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Final report

project

Enhancing role of small scale feed milling in the development of the monogastric industries in Papua New Guinea

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2 Executive summary

Smallholder and semi commercial aquaculture, pig and poultry farming are making an important contribution to the livelihoods of rural households in PNG. An increasing number of farms are being established around major urban markets because of the demand for high quality animal protein. Currently the monogastric sector in PNG has a market value of A$200m/annum comprising about 600,000 smallholder farmers. Local feed resources are available that could be utilized better to feed fish, pigs and poultry. This project aimed to assist the monogastric sector to develop cheap balanced diets and to encourage the establishment of small scale regional feed mills to manufacture diets based mainly on local feed resources rather than imported ingredients. Previous research has identified that there is a significant reduction in costs when poultry diets are manufactured by mini mills using local feed ingredients.

One focus of the project was to determine the factors affecting the development of mini mills by undertaking a survey in the Madang Province, Eastern Highlands Province, Western Highlands Province, Jiwaka Province and the Western Province. The survey included mini mills in the provinces and farmers who had previously participated in poultry and aquaculture projects as well as other pig, poultry and fish farmers close to the mini mills.

The survey showed that farmers had a favourable attitude but little knowledge of the role of mini mills in PNG. Farmers were keen to use feed made by mini mills but were constrained by lack of training. The level of farmer training, extension and knowledge was found to have a positive relationship with the attitude of farmers towards mini mills. In addition family size, farmer's age and attitude, training and access to extension had a positive relationship with farmer's knowledge. The survey results also showed that the main reasons for farmers becoming involved in livestock farming were for its socio-cultural importance, the market and business opportunities it presented and as a hobby. The training required by farmers was in feeding of livestock and fish, animal health and animal breeding. The issues affecting industry development were lack of extension, training and technical assistance. There were also inconsistent supply of expensive feed, fingerlings, piglets and day old chickens. Industry development was also constrained by limited infrastructure, an inefficient market supply chain and lack of capital. Other issues included poor animal health and welfare, high mortality and lack of medication, poor transport and access to the market and issues caused by natural disasters.

The development of mini mills was supported by preparing a manual titled "Mini feed milling in Papua New Guinea" which provides details of the milling process, business and financial plans, mill layout and equipment, mill management, feed ingredients available and diets based on use of PNG feed ingredients. Business models were developed for mini mills that sell feed to enterprises producing broilers, eggs, fish and pigs including cost of production models for these village farms.

To support development of the market, industry value chains were developed for the layer, broiler, pig and inland aquaculture sectors with emphasis put on the value chain sectors that require further market development particularly farmer sales to local markets. Value chain research was conducted on selected mills. The value chain research highlighted the need to encourage improvement of the livestock and fish value chains in PNG, develop new value added products and provide greater incentives for market participation. There is a need to increase the output, quantity, quality, prices and distribution of pigs, poultry and fish products in enterprises associated with feed mills. Following the value chain analysis a strategic plan for the mini mill sector in PNG was developed to promote development of mini feed mill enterprises by implementing improved operation, business and marketing skills and greater use of local feed.

A second focus of the project was to formulate a range of least cost diets for fish, pigs and poultry using local feed resources that can be produced by mini mills. The diets were evaluated in on-station and on-farm feeding trials with pigs, poultry and aquaculture. An experimental set up for the aquaculture trials with tilapia was built at NARI and included a water recirculation system, a biofilter and water quality evaluation system. The tilapia diets comprised a fish concentrate, mixed with cassava or sweet potato or cassava leaf plus sweet potato and cassava roots and compared to a control diet. Fish fed the local diets performed better than the standard diet when assessed on the basis of body weight and weight gain.

Research examined the role of sweet potato, cassava and sweet potato and cassava silage in pig grower diets mixed with a pig grower concentrate. Three digestibility experiments examined feeding value of milled, boiled or ensiled cassava and sweet potato. Regardless of preparation as boiled, ensiled or milled, cassava and sweet potato roots, blended with a complimentary protein concentrate, improved nutrient digestibility and growth in pigs compared to a standard commercial feed. The results confirm the effectiveness of cassava and sweet potato roots as energy feed substitute for imported grains. These blended cassava and sweet potato root diets are recommended for village farms producing local mixed genotype pigs. An on-farm proof of concept pig feeding trial was conducted using ensiled sweet potato roots fed to local mixed genotype pigs in the Western Highlands Province. The diet tested was mixed at a mini mill and comprised a pig concentrate blended with sweet potato ensiled roots and compared to commercial grower pellets. Pigs fed the silage diet had a superior feed efficiency and was cheaper to feed than the commercial diet.

Research also was undertaken to examine the types of insoluble fibres present in sweet potato cultivars and the role of insoluble sweet potato fibre on broiler performance, digestibility, gut capacity and gut micro flora. The metabolizable energy of sweet potato diets was improved when a multipurpose enzyme was included. There was a decrease in gut levels of E. coli and Enterobacteriaceae in birds fed sweet potato diet with the enzyme included. A growth study was conducted in broilers fed five selected PNG sweet potato varieties. Bird performance was influenced by non-starch polysaccharide content of the sweet potato variety. There was a slight improvement in feed conversion of birds fed with sweet potato varieties which had a high glucose and high non-starch polysaccharide content and when the enzyme was included in the diet.

Layer feeding trials compared egg production and egg quality of hens fed sweet potato and cassava based diets blended with a protein concentrate with hens fed a standard layer commercial diet. The results with layers suggest that feeds containing the local feedstuffs can be used by farmers to produce eggs from both exotic and local chickens.

Proof of concept trials were conducted to assess the production and economic aspects of mini mills supplying feed