwe and Tanzania.

SIGNIFICANCE OF OUTPUTS DISSEMINATED

17. Some of the uses to which the data contained in the papers disseminated in this project were put deserve mention.

(a) Adaptive Field Project in Cameroon (F0004).

18. The Adaptive Field Project in Cameroon (F0004) aims to demonstrate the use of root crops in poultry diets by testing high dietary rates of inclusion of cassava root meal and sweet potato tuber meal. The Stage 2 on-station feeding trials make use of findings reported in Papers one, five, six and eight [for dietary treatments in the on-station trial see NRI Visit Report R2207(S)].

19. Of particular significance is the fact that consideration of the prices of the local feeds that were complementary to root crops for formulating poultry diets necessitated the testing of another technology developed at NRI. This involves the treatment of cottonseed cake with a solution of ferrous sulphate to prevent the gossypol-related brown egg discolourations and reduction in egg production (Paper one). Furthermore, the finding that preventing egg discolourations using ferrous sulphate may produce an adverse effect on egg production, but can be ameliorated by additional dietary phosphorus (Paper six) led to the phosphorus content of these test diets being increased above those of the control treatment.

(b) Interest generated in NRIs poultry programme

20. Since it is not possible to conduct adaptive research to transfer technology (Stages two and three) in every country, it is of paramount importance that the findings from the Stage one research are publicised as widely as possible to enable scientists in NARS to conduct their own field research. The previous publications have generated much interest. For example, Professor Oguntona of the University of Abeokuta, Nigeria, referred to Paper five in requesting that he be permitted to spend his Senior Carnegie Research Fellowship at NRI to collaborate on developing root crops-based poultry diets. More recently, the Centre de Cooperation Internationale en Recherche Agronomique pour le Developpment referred to NRIs publications (eg Papers one and six) on the use of cottonseed meal in poultry diets in requesting the Institute to join in a project submission to the Fourth Framework Programme of the European Union on the development and transfer of glandless (gossypol-free) cottonseed meal in livestock diets.

21. <u>Reprint requests</u>. Finally, NRI has also received a steady flow of requests for reprints of the papers it has published on tropical poultry nutrition and production.

FOLLOW-UP PROJECTS

22. There are a further fifteen scientific papers (Appendix 5) that still need to be disseminated from the research project conducted on poultry feed development. Funds for dissemination will be sought from the Livestock Production Programme.

23. Recent experiences of the author in a number of countries of sub-Saharan Africa and South Asia have indicated scope for introducing poultry feed technology of the type discussed in this report into mixed farming systems. Where clear opportunities exist for increasing farm productivity with a poultry component, collaborative concept notes will be developed with NARS or local NGOs and submitted for the consideration of the Livestock Production Programme.

APPENDICES

APPENDIX 1. PAPER IN PRINT: EFFECTS ON DIETARY PHOSPHORUS OF TREATING COTTONSEED MEAL WITH CRYSTALLINE FERROUS SULPHATE FOR THE PREVENTION OF BROWN YOLK DISCOLOURATION

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ABSTRACT

1. Two experiments were carried out to examine whether the adverse effects on laying hen performance of treating cottonseed meal (CSM) with crystalline ferrous sulphate heptahydrate (FSH) for the prevention of brown yolk discolouration, was due iron reducing the availability of dietary phosphorus. Two batches of CSM, with different free gossypol and cyclopropenoid fatty acid contents, were treated with FSH at a 4:1 weight ratio of iron to free gossypol, and fed to hens at 300 g/kg diet with or without supplementation with sodium dihydrogen phosphate (SHP).

2. FSH treatment of CSM reduced food intake and egg production. Although performance was improved by supplementing the FSH-treated CSM diets with SHP, it was still poorer than that achieved by hens fed a non-CSM control diet.

3. Brown yolk discolouration was prevented by treatment of CSM with FSH. Additional phosphorus did not produce any significant effects on brown colour development in yolks, indicating that the bioavailable gossypol content of diets had not been altered; however, chemical analyses showed an apparent increase in the free gossypol content of diets with the inclusion of SHP, suggesting that the assay method gives misleading results.

INTRODUCTION

Recent studies have shown that treatment of cottonseed meal (CSM) with crystalline ferrous sulphate heptahydrate (FSH) at a 4:1 weight ratio of iron to free gossypol prevents the gossypol-related brown yolk discolouration in eggs, but could depress the laying performance of hens (Panigrahi and Morris, 1990). The use of FSH in solution avoids most of the adverse effect on egg production by, it is believed, reacting more effectively with gossypol (and perhaps other feed components) so that less iron is consequently bioavailable for toxic interaction (Panigrahi, 1992).

The mechanism by which excess crystalline FSH depresses egg production in hens is unclear. However, there are numerous reports that the addition of metal salts such as those of iron, aluminium and beryllium, to animal diets leads to a lowering in phosphorus availability by the formation of insoluble phosphates in the intestine (Cox et al. 1931; Deobald and Elvehjem, 1935; Jones, 1938). Cox et al. (1931) and recently Rossi et al.

(1990) further reported that the addition of extra phosphorus to the diet could prevent the detrimental effects of metal salts.

The present study was undertaken to test the hypothesis that the adverse effects on laying hen performance resulting from crystalline FSH treatment of CSM are due to iron reducing the availability of dietary phosphorus: iron-treated CSM-based diets were supplemented with phosphorus to determine whether this would improve egg production whilst producing eggs with gossypol-free yolks.

MATERIALS AND METHODS

The CSM were produced in China and were of similar proximate composition to that reported previously (see Panigrahi et al. 1989). However, CSM-1 contained 711 mg free gossypol/kg, determined according to AOCS (1973), 64.3 g residual lipid/kg and 174 mg cyclopropenoid fatty acids (CPFA)/kg, determined according to Hammonds et al. (1971) (2.7 g CPFA/kg cottonseed lipid), whereas the corresponding values for CSM-2 were 1086 mg free gossypol/kg, 69.2 g residual lipid/kg and 361 mg CPFA/kg (5.2 g CPFA/kg cottonseed lipid). Treatment of the CSM with iron was carried out using crystalline FSH at a 4:1 weight ratio of iron to free gossypol present. Attempts were made to balance the content, and with SHP supplementation, the sodium content of diets.

In experiment 1, the dietary treatments were:
0CSM - CSM-free control diet, containing 5.8 g phosphorus/kg
CSMFe - 300 g FSH-treated CSM-1/kg diet, containing 5.8 g phosphorus/kg
CSMFe+1P - 300 g FSH-treated CSM-1/kg diet, containing 6.8 g phosphorus/kg
CSMFe+2P - 300 g FSH-treated CSM-1/kg diet, containing 7.8 g phosphorus/kg

Iron treatment was carried out by mixing 425 g of FSH, ground to pass a 0.2 mm screen, with 30 kg of CSM-1 in a horizontal mixer for 30 minutes. Thus, the supplemental dietary iron concentration was 854 mg/kg.

In experiment 2, the dietary treatments were:

0CSM - CSM-free control diet
CSM - 300 g CSM-2/kg diet
CSMFe - 300 g FSH-treated CSM-2/kg diet
CSMFe+P - 300 g FSH-treated CSM-2/kg diet, with an additional 2.5 g phosphorus/kg

Iron treatment was carried out mixing 766 g of FSH, ground to pass a 0.2 mm screen, with 36 kg of CSM in a horizontal mixer for 30 minutes; this was left to stand for a further 6 days before other dietary ingredients were added. Thus, the supplemental dietary iron concentration was approximately 1300 mg/kg. The constituents of the diets and analyses are shown in Tables 1 and 2.

Feeding trials

In Experiment 1, 68 point-of-lay Hubbard Golden Comet pullets were housed individually in battery cages that were arranged in 2 blocks of 2 tiers, each cage supplied with an individual hopper and nipple water drinker. The room was maintained at 20oC and photoperiod increased gradually from an 8 h daylength at 18 weeks to 15 h (maximum) at 26 weeks. Pullets were fed on the control diet until all were in lay. They were then allocated to the 4 dietary groups in an incomplete randomised block design with 17 hens per treatment, ensuring at least 4 hens from each treatment in each tier. Food intakes, egg production and changes in bodyweight were monitored during 12 weeks of feeding.

At the end of Experiment 1, hens were fed on the control diet for 10 days to ensure that each laid a minimum of 0.7 eggs/hen d. Eighty-five, 41-week old hens (including 68 of those used in Experiment 1) were then allocated to the diets of Experiment 2 in an incomplete randomised block design, but ensuring equal number of hens from each treatment in each tier. The performance of hens was monitored for a period of 8 weeks.

Egg discolouration study

After 5 weeks of each experiment, eggs were collected and examined for changes in the colour and pH of their yolks and albumen. Tests were carried out on fresh eggs, on eggs stored at 23°C for 1 month, and on eggs stored at 5°C for up to 4 months. Fresh eggs were also exposed to ammonia gas by placing petri dishes with the contents of eggs, in 4.4 l desiccators containing 25 ml of a 350 g/kg ammonia solution, for 30 minutes (Panigrahi, 1990). Brown yolk discolouration was evaluated according to a pre-determined colour standard ranging from 0 for none, 1 for very light brown (not objectionable) to 8 for black colour. Yolk mottling was scored on a 0 to 3M grading system with 3M representing severe mottling in patches that resembled a discolouration score of 1. Pink albumen and apricot yolk discolourations were evaluated according to 0-8 visual standards.

Statistical analyses

The laying performance data were treated to analysis of variance, using SPSS (1988). In instances where significant treatment effects were observed, the multiple comparison test procedure of least significant differences ($P<0.05$) was used to determine any significant differences between means. Standard errors were generated using a fixed effects model.

RESULTS

Experiment 1

Egg production

These are summarised in Table 3. Egg output of hens fed the CSMFe diet was significantly lower than that of hens fed the 0CSM diet. Addition of phosphorus to the CSMFe diet at 1 g/kg increased food intakes and egg output slightly, the improvements not being statistically significant; however, addition of phosphorus at 2 g/kg increased egg production significantly, both in terms of the number and mass of eggs laid. In the CSMFe group, total egg output was 13.1 per cent lower than in the control group, whereas in the CSMFe+1P and CSMFe+2P groups it was 10.5 and 6.2 per cent lower, respectively. With the addition of phosphorus at 2 g/kg diet, the efficiency of lay in terms of the number of eggs laid per kg food consumed, increased significantly.

Hens fed the CSMFe diet initially lost body weight (not shown in Table), but they recovered and the overall change during 12 weeks was similar to controls. In the phosphorus-supplemented CSMFe groups, the initial loss in body weight was much lower than that in the CSMFe group, and by the end of the feeding trial hens had gained weight relative to controls.

Discolourations in eggs
Chemical analyses of diets indicated that the free gossypol content of the CSMFe diet had increased with the addition of SHP to the diet (Table 1). There were however no significant differences in the colours of fresh eggs, or eggs exposed to ammonia, between the various treatment groups (Table 4), indicating that SHP supplementation had no effect on brown colour development. Some yolk mottling was present in fresh and warm-stored eggs in all treatment groups. Cold storage of eggs for 4 months did not result in any significant treatment differences in the colour and pH of yolks and albumen, with no discolouration developing in any group.

Experiment 2
Egg production
These results are summarised in Table 5. The food intake and egg output (P=0.0524) of hens fed on the CSM diet were significantly lower than those of controls, whilst the performance of hens fed on the CSMFe diet was lower than of hens fed the CSM diet.

The food intake of hens fed the CSMFe+P diet was significantly greater than of hens fed the CSMFe diet. This was reflected in the increased body weights and greater increases in egg weight with age of the former. However, food intake and egg output of these hens were still lower than those of the non-CSM controls.

Discolourations in eggs
Fresh eggs from hens fed on the CSM diet had slightly brown (not objectionable) yolks, the colour becoming intense chocolate-brown after exposure to ammonia, and brown with orange patches on yolk surface after cold storage for 2 months. No significant differences could be observed between the 0CSM, 0CSMFe and CSMFe+P groups in the colours of yolks of fresh or ammonia-treated eggs (Table 6). However, cold storage of eggs resulted in significant increases in yolk pH and apricot yolk and pink albumen discolourations in both FSH-treated CSM diet groups.

Addition of extra phosphorus to the diet did not have any significant effect on brown yolk colour development in fresh, ammoniated or cold-stored eggs. However, chemical analysis showed an apparent increase in the free gossypol content of CSMFe diet with the inclusion of SHP (Table 2). The presence of additional phosphorus in the CSMFe ration did not have a significant effect on the extent of pH changes and discolourations in cold-stored eggs.

DISCUSSION

This study has shown that the lowering in egg production in hens caused by crystalline FSH treatment of CSM may be at least partly due to iron reducing the availability of dietary phosphorus. In comparison with controls, egg output of hens fed iron-treated CSM-based diets were 13.1 and 17.9 per cent lower in experiments 1 and 2, respectively, but improved by 7.9 and 7.4% with phosphorus supplementation in the form of SHP. This finding is consistent with earlier reports that soluble metal salts, including those of iron, lower phosphorus absorption from the gastro-intestinal tract by forming insoluble phosphates (Cox et al, 1931; Deobald and Elvehjem, 1934).

In both experiments the performance of hens fed on phosphourus-supplemented CSMFe diets were still lower than those of the respective controls. Thus, unlike the studies of Cox et al. (1931) and Rossi et al. (1990), the results indicate that supplementation may not prove to be an effective method of overcoming the phosphorus deficiency. In this context the suggestion of Jones (1938) that the imbalance in phosphorus (and hence calcium) caused by a rachitogenic diet may require additional cholecalciferol for correction may be significant. However, it is also possible sufficient iron could be absorbed from the diets to produce toxic effects in laying hens by interfering with other minerals such as copper (McGhee et al. 1965). Furugouri (1972) suggested that the 'iron block' in the intestine, the high iron-binding capacity of plasma, and the iron storage capacity of the liver may rule out the possibility of direct iron toxicity. The addition of sulphur in the form of sulphate to the diet may also needs to be considered when examining the possible causes of FSH toxicity.

It has been observed that the reduction in free gossypol content of CSM by crystalline iron salts occurs primarily in the feed (Plumb, V.E. unpublished), although some complex formation could also takes place in the intestine. In both experiments chemical analysis of the iron-treated CSM-based diets showed an apparent increase in free gossypol content with SHP supplementation, suggesting that SHP reduced the formation of iron-gossypol complexes or liberated gossypol from these complexes. However, cold storage of eggs and ammonia tests provided evidence that the bioavailable gossypol in the diet had remained largely unaltered by the SHP inclusion. These findings provide further evidence for the suggestion that the AOCS (1973) method for free gossypol estimation may give misleading results when applied to complete diets (Panigrahi et al. 1989, Panigrahi and Hammonds, 1990; Marquie and Bourely, 1991), and also casts doubts on the applicability of the method on CSM since the feed may contain up to 13.6 g phosphorus/kg (Gohl, 1982).

It was of interest that in Experiment 1, pH changes and apricot yolk and pink albumen discolourations did not develop in the CSMFe groups when eggs were cold-stored for 4 months, but these effects took place in Experiment 2 when eggs were stored for only 2 months. As the same flock of hens were used in the two experiments, the different results obtained would appear to reflect the different CPFA contents of CSM. Thus, the CPFA content of the residual lipid of screw press-expelled CSM is an important factor for consideration in deciding the maximum inclusion rate of CSM in laying hen diets.

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Table 1. Composition of diets in experiment 1 (g/kg).

Diets	0CSM	CSMFe	CSMFe+1P	CSMFe+2P
Fish meal	38.7	62.4	63.4	64.4
Maize	456.5	502.1	495.1	487.9
Soyabean meal	100.0	-		
Wheat middlings	78.7	-		
Meat and bone meal	7.5			
Sunflower meal	210.0			
Maize gluten meal	5.0	-	-	-
Cottonseed meal	-	300.0	300.0	300.0
Dicalcium phosphate	1.0	3.0	3.0	3.0
Limestone	84.9	82.1	81.9	81.8
Salt	4.1	3.9	3.2	2.5
Methionine	0.6	-	-	-
Maize oil	10.0	39.3	41.7	44.2
Vitamin/mineral premixes1	3.0	3.0	3.0	3.0
Ferrous sulphate heptahydrate		4.2	4.2	4.2
Disodium hydrogen phosphate			4.5	9.0
Determined analyses of diets:				
Moisture	112.8	106.0	103.6	102.4
Crude protein	174.6	187.5	190.3	195.3
Crude fibre	86.6	58.1	58.5	57.3
Crude fat	40.1	84.9	84.2	84.9
Ash	132.3	123.2	127.3	130.5
Calcium	37.8	36.4	35.6	35.4
Phosphorus	6.3	6.3	7.4	8.0
Free gossypol (mg/kg)	15	117	157	183
Iron (mg/kg)	437	1270	1292	1316
Metabolisable energy (MJ/kg)[2]	12.0	12.0	12.0	12.0
Lysine[2]	9.5	9.5	9.5	9.5
Methionine+cystine[2]	7.0	7.0	7.0	7.0

Notes: 1. For premix composition see Panigrahi et al. (1989). 2. Calculated on raw material composition.

Table 2. Composition of the diets in experiment 2 (g/kg unless otherwise stated).

Diets	0CSM	CSM	CSMFe	CSMFe+2.5P
Cassava root meal	-	45.2	31.4	11.1
Fish meal	20.0	25.0	25.0	25.0
Maize	531.6	515.8	519.9	526.0
Soyabean meal	180.0			
Meat and bone meal	2.8	-	-	
Sunflower meal	152.8	-	-	
Cottonseed meal	-	300.0	300.0	300.0
Dicalcium phosphate	10.4	8.0	8.0	8.0
Limestone	84.4	85.2	85.3	85.4
Salt	3.4	3.6	3.6	1.8
Lysine hydrochloride	-	3.0	3.0	3.0
Methionine	0.6	0.9	0.9	0.9
Maize oil	11.0	10.3	13.4	17.9
Vitamin/mineral premixes[1]	3.0	3.0	3.0	3.0
Ferrous sulphate heptahydrate			6.5	6.5
Disodium hydrogen phosphate				11.4
Determined analyses of diets				
Moisture	104.4	95.2	95.6	93.7
Crude protein	171.5	168.1	189.0	177.7
Crude fibre	69.0	67.0	62.1	75.9
Crude fat	37.1	50.4	54.3	57.1
Ash	127.7	130.4	119.6	125.1
Calcium	37.1	38.8	36.1	36.0
Phosphorus	6.4	6.3	6.1	8.0
Free gossypol (mg/kg)	18	218	74	140
Iron (mg/kg)	277	324	1608	1659
Metabolisable energy (MJ/kg)[2]	11.6	11.6	11.6	11.6
Lysine[2]	9.5	9.5	9.5	9.5
Methionine+cystine[2]	7.0	7.0	7.0	7.0

Notes: 1. For premix composition see Panigrahi et al. (1989). 2. Calculated on raw material composition.

Table 3. Performance of hens from 23 to 35 weeks of age in Experiment 1.

Diet	0CSM	CSMFe	CSMFe+1P	CSMFe+2P	SEM	Probability (< or=to)
Food intake (g/hen/d)	125.0^{a}	109.0^{b}	111.7^{b}	112.0^{b}	3.26	0.0035
Eggs laid per hen d	0.92^{a}	0.82^{b}	0.84^{b}	0.92^{a}	0.020	0.0003
G eggs laid per hen d	55.0^{a}	47.8^{b}	49.2^{c}	51.6^{ac}	1.34	0.0015
Change in egg weights (0-84d)	+9.20^{a}	+6.10^{b}	+6.69^{b}	+5.99^{b}	0.775	0.0151
Change in body weights (0-84d)	+102	+99	+120	+128	42.9	0.9545
Egg output per kg food intake (g)	440	439	440	461	9.9	0.4619
Number of eggs laid per kg food intake	7.4^{a}	7.5^{a}	7.5^{a}	8.2^{b}	0.19	0.0207

Notes: SEM - standard error of treatment means. residual degrees of freedom 60. Values in the same horizontal line with different superscripts are significantly different ($P<0.05$).

Table 4. Discolourations and pH changes in eggs in Experiment 1.

Diets	0CSM	CSMFe	CSMFe+1P	CSMFe+2P
Fresh eggs:				
Yolk colour	0(0.1M)	0(0.1M)	0(0.3M)	0(0.3M)
Albumen colour	0	0	0	0
Yolk pH	5.90±0.05	5.93±0.12	5.93±0.04	5.87±0.03
Albumen pH	8.98±0.14	9.12±0.05	9.08±0.02	9.13±0.17
Yolk colours after ammonia tests:	0.42±0.25	0.53±0.22	0.82±0.18	0.65±0.21
Eggs stored at 23oC for 1 month:				
Yolk colour	0(0.5M)	0(1.1M)	0(0.8M)	0(1.6M)
Eggs stored at 5oC for 4 months:				
Yolk colour	0	0	0	0
Albumen colour	0	0	0	0
Yolk pH	6.51±0.11	6.82±0.12	6.57±0.18	6.62±0.22
Albumen pH	9.28±0.05	9.29±0.05	9.33±0.04	9.26±0.06

Notes: Each colour and pH figure is the mean of readings from 17 eggs; Yolk colour scores in fresh and warm-stored eggs refer to chocolate-brown discolouration and those of cold-stored eggs refer to apricot discolouration. All albumen colour scores refer to pink discolouration, M - denotes mottling. Standard deviation of means are indicated as ±.

Table 5. Performance of hens from 43 to 51 weeks of age in Experiment 2.

Diets	0CSM	CSM	CSMFe	CSMFe+P	SEM	Probability (< or=to)
Food intake (g/hen/d)	126.5[a]	109.0[bc]	99.9[c]	111.0[b]	3.68	0.0001
Eggs laid per hen d	0.88[a]	0.83[ab]	0.76[b]	0.78[b]	0.030	0.0338
G eggs per hen d	55.9[a]	51.1[ab]	45.9[b]	49.3[b]	1.86	0.0036
Change in egg weights (0-56d)	+2.15[a]	+0.91[a]	-1.29[b]	+1.32[a]	0.495	0.0001
Change in body weights (0-56d)	+83	-103	-149	-55	32.6	0.0001
Egg output per kg food intake (g/kg)	442	469	459	444	10.6	0.2804
Number of eggs per kg food intake	7.0[a]	7.6[b]	7.6[b]	7.0[a]	0.19	0.0260

Notes: SEM: standard error of treatment means. residual degrees of freedom 60. Values in the same horizontal line with different superscripts are significantly different ($P<0.05$).

Table 6. Discolourations and pH changes in eggs in Experiment 2.

Diets	0CSM	CSM	CSMFe	CSMFe+P
Fresh eggs:				
Yolk colour	0	1.1	0	0
Albumen colour	0	0	0	0
Yolk pH	5.91±0.05	5.90±0.13	5.89±0.06	5.92±0.04
Albumen pH	8.79±0.12	8.93±0.19	8.95±0.14	8.69±0.17
Yolk colours after ammonia test:	0.35±0.36	6.04±0.36	0.36±0.50	0.50±0.45
Eggs stored at 20oC for 1 month				
Yolk colour	0	1.64±0.46	0	0.12±0.20
Albumen colour	0	0	0	0
Yolk pH	6.42±0.13	6.60±0.10	6.52±0.08	6.42±0.08
Albumen pH	9.62±0.03	9.63±0.05	9.60±0.03	9.62±0.04
Eggs stored at 5oC for 2 months:				
Yolk colour	0	3.94±2.04	2.13±1.78	2.22±1.86
Albumen colour	0	0.30±0.45	0.10±0.35	0.10±0.42
Yolk pH	6.32±0.07	7.51±0.78	7.50±0.83	7.39±0.69
Albumen pH	9.24±0.05	8.98±0.19	8.95±0.21	9.00±0.20

Notes: Each colour and pH figure is the mean of readings from 17 eggs; Standard deviation of means are indicated as ±. Yolk colours scores for eggs from the CSM diet group refer to chocolate-brown discolouration while those for the iron-treated CSM diet groups refer to apricot discolouration. All albumen colour scores refer to pink discolouration.

APPENDIX 2. PAPER IN PRINT: THE POTENTIAL FOR SMALL-SCALE OILSEED EXPELLING IN CONJUNCTION WITH POULTRY PRODUCTION IN DEVELOPING COUNTRIES

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The potential for small-scale oilseed expelling in conjunction with poultry production in developing countries

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Small-scale oil expelling is a natural component of agricultural systems in the poorer African and Asian countries. This paper relates to the work of the Natural Resources Institute and the assistance it has given to the installation and operation of small-scale oilseed expellers in a number of countries including Zambia, Gambia and Sudan. A concept of integrated agricultural development is outlined comprising oilseed cultivation, small-scale expelling and poultry production. Consideration is given to differences in nutritive value of the oilseed meals produced, oilseed processing technology and the need for interdisciplinary research, coupled with co-ordinated strategies, in order to maximize the impact on farming communities which have desperately few resources.

Keywords: Development; diet; expellers; feed; nutrition, oilseed; poultry

Introduction

In recent years there has been a high rate of increase in poultry production in many developing countries, e.g. India where per capita annual egg consumption has increased from six in 1962 to 30 in 1991 (Panda, 1992). Although much of this increase has been due to proliferation of the more intensive production systems that use exotic high yielding varieties of domestic fowl, the traditional rural and backyard poultry sector has continued to prevail because indigenous birds require little attention and have characteristics suited to the harsh tropical environment (Vietmeyer, 1984). Thus, during the 1980s, poultry production in Africa increased by two-thirds, 80% of which was met by small-scale farmers with free range-birds (Farrell, 1992). According to Spore (1991) villages produce more than 75% of the poultry meat consumed in Africa and have the economic potential to achieve more.

As might be expected, traditional poultry production systems are common in economies with large subsistence or semi-subsistence sectors. For example, the 1988 livestock census (SALC, 1988) showed Tanzania, which has one of the largest agricultural sectors in Africa (Harvey, 1985), to have 13.6 million indigenous domestic fowl fairly evenly distributed throughout the country. The 1986/87 Agricultural Sample Survey (ASSTM, 1992) estimated the national poultry population to be 16.13 million, including commercial birds, and further showed that 58% of farming households kept poultry, including 55% of households with less than 0.5 ha, while 7% of farming households kept ducks; the average flock size was 6–8 and average egg production was 55 eggs per bird per year. Similarly, in Bangladesh there are an estimated 66 million domestic fowl and 12 million ducks, seven birds for every 10 people. The birds are ubiquitously distributed at the rural household level with about 70% of landless and 85% of landed households holding some (Mustafa *et al.*, 1991). Significantly, these are the very countries where small-scale vegetable oil extraction technologies are of greatest importance in agricultural and rural development.

Despite the acknowledged importance of rural and backyard poultry in the poorer developing countries, agricultural projects designed to improve the productivity of this sector have generally failed for three main reasons. Firstly, inappropriate technology was promoted: for example, attempts have been made to secure improvements by providing supplementary feed through the use of local grains. However, cereals are valuable human food and, unless accompanied by other measures, their addition to the diet of birds is unlikely to have a significant impact on egg production. Secondly, as pointed out by Bradford (1989), development agencies have too often assumed that relatively low productivity of local animals is due to their inferior genetic potential without first evaluating local stock. Thirdly, at the conceptual stage projects did not recognize that village poultry production is a subsystem within a complex agricultural structure. In order to assist small backyard poultry producers a multidisciplinary approach is required. To be effective the application of the results of 'Farming Systems Research' or 'Integrated Research', such as the duck cum fish farming of south-east Asia, is likely to be necessary (Edwards, 1983).

Integration of oilseed cultivation, small-scale oil expelling and poultry production activities

The developing world abounds with various types of traditional and modern screw press oil expellers because rural and urban dwellers need cooking oil. The further the oil is produced from the location in which it is needed, the greater is the storage and transport cost and the likelihood of the oil deteriorating in quality in hot or humid tropical climates. The Natural Resources Institute (NRI) has therefore promoted a concept comprising the cultivation of oilseeds, small-scale oil expelling and poultry production (COSEP) under the premise that integration of local oil expelling and poultry production activities will encourage the cultivation of oilseeds as a cash crop on a sustainable basis. The concept is best illustrated by some case study notes taken from two recent NRI-assisted projects, one in the Gambia extracting groundnut and sesame seed and the other in Zimbabwe extracting sunflower seed.

Gambia

In the Gambian project, located at the Anglican Training Centre (ATC) in Farafenni, an NRI-designed prototype oilseed expeller was linked to a poultry production unit and the economics of the operation were assessed in terms of a combination of the value of the oil produced and the poultry meat and eggs sold in Farafenni town where, in 1992, there was no other local production. The project utilized substantial quantities of local oilseeds and demonstrated cost savings of 20–25% of those incurred using an equivalent feed imported from Senegal. The compositions of the oilseed meals and some of the diets that were formulated are shown in *Tables 1* and 2.

The local demand for oil expelling facilities for pressing sesame seed and groundnuts was met in the following ways. People brought their seed to the expeller operator, paid for the processing and took the oil or seed cake; or the operator purchased the seed which he processed and then sold the oil and used or disposed of the seed cake. Normally, the cultivator took oil in exchange for seed.

The availability of these options added to the sustainability of the system and encouraged oilseed cultivation by small farmers. The profitability of the Gambian oil expelling project was dependent on the cost of seed, the charge made for oil

Table 1 Compositions of the groundnut and sesame seed cakes produced by an NRI prototype expeller in Gambia and the sunflower seed cake produced by a Tinytech expeller in Zimbabwe (g/100 g)

	Oilseed cakes		
	Groundnut	Sesame	Sunflower
Moisture	7.7	7.9	6.3
Crude protein	42.2	36.6	25.66
Ether extract	13.2	19.4	19.34
Crude fibre	4.0	4.7	21.24
Ash	4.8	8.1	5.65
Calcium	0.1	1.9	0.40
Phosphorous	0.5	0.5	0.85
Amino acids:			
Aspartic acid	4.58	2.79	2.33
Threonine	1.13	1.17	1.01
Serine	2.07	1.55	1.11
Glutamic acid	8.41	7.14	5.88
Glycine	2.58	1.77	1.59
Alanine	1.49	1.52	1.15
Valine	1.67	1.64	1.29
Isoleucine	1.31	1.28	1.03
Leucine	2.48	2.25	1.59
Tyrosine	1.78	1.39	0.67
Phenylalanine	2.12	1.69	1.18
Histidine	1.00	0.95	0.77
Arginine	4.63	4.29	2.37
Proline	2.13	1.19	1.10
Total lysine	1.49	0.98	1.17
Available lysine	1.45	0.96	1.14
Lysine availability (%)	97.7	98.1	97.7
Cystine	1.59	0.88	0.62
Methionine	0.49	0.82	

Table 2 Examples of the least cost and nutritionally best balanced poultry diets that could be formulated using imported and locally produced groundnut cake (ATC-GNC) in the Gambian project

Ingredients (g/100 g)	Broiler chick		Egg layer	
	Imported GNC	ATC GNC	Imported GNC	ATC GNC
Groundnut cake (Senegal)	12.04	-	9.80	-
Groundnut cake (local)	-	[1]20.00	-	18.00
Corn soya mix (USA)	43.03	63.77	26.05	45.21
Millet	34.54	9.71	47.64	23.63
Rice mill feed	-	1.20	-	-
Fishmeal	5.34	-	3.67	-
Oyster shell	-	-	7.74	7.97
Salt	0.05	0.32	0.10	0.19
Premix	5.00	5.00	5.00	5.00
Cost per ton (Gambian Dalasis)[1]	2529	2148	2406	2120
Calculated analyses:				
Crude protein	21.23	22.75	17.00	19.42
Metabolizable energy (MJ/kg)	11.95	11.95	11.30	11.30
Calcium	1.25	1.08	3.60	3.60
Phosphorus	0.94	0.85	0.80	0.76
Lysine	1.03	1.04	0.79	0.86
Methionine + cystine	0.74	0.90	0.61	0.79

[1]Prices are for June 1992. All feed ingredients were Gambian unless otherwise stated.

expelling, the rate of oil recovery, the rate of seed throughput through the expeller, the price of oil and the value of residual cake. With the slow throughput experienced in the NRI-designed expeller, the margin of profit from expelling alone proved small, but the use of the oilseed cake in the ATC poultry farm diets enhanced the profitability of the operation. Furthermore, by the end of the first phase of the project the COSEP enterprises were shown to be of benefit to the ATC, students in the college, and the local community.

Zimbabwe

Until recently the vegetable oil industry in Zimbabwe was dominated by industrial scale plants which used a combination of expelling followed by solvent extraction processing on soyabeans and sunflower seed. These processing plants were located in urban areas to which oilseeds had to be transported from the growing areas. Demand for the oil in the urban areas was high, with the result that remote rural areas were often undersupplied. In recent years, aid agencies have therefore encouraged the introduction of small-scale oilseed processing units in the rural areas to enable farmers to produce local supplies of cooking oil. The Intermediate Technology Development Group (ITDG) has established seven 'Tinytech' oil expellers, with a further seven mills scheduled to be installed during the next two years. There are, in addition, a further three oil millers operating similar power expellers in Zimbabwe, and more than 54 users of manual oil presses. These decentralized edible oil producers process sunflower seed, the most widely grown communal cash crop, which also produces a cheap and nutritious cooking oil that is palatable in the unrefined state. An added benefit is that sunflower seed oilcake has become available in the rural areas. Since the price paid by animal feed companies for the oilcake is low due to the high cost of transporting the relatively small quantities of cakes generated, it is apparent that integration with poultry production enterprise is an appropriate option.

The nutritional value of high residual oil sunflower seed cakes for different livestock is, however, not clear, and research has had to be undertaken to determine the effect of processing conditions on its nutritive value for different classes of livestock. Effort has been concentrated on poultry where the greatest financial benefits lie. As the project developed a winnower was included in one of the oil milling operations to decorticate partially the sunflower seeds in order to improve extraction efficiency and reduce the fibre content of the oilcake and enhance its nutritive value for poultry. Preliminary research has also indicated that a 60:40 ratio of sunflower seed oilcake to commercial soyabean meal (which is 20% more costly) produced the best results in terms of weight gain in a broiler chick feeding trial. However, an integrated commercial operation in Zimbabwe worthy of mention concerns an enterprise that has included a Tinytech oil expeller, a maize mill and a poultry production unit. The laying birds are fed on a simple diet consisting of 48% partially decorticated sunflower seed oilcake from the expeller, 42% maize bran generated in the maize mill and 10% of a commercial vitamin-mineral premix. This diet has resulted in peak egg production rates of about 80%. The sunflower hulls generated by the winnower were used in the poultry hosue as litter material and at which the birds consumed any residual kernel present. The nitrogen-enriched poultry litter was sun-dried and fed to pigs, particularly at the finishing stage. (This raw material is, of course, also excellent feed for ruminant livestock.)

General considerations in COSEP

Socioeconomic features

There is generally a shortage of poultry feeds in semi-urban and rural areas, particularly in those developing countries in which the oil crushing and animal feed industries are dominated by a small number of companies operating major urban centres (e.g. in Zimbabwe). Small-scale oil expelling provides an opportunity to help to develop rural poultry production to meet the local demand for feeds and poultry products. Although fully integrated systems are likely to be more efficient, there is normally a clear opportunity for local poultry keepers to procure oilseed cakes from the oil miller to give to their birds as a supplementary feed. However, in suitable circumstances the ultimate objective in COSEP is for oil millers to produce and sell a variety of balanced finished feeds, concentrates and protein supplements, based on the oilcake from the locally grown oilseed. The potential benefits are the increased cash income to farmers due to the increased value of the oilcake; the reduced price of poultry feeds enabling greater sales; the ability to meet the animal feed requirements of local livestock producers; and the increased availability of livestock products in rural areas and urban markets. Such developments would enhance the viability of small-scale oil expelling, and thus the sustainability of oilseed cultivation, with many beneficial effects on rural communities including a regular supply of cheap cooking oil. The central feature of this integrated system is that a number of rural needs are met by linking together various income-generating activities for a number of participants who therefore have a stake in attempting to ensure its success.

Nutritive value of oilcakes from small-scale expellers

It is estimated that there are more than 200 small-scale oil expelling activities in sub-Saharan Africa, with more than 20 in Zambia, more than 30 in The Gambia, plus numerous others in Sudan, Somalia, Cameroon, Kenya and Ghana. The NRI has been instrumental in installing a number of oil expellers, including five Simon Rosedown Mini-40 expellers in Zambia in addition to the NRI-designed prototype expeller in the Gambia. In some of these projects NRI has also provided support in the form of nutritional analysis of feeds and ration formulation advice to associated livestock production enterprises that use the cake resulting from oil extraction.

The most efficient use of oilseed meals, based on feed energy:livestock produce conversion ratios, is their inclusion in poultry diets (Whittemore, 1987) where these meals often represent the single most important source of protein. Depending on the type of expeller used, oilseeds meals are also an important source of dietary energy. For these reasons they are often the most costly ingredient of the feed, calling for particular care to ensure that they are put to the most efficient use. It is, however, also pertinent to recognize the contribution that oilseed meals can make to the diet of ruminants, particularly within the context of farming systems where, with perfect knowledge and profit maximizing motives, considerations of equimarginal returns to feed usage in livestock production would predominate in decision making (Ellis, 1988). Oilseed meals are also used in peri-urban dairy enterprises throughout much of India, indicating that the price mechanism largely dictates the use to which the feed is put. There are, however, examples of livestock holdings of mixed species under considerable seasonal fluctuations in feed availability that may necessitate a more complex pattern of feed allocation.

Studies at the NRI have shown that coconut cake may be included in poultry diets at a concentration up to 400 g/kg (Panigrahi *et al.*, 1987; Panigrahi, 1989) and palm kernel meal up to 500 g/kg (Panigrahi and Powell, 1991). After treatment with a solution of ferrous sulphate to inactivate the gossypol (which causes a brown discolouration of the yolks of the eggs), cottonseed meal may be incorporated at up to 300 g/kg in layer diets (Panigrahi, 1992a) and at even higher levels in broiler chick diets (unpublished). There are no known toxicological factors that limit the use of the more conventional oilseed meals (groundnut cake and sunflower cake) in poultry diets, although with soyabean meal the trypsin inhibitors present must be destroyed by heat treatment during processing. Sesame seed cake has not been adequately studied and it may be restricted to 150 g/kg of poultry diets. This seed contains phytic acid, which may bind dietary calcium, and is also believed to be particularly prone to rancidity, thus reducing the period for which it can be stored (Gohl, 1981).

The single most important factor affecting the management of oilseeds as a resource is the oil extraction method employed, which is primarily dictated by the market conditions for oil. There is, however, a frequently ignored trade-off between maximizing the oil yield and maintaining the nutritional (and hence financial) value of the meal. The residual oil content is a valuable source of dietary energy for poultry and pigs; a component which is invariably in short supply in developing countries. Small-scale screw press expellers generally leave a higher level of lipid in the meal than the larger scale mills or solvent methods of oil extraction. These therefore have particular attraction for poultry farmers in semi-urban and rural areas where production is generally constrained by the limited availability of high energy foods that do not directly complete with food used by humans.

Of greater concern is the trade-off between maximizing the revenue from the oil and achieving the desired nutritional characteristics in the resultant meal in terms of protein digestibility for non-ruminant livestock. Excessive heat treatment resulting from the high temperatures generated under some screw press expelling procedures reduces the bioavailability of protein, the very nutrient that gives the feed its premium value. Oilseeds are often subjected to multi-stage processing, as in the Gambian project where the seeds were frequently expelled up to four times. Variation in the nutritive value of oilseed meals has been observed for cotton seeds (Panigrahi, 1988) and coconuts (Panigrahi, 1992b and other unpublished results). Shen and Yang (1992) also reported *in vitro* protein solubility of 29.5–96.3% for 13 soyabean meals produced by various screw press techniques in China.

A third factor affecting the economic value of the meal is the extent of seed decortication prior to oil removal. Here, too, technical aspects in terms of oil extraction efficiency and the cost of seed decortication remain the major considerations. However, the choice of technique is also of interest to poultry producers because the high fibre content of undecorticated seed meal effectively lowers its metabolizable energy value and thus its feeding value.

Both pre-harvesting and post-harvesting factors have been implicated in the variation in the nutritive value of oilseed meals, e.g. for copra meal the maturity of the nut at harvest and the kernel drying method are important factors. Weigel (1993) has summarized the factors that affect the quality of soya bean protein products as: variety, planting practices, weather conditions, soil characteristics, fertilization rates, storage conditions and processing conditions.

Another factor that must be considered in relation to animal feeds generally, but for oilseeds such as groundnuts in particular, is the danger of mycotoxin formation from both preharvest fungal contamination and during storage after harvesting. The use of oilseed meals from local small-scale expellers soon after production should minimize post-harvesting contamination because the storage period will be short.

On the basis of these considerations, it is reasonable to state that the nutritive value of an oilseed meal is a function of the processing methods employed, and is especially dependent on the conditions under which the expeller is operated. Unpredictable variation in the nutritive value of oilseed meals resulting from operation under different conditions will lead to less optimal poultry production, because there is a paucity of literature on nutritional strategy to be followed for optimizing production with meals of varying protein digestibility. As well as having a detrimental effect on livestock production, inappropriate processing conditions may adversely affect a country's foreign exchange reserves if a need to import is created.

Nutritional advantages of integrating activities

In addition to the socioeconomic advantages discussed above, there are technical advantages concerning the nutritional value of poultry feeds inherent in the COSEP system.

Firstly, an important factor in the management of oilseeds as a resource is that, in contrast to cereals which are important human food in developing countries, oilseed meals are generally unpalatable to humans and are not therefore in direct competition with human food (e.g. the layer diet used in the Zimbabwe case referred to above).

Secondly, as discussed above, oilseed meals from small-scale expellers are a good source of both energy and protein, the two major nutrients required by livestock. Panigrahi *et al.* (1987) give an example of how copra cake can be formulated into poultry feeds so as to replace cereals completely. It is of interest that the first press copra cake from a Simon Rosedown Mini-40 expeller supplies about 13.2 MJ/kg of metabolizable energy and 23% crude protein, roughly the nutrient requirements of poultry when the minor ingredients are taken into account.

Thirdly, whilst meals from small-scale oil expellers are generally high in residual oil (and thus dietary energy), the fat is prone to rancidity, the vulnerability being dependent on the oilseed concerned, the storage period and storage environment. The integration of activities enables the rapid use of the oilcakes, thereby reducing the possibilities of both the rancidity-related feed palatability problems and post-harvesting fungal contamination leading to mycotoxin formation.

Finally, in small scale oil expellers a lower level of heat is generated during processing compared with that in more efficient large-scale screw press expellers. This helps to preserve the bioavailability of lysine in the resultant meal (as shown in *Table 1* for groundnut, sesame and sunflower meals), a major consideration in developing countries which have neither the technical capacity to produce synthetic amino acids nor the foreign exchange to import them.

These are important reasons why the development of the oilseed and animal feed industries of developing countries should go hand in hand. The arguments presented here also apply, albeit to a lesser extent, to the integration of large-scale oil expelling and animal feed industries in more developed countries.

The diets formulated under a COSEP system will not have an ideal nutritional specification (see analyses in *Table 2*), and poultry productivity will not necessarily be comparable with that obtained using commercial compound feeds. Each socioeconomic environment determines the diet, and hence productivity, that is optimal under its own constraints. Least cost diet formulation becomes a complex art when used strategically in relation to small-scale oil expelling operations where the overriding objective is that of improving the financial viability of the operation. For example, in addition to the considerations that have been highlighted, it might sometimes be appropriate to increase oilseed dietary inclusion rates above the optimum to use up excess (seasonal) production. The Zimbabwean case study has also shown that, with oilseeds of high fibre content, there is a need to consider the nutritional, technical and financial aspects of seed decortication. This helps in the determination of the optimal choice of technology, and assists in channelling appropriate proportions of the oilcakes into feed for poultry, pigs and ruminants.

Technical research needs

Research has shown that the monitoring of the nutritive value of high protein oilseed meals by chemical analysis alone (including amino acid profiles) is normally insufficient to reveal their true feeding value for poultry. In addition, some oilseeds such as sesame seed cake have had insufficient study, especially under the low productivity backyard systems widely found in developing countries. Without reliable data, the nutritionist is unable to provide sound advice on how multi-processed meals may be incorporated in the poultry diets using the standard least-cost diet formulation approach, and how the basic nutritional strategy may be modified to optimize livestock production with meals of sub-standard quality.

Since aid organizations will, it is believed, continue to support the installation and operation of small-scale expellers for developmental and, in some cases, philanthropic reasons, there is a need for strategic research on the quality of oilseed meals produced by a range of small and large-scale oil expellers. The specific objectives of this research should be to (1) evaluate the nutritive value for poultry of oilseed meals produced by a range of expellers under different operating conditions; (2) conduct simultaneous studies on oil yield and quality; (3) determine whether any other major pre-harvesting or post-harvesting factors affect the nutritive value of oilseed meals; (4) develop appropriate nutritional strategies to optimize poultry production with oilseed meals of sub-standard quality; (5) examine the 'protein bypass' value and the effect of including cakes of high residual lipid on ruminant performance; and (6) conduct financial and economic appraisals of oil and oilcake production under different processing conditions in integrated oil milling cum livestock production operations. On the basis of their importance to the economies of subSaharan Africa and Asia, the following oilseeds need to be examined: groundnut, coconut, sesame seed, sunflower seed, palm kernel seed and safflower seed.

Conclusion

Small-scale oilseed expelling is a natural component of agricultural systems in most developing African and Asian countries. The COSEP concept, which builds on this foundation, should be seen as an approach to sustainable development because it attempts to generate income for under-resourced oilseed and poultry farmers while increasing the availability of vegetable oil and poultry products. It also addresses national concerns on the efficiency with which an important renewable natural source (namely oilseeds) is utilized. The concept is based on the hypothesis that ready access to an oil mill will stimulate the cultivation of oilseeds as a cash crop. This increases the production of oil for domestic (local or national) consumption or for export, while adding value to what has historically been treated as a by-product. This is achieved by linking the mill to livestock enterprises so as to make oilseed cultivation and oil expelling more attractive on financial grounds. With respect to livestock production, some technical aspects of this 'systems' approach may be emphasized. Firstly, the nutritive value of oilseed residues for poultry and other livestock in terms of metabolizable energy, digestible crude protein and available lysine depends on the oilseed concerned and on the conditions of processing. Secondly, a flexible approach to formulation of the diet is needed with the objective of achieving optimal poultry production under the prevailing socioeconomic conditions. Thirdly, the oilcakes may also play a significant role in the diet of ruminants in rural areas depending on the prevailing farming system. Finally, insufficient knowledge of their nutritive value will limit the utilization of residues from small-scale oilseed expelling in rural and backyard poultry and other livestock production systems.

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Section 4.33 Sesamum indicum L (S. orientale L.)

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APPENDIX 3. PAPER IN PRINT. A RE-VIEW OF THE POTENTIAL FOR USING CASSAVA ROOT MEAL IN POULTRY DIETS

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ABSTRACT

An investigation was conducted to reassess the potential for using cassava root meal in poultry diets. The results confirm that slow rates of drying a high-cyanide variety of cassava roots produce meals of lower cyanogen content which are consequently less toxic to poultry.

Low-cyanide cassava root meals may be incorporated in nutritionally-balanced poultry diets at between 500 and 600 g/kg without any reduction in weight gain or egg production. Whereas a dietary cyanide content in excess of 100 mg/kg diet appears to adversely affect broiler performance, laying hens may be affected by levels as low as 25 mg total cyanide/kg diet. This difference in susceptibility may however reflect the different dietary methionine requirements of the two classes of birds.

Whilst methionine supplementation of a high-cyanide cassava root meal improved poultry meat and egg production, it did not overcome the toxicity, whilst inorganic sulphur did not improve performance.
The cyanide content of cassava root meal in poultry diets produces an increase in bile excretion and watery excreta, both effects reduced by supplementation of the diet with methionine.

INTRODUCTION

The toxicity of cassava root meal is largely, if not solely due to it's cyanide content, that is derived from the cyanogenic glucosides (linamarin and lataustralin) present in the fresh tubers. The mechanism of cassava toxicity in humans is much better understood today than it was perhaps 15 years ago (Delange et al. 1983), and may be summarised as follows: Cyanogenic glucosides release the highly toxic hydrocyanic acid (HCN) during hydrolysis by the enzyme linamarase, that is present in the root peel, or by the glucosidic enzymes of intestinal microflora, or HCN may be released in the intestine by acid hydrolysis. HCN obstructs respiratory processes in animal tissues by deactivating the cytochrome-oxidase enzyme system, a reversible reaction that at high doses can lead to a sufficient build-up of lactate in the brain to cause degeneration of nerves. HCN is transformed in the liver by the enzyme rhodanese to thiocyanate (SCN), which is excreted in the urine, a process that utilises sulphur from methionine. More importantly, SCN produces a goitrogenic effect by inhibiting (a) iodine concentration by the thyroid, (b) the conversion of iodide to iodine necessary for the iodination of tyrosine, (c) the iodination of monoiodotyrosine, and (d) the uncoupling of diiodotyrosine for the synthesis of thyroxine, the hormone regulating oxidative processes in the tissues.

The use of cassava root meal in animal diets has been the subject of several reviews, notably by Oke (1978) and, most recently, by Tewe (1992). Whilst the fundamental biochemical pathway of the transformation of cyanide into SCN which then inhibits throid function might be broadly the same for most animals, there are some species differences in the mechanism of toxicity; for example, in ruminant animals, SCN is readily formed in the rumen and then absorbed into the blood (Onwuka et al. 1992). The differences in the physiology and nutritional requirements of livestock species is an important reason that makes it difficult to assess their suseceptibility to dietary cyanide from cassava root ingestion. The relative lack of comparative data for different species is also not surprising in view of the differences that exist in the cyanide content of different cassava cultivars, which may range between 75 and 1000 mg HCN/kg, variations arising from different methods of processing the roots, and the complexities involved in determining the cyanogen concentrations in feeds, the enzymatic method for which was still undergoing modification until recently (O,Brien et al, 1991).

On the basis of reports that broiler chicks and laying hens have been successfully fed on diets containing 500-600 and 400-600 g cassava root meal/kg, respectively, Khajerern and Khajerern (1992) concluded that cassava root could replace cereals in nutritionally balanced poultry diets. Recent reports also indicate that a safe level of dietary cyanide for poultry might lie between 83 (Gomez et al., 1988) and 100 mg total cyanide/kg (Tewe, 1992). However, there appears not to be any reliable data on the susceptibility of laying hens to cyanide toxicity arising from cassava root meal ingestion, although Khajerern and Khajerern (1992) indicated that laying hens were more susceptible than broiler chicks. These authors also pointed out the uncertainty in the literature concerning the value of extra methionine supplementation of non-ruminant diets as a means of achieving cyanide detoxification physiologically, and also referred to the palatability problems arising from the dustiness and bulkiness of cassava root meal, suggesting further that this problem could be overcome by pelletising the feed or by adding molasses or fat.

This paper presents the results of research carried out at the Natural Resources Institute to assess the potential for including cassava root meal in broiler chick and laying hen diets.

MATERIALS AND METHODS

Processing of cassava roots

The tuberous roots of a high cyanide cultivar of cassava (MCol 1684) were harvested on the same day at the Centro Internacional de Agricultura Tropical, Cali, Colombia. Unpeeled roots were chipped in a modified Thia chipper and sun-dried at identical temperatures (25oC$\pm$2^{o}C) to a moisture content of below 150 g/kg. To vary the drying rate different loading densities were used: for fast-dried meal (FD) chips were loaded at 8 kg/m2 on inclined mesh trays, the drying being complete in 24 hours, and for slow-dried meal (SD) chips were placed on plain concrete floor at 14 kg/m2, the drying being complete in 3 days.

Broiler feeding trials
Day-old Ross-1 broiler chicks, and semi-synthetic pelleted diets were used. Experiment 1 was conducted using the following diets: control (no cassava root meal), 25FD, 50FD, 25SD and 50SD, where the figures 25, 50 (and 60 for the layer trial) represent 250, 500 and 600 g cassava root meal/kg inclusion rates, and FD and SD slow-dried and fast-dried meals respectively (for details, including method of cyanide determination, see Panigrahi et al 1992). In Experiment 2, the 50SD diet was supplemented with methionine or sodium metabisulphite at 4 g/kg to determine whether these sources of sulphur could overcome the adverse effects of cyanide on performance.

Layer feeding trial
The laying hen trial was conducted using the following Hyline Brown hens and mash diets, containing natural feed ingredients (Table 1). Experiment 3 was conducted using the following diets: control, 60FD, 60SD, 60LC (LC representing a low-cyanide commercial cassava root meal), and 60LC+2 g methionine/kg. The 60FD diet was supplemented with 5 g methionine/kg after 2 weeks, 10 g methionine/kg after 4 weeks and 10 g methionine/kg+ 5 mg selenium/kg after 6 weeks. The 60SD diet was supplemented with 2 g methionine/kg after 6 weeks. All hens were transferred to the control diet after 8 weeks.

RESULTS AND DISCUSSION

The method of drying cassava root had a pronounced effect on cyanogen contents, which were 38 and 482 mg total HCN/kg for the SD and FD samples, respectively.

In Experiment 1, The performance of broiler chicks was significantly better on SD than on FD-based diets, with significant interactions for weight gain, food intake and EFU showing a greater detrimental effect of the higher cassava root meal inclusion rate in FD- than in SD-fed chicks. Weight gain of chicks fed on the 50FD diet was 77% lower than that of controls (Table 2). The ratios of water:food intake was higher in FD than in SD groups, and significant interaction showed a greater effect of the higher cassava root meal inclusion rate in FD- than in SD-fed chicks. The water content of excreta was higher in FD than in SD groups, and increased with dietary cassava root meal inclusion rate. The excreta of chicks fed on FD also contained significant quantities of bile which was not present in the control and 25SD groups, and only a trace quantity was present in the 50SD group. There was no treatment-related mortality.

In Experiment 2, methionine supplementation of the 50FD diet significantly increased weight gain, food intake and efficiency of feed utilisation compared to the unsupplemented diet (Table 3). There were also reductions in bile excretion, the water:food intake ratio and watery excreta in the methionine supplemented groups. Sodium metabisulphite supplementation had no effects.

In short term toxicity feeding trials with laying hens it is necessary to focus on the on food intake as the important parameter of harmful effects on the animal rather than egg output, because the hen is initially able to maintain its rate of lay by using body reserves. Once the body reserves of nutrients starts getting depleted, egg output will gradually be affected, if there is a genuine toxicological problem rather than one of palatability.

In the laying hen feeding trial (Experiment 3), the 60FD diet produced an almost instant reduction in food intake, which in the first day was 27 g, which recovered to about 46 g by the 10th day; these intakes compare with a almost constant food intake of around 120 g/d in the control group (Table 4). The reduction in food intake was accompanied a loss in body weight and egg output. The 60SD diet produced a smaller but significant reduction in food intake, which was reflected in a reduction in body weight but not egg output after 2 weeks. There was however a small reduction in egg output and a recovery in body weight between 2 and 6 weeks of feeding (Figures 1, 2 and 3). The performance of hens fed the 60LC diet was not significantly different from that of controls. The cyanide content of the diet was correlated with bile excretion and the production of watery excreta. Supplementation of the 60FD diet with methionine produced an increase in food intake, egg output and body weight; selenium supplementation appeared to have no effect. These improvements were accompanied with a reduction in bile excretion and watery excreta (Figure 4 and 5).

Thus, this study has revealed that two symptoms of cyanide toxicity from cassava root meal ingestion in poultry: the appearance of bile in the excreta and the production of watery excreta from a higher water intake. Bile excretion in particular may have a limited diagnostic role in detecting severe cyanide toxicity in the field. Both these symptoms were reduced by methionine supplementation of the diet which also improved food intake, weight gain and efficiency of feed utilisation. However, it is important to note that methionine did not fully overcome the toxicity, suggesting that there is another mechanism involved in the manifestation of cyanide toxicity in poultry than simply the assumed depletion of body sulphur that is mediated by the formation of thiocyanate. Thiocyanate itself may be the primary toxic factor by its direct action on the thyroid, although various other supplementation techniques, such as with iodine, may need to be attempted with methionine to see how far performance can be improved by diet modification.

These resulted obtained here have also indicated a marked difference in the susceptibility of broiler chicks and laying hens to dietary cyanide, as was suggested by Khajarern and Khajerern (1992). A total cyanide concentration of 23 mg/kg reduced performance in laying hens but more than 100 mg was required for growth retardation in broiler chicks. In view of the marked improvement achieved by methionine supplementation, it is possible that this apparent difference may simply be a reflection of the different methionine (and perhaps iodine) requirements of the two classes of birds. The broiler trials were conducted with dietary cyanide concentrations of 9.0 g/kg whereas for the layer trial was conducted with 5.8 g/kg.

The results of this study demonstrate that the rate at which cassava root is dried has a marked effect on its cyanide content and the consequent toxicity of the meal in broiler chicks. Appropriately processed cassava root meal will be acceptable in broiler chick diets at 500 g/kg and in laying hens at 600 g/kg dietary inclusion rates. The mechanism of cassava toxicity is summarised in Charts 1 and 2.

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Table 2. Performance of chicks fed on pelleted cassava root meal-based diets for 2 weeks.

Diets:	Control	25FD	50FD	25SD	50SD	SEM	Main effects & interactions3 (P<or=)		
							Dry	Level	DryxLevel
Growth performance:									
Initial body weight (g)	48	48	48	48	48	0.2			
Weight gain (g)	323	303	74	287	308	20.2	0.0001	0.0001	0.0001
Food intake (g)	406	369	136	369	377	19.0	0.0001	0.0001	0.0001
Efficiency of food utilisation1	0.79	0.82	0.56	0.78	0.83	0.019	0.0001	0.0001	0.0001
Food spillage (g/kg intake)	4.4	8.9	66.3	6.4	6.0	2.67	0.0001	0.0001	0.0001
Water:food intake (ml/g)	2.9	3.4	8.2	3.2	3.3	0.13	0.0001	0.0001	0.0001
Bile in excreta2	0	1.0	2.7	0	0.3	0.41	0.002	0.028	0. 1
Excreta water content (%)	45.1	58.1	69.4	54.5	59.5	3.26	0.034	0.015	0.266

Notes: 1. weight gain:food intake. 2. on 6th day, scored on a 0-3 grading system where 3 indicates severe condition. 3. Dry - tuber drying method, Level - cassava inclusion rate. Residual degrees of freedom - 8. SEM - pooled standard error of means.

APPENDIX 4. THE POTENTIAL FOR USING RAM-PRESSED SUNFLOWER SEED CAKE AS A LIVESTOCK FEED COMPONENT IN RURAL AREAS OF ZIMBABWE AND TANZANIA.

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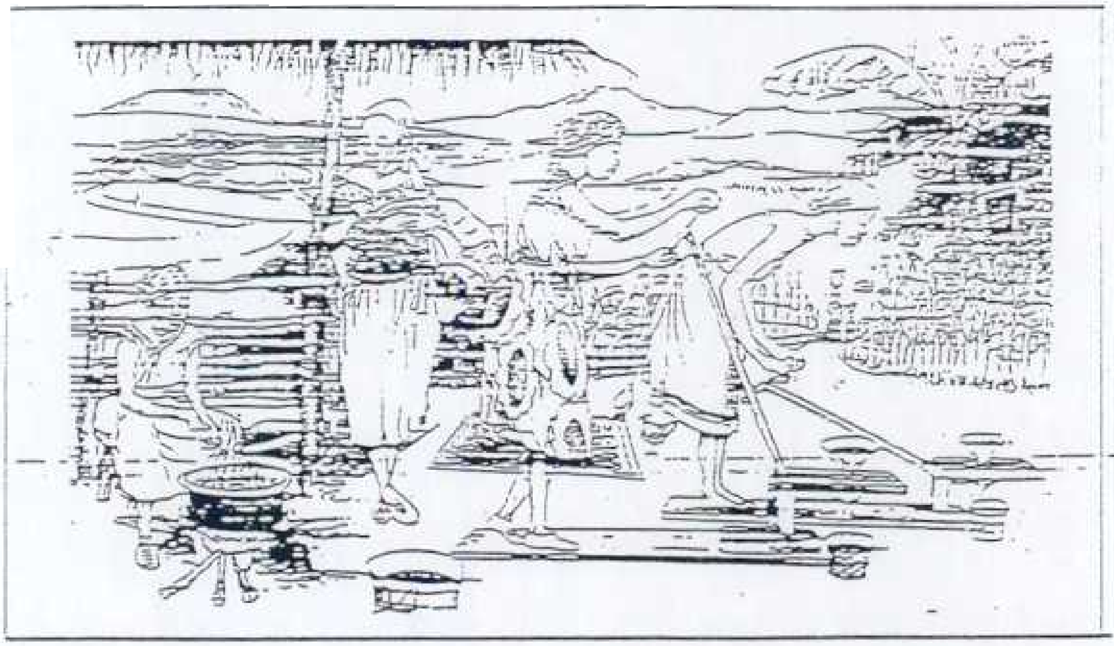
AGROTEC

Agricultural Operations Technology for Small Holder Farmers in East and Southern Africa



SMALL SCALE OIL PROCESSING IN EAST AND SOUTHERN AFRICA

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THE POTENTIAL FOR USING RAM-PRESSED SUNFLOWER SEED CAKE AS A LIVESTOCK FEED COMPONENT IN RURAL AREAS OF ZIMBABWE AND TANZANIA

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ABSTRACT

This paper describes a project strategy to improve the sustainability of oilseed cultivation and rural oil milling and increase the supply of cooking oil and livestock products (eggs, meat and milk) in rural areas of Zimbabwe and Tanzania. The key elements are to collect and analyze a wide range of sunflower cakes from ram -press activities currently being carried out by numerous small-holder farmers in Tanzania and Zimbabwe. Analysis results will high light the potential for utilization of the sunflower seed-cake (with other low-cost local materials) by livestock. Whilst the direct beneficiaries of the project will be small-holder farmers cultivating sunflower seed as a cash crop, and small-scale rural oil millers and livestock producers, the wider effect will be to stimulate the rural economy by creating income-generating opportunities, particularly for women.

INTRODUCTION

Agricultural policy plans in developing countries normally accord high priority to small-scale agro-processing and to the use of crop by-products. Small-scale oil extraction operations and the upgrading of by-products for the animal feed (and other) industries are linked activities which add value at several stages in processing and utilization. Efficient utilization of the by-products from vegetable oil production will assist in securing the financial viability and sustainability of cooking oil production and oilseed cultivation. Government policies also aim to assist women in development and this project, with its emphasis on ram-pressing - an activity being increasingly adopted by women both in Tanzania and Zimbabwe - will bring direct benefits to them.

Oilseed processing in Zimbabwe and Tanzania

The vegetable oil processing industry in many African countries - certainly in Zimbabwe (and to a lesser extent in Tanzania) - is dominated by industrial scale plants, using an expelling process followed by solvent-extraction. These processing plants are located in the urban areas and oilseeds need to be transported from the rural growing areas. Demand for oil in the urban areas is high with the result that remote rural areas are often under-supplied. The rural population pay high prices for cooking oil because of the double transportation costs incurred and shortages in availability; and the oil-cake which could have supported livestock production by small-scale rural farmers accumulates in urban areas where capital- and import-intensive animal feed milling industries are located. This has led to the development of intensive animal production for most classes of livestock. As a result of the transfer of rural resources to urban areas, economic activity in rural area remained depressed. The introduction of small-scale oilseed processing units (both small-scale expellers and ram presses) has enabled small-holder farmers to produce a local supply of cooking oil together with press-cake suitable for inclusion in livestock feeds. The full benefits of the cake in livestock feeds at the small-holder farmer level has yet to be exploited. Additionally, the sediment produced (around 10% by weight of the crude oil) after filtering the oil is a waste product which could have value as a feed material. The chemical analysis of this material has not been documented.

In 1990, ATI established the Zimbabwe Oil Press Project (ZOPP), introducing an ATI designed ram press which had already been tested in several countries in Africa as a result of ATI's original project established in 1985 in Tanzania (the Village Oil Press Project - VOPP) . Over 1000 ram presses have been sold in Tanzania, mostly to rural farmers. In Zimbabwe, almost 200 ram presses were sold in 1993. Both VOPP and ZOPP are currently gathering independent baseline data by monitoring several versions of ram press currently in use. Among other information, figures on seed throughput, oil and cake output together with wear characteristics of the presses will be documented. A further element of this exercise is to collect representative samples of sunflower seed and cake from each of the monitored presses over a six-month period. These samples could form the basis of the analytical work for the project described here.

Proposed Activities

- feed sampling during field surveys and advisory visits to ram press sites;
- investigation of the low-cost materials available locally to incorporate into the specific feeds for the different classes of livestock;
- chemical analysis of the sunflower seed, cakes from press operations and the other local ingredients;
- strategic research (including feeding trials) to determine the nutritive value of a range of ram-pressed sunflower seed cakes and
- the publication of technical literature on sunflower seed cake utilization and extension literature on simple feeding strategies for rural livestock production.

Outputs of the project will be:

- specifically-designed low cost, locally-produced poultry, pigs, rabbits, goats, sheep, beef and dairy cattle diets and appropriate feeding strategies for use by rural livestock producers. These will be documented and distributed widely to interested workers in the agro-processing field. (Such documents aimed at this audience do not exist at the moment);

- knowledge of the chemical constituents of the several varieties of sunflower seed currently being grown in Tanzania and Zimbabwe and of ram-press cakes;

knowledge of the ratio of oil to sediment in crude sunflower seed oil produced from the different ram press types and

a systematic protocol for carrying out similar activities with other agro-processing operations with outputs that can be used for livestock feed.

Sunflower seed

In Zimbabwe, sunflower is chiefly a small-holder and communal sector cash crop, which accounts for 90% of the current annual production of over 40,000 tonnes. There are two distinct varieties of seed: open-pollinated and hybrid varieties. They differ in oil content and in the amount and hardness of the seed hull. The open-pollinated varieties have lower oil content and harder hulls than the hybrid. Small-scale farmers may grow sunflower in small patches or along the edges of the main crop plot. A major reason for its recent emergence as an important crop is its drought tolerance compared with other oilseeds. The recent introduction of hybrid varieties with higher yield and higher oil content is expected to further increase sunflower seed production in the future. Thus, sunflower has considerable developmental importance for small-scale farmers. Both these varieties of sunflower seed are processed in the ram press, producing press-cakes with different chemical compositions which in turn affects their rates of inclusion into animal feeds. It is much more difficult to operate the ram press using seeds with hard hulls.

In Tanzania, the main variety of sunflower seed is an open-pollinated type which has characteristics similar to hybrid types (soft hull and high oil content). The benefit of open-pollinated seed types for small-scale farmers is that seed from a harvest can be kept for re-planting the following season. This cannot be done with hybrid types as the yields the following season are drastically reduced. This means that the farmer has to purchase a fresh supply of hybrid seed every season. The annual production in Tanzania is a round 40,000 tonnes mostly grown by small-holder farmers.

Utilization of sunflower seed cake

Technical considerations. In Zimbabwe, a recent survey of 50 ram press owners (carried out by ATI) showed considerable potential for improving the utilization of the cake produced. The price that some feed millers were prepared to pay for ram press cake was considerably lower than the value that could be obtained by using it in a balanced feed together with other local raw materials. Ram presses are selling well in both Zimbabwe and Tanzania and the amount of cake generated by the presses is increasing. At the moment farmers feed the cake to animals in a casual manner without realizing the greater benefit that could be obtained by admixing with other locally-available materials. The rates of inclusion of the ram press-cakes in feeds varies whether the feed is to be fed to chickens, cattle, goats or pigs. The rates of inclusion will also vary depending on the composition of the cake and this depends on the sunflower seed variety (see above) and the processing efficiency.

The most common reason for under-utilization of the sunflower seed oil-cake is that livestock producers do not know how to feed the cake to maximize benefits. The uncertainty is, however, not limited to rural livestock producers as feed millers also display a marked reluctance to incorporate sunflower seed cake in commercial livestock diets, complaining o f its unpalatability. This is surprising to the animal nutritionist since the proximate composition of sunflower oil-cake suggests t hat it is of considerable value for poultry production, for example. However, it suggests that there may be factors associated with the seed that cause concern to livestock producers,

Since the introduction of ram presses for processing sunflower seed is a recent development, the potential for utilizing the oil-cake in livestock diets is largely un-researched. A simultaneous development is the introduction of hybrid sunflower with lower crude fibre and higher oil content. Ideally, the technical data on the nutritive value of the cake for different classes of livestock should be obtained while the project is still in the developmental and proliferation stage, so that non-optimal methods of utilization do not get established in the field that might be difficult to dislodge at a later date.

DEVELOPMENTAL CONCEPT

Integration of rural oil expelling and livestock activities

Oilseed processing using the ram press is currently profitable in both Zimbabwe and Tanzania if sufficient seed throughput can be achieved. The sunflower seed and oil price ratio is sufficient to achieve a margin which can cover all costs. There is concern that cheap palm oil imports into both Zimbabwe and Tanzania as a result of structural adjustment policies being implemented will depress the cooking oil price generally and thereby the financial margin gained using the ram press unless the value of the cake is also maximized. The concept promoted in this project is the closer integration of rural small-scale oil processing and livestock production activities to enable the maximization of income from oil and oil-cake. Integration will also improve the sustainability of oilseed cultivation because of the additional employment in the associated industries. Further, the rural economy will benefit from the availability of cheaper cooking oil and livestock products (such as, eggs and milk), with a direct impact on the health of the rural population. Currently it is not uncommon for consumers in the rural areas around Harare to have to travel to the city for produce of some livestock products.

Environmental implications Increased utilization of sunflower oil-cake in rural areas represents an improvement in the management of the resource, as feed storage time, and hence, the possibility of its deterioration through rancidity or mycotoxin formation, is reduced. An environmental benefit of utilizing rural resources in the rural areas relates to nutrient cycling in farming systems, as excreta from the livestock enterprises are returned to the soil as manure (contrast with the prevailing situation of the transfer of nutrients to the urban areas).

Gender concerns

Rural oilseed processing is a technology currently being promoted as a means of encouraging rural business development and employment for women. There are many women operators of ram presses in both countries. Small-scale poultry production is also a popular income generating activity of small-holder co-operatives and women.

In summary, the integration of proposed activities will:

- make domestic agriculture more efficient;
- increase rural incomes;
- increase the availability of cooking oil and livestock products (eggs, milk and meat) for rural households.

The mechanism for integrating will vary with the socio-economic environment, but will require basic research data for adapting anima l feed technologies.

ACTIVITIES

This project will investigate the principle factors that affect the utilization of sunflower seed cake by different classes of livestock, and then determine appropriate feeding strategies for use of the oil-cake to realize it's optimal value under different socio-economic situations.

The activities include a comprehensive analysis of oil-cake samples collected from ram press operating sites in Zimbabwe and Tanzania to determine the variability in nutritive value under different pressing conditions and the type of seed (open-pollinated or hybrid) processed. NRI will analyze the oil-cakes for amino acid and mineral composition; metabolisable energy values using chicks; in vitro rumen degradability using 'gas production' technique; free fatty acid, peroxide and panisidine values (measures of oil oxidation); and mycotoxin contamination (aflatoxin, tenuazonic acid, alternariol, cyclopiazonic acid, and ochratoxin A). The sediment remaining after clarifying the crude sunflower oil will also be analyzed to determine its potential as a feed ingredient.

Based on these data, prediction equations will be established to determine the metabolisable energy value of the sunflower seed oil-cake for poultry and the development of simple mixed feeds for rural poultry production, and feeding strategies for other major classes of livestock. It is stressed that the project aims to produce balanced feeds at low cost. These will be the optimum that can be easily attained within the constraints of the rural environment.

The feeding strategies developed will be extended to rural ram press owners and livestock owners in conjunction with local institutions and NGOs.

BENEFITS AND BENEFICIARIES

The immediate beneficiaries are expected to be rural oilseed processors and their dependent workers, through increased local sales of oil-cake-based feeds, through the use of cakes to feed their own livestock and through savings in transporting cake elsewhere. Secondary beneficiaries will be rural poultry, dairy and beef producers, who will be able to benefit from a local supply of cheaper animal feed products. It is envisaged that the supply of eggs and poultry will also increase due to the benefits of more nutritious feeds.

WIDER DISSEMINATION

The wider aspect of this project concerns the development of sunflower seed cake and small- scale oil-expelling in sub-Saharan Africa generally. The introduction of ram presses has produced direct developmental benefits for the rural population in several developing countries. Furthermore, sunflower is a neglected but important small-holder cash crop in many other tropical countries besides Zimbabwe and Tanzania. Thus, in the longer term, the results of the proposed project could have applicability in other countries where the model is replicated. Farmers in several African countries are expressing interest in the ram press and ATI have several more country programmes either underway or planned. None is yet as far advanced as the Zimbabwe and Tanzania projects. Other oilseeds are capable of being processed in the ram press and sesame, groundnut, nigerseed and coconut are likely to be the subject of later projects. The successful implementation of this project will provide a template for similar exercises elsewhere using press-cakes from these oilseeds as raw materials in animal feeds.

APPENDIX 5. TITLES OF FIFTEEN OTHER PAPERS OUTSTANDING FROM PREVIOUS RESEARCH ON TROPICAL POULTRY FEED DEVELOPMENT AT NRI

1 The effects of cassava root meal of different cyanide content on egg production

2. The effects of sulphur supplementation in the form of methionine, the metabisulphite, thiosulphate, sulphate and sulphite salts of sodium on broiler and layer performance

3. Use of pelleting and inclusion of vitamin-mineral premixes on the utilisation of cassava roots in broiler chick diets

4. Responses of laying hens to copra cakes of different residual oil content, and the influence of storage period

5. Responses of laying hens to dietary palm kernel meal at up to 40 per cent dietary inclusion rate

6. Effects of assuming different values for the metabolisable energy value of palm kernel meal on egg production at 50, 60 and 70 per cent dietary inclusion rates

7. Responses of broiler chicks fed cottonseed meal treated with ferrous sulphate at two concentrations

8. The effects of pelleting on the free gossypol content of cottonseed meal and its utilsation by broiler chicks at up to 50 per cent dietary inclusion rate

9. Effects of assuming different values of metabOlisable energy and lysine contents on the performance of broiler chicks fed cottonseed meal

10. Effects of ammonia-treated, aflatoxin-contaminated cottonseed meal on the growth responses of broiler chicks

11 Effects of different plant and animal fats on egg production and yolk fat saturation

12. Effects of different processing methods on the nutritional value of *Cassia tora* seeds for broiler chicks

13. Effects of formic acid-ensiled fish by-catch and subsequent drying on copra cake on egg production: results of taste panel studies

14. Effects of dietary cottonseed meal of different free gossypol and cyclopropenoid fatty acid content on egg production and egg discolourations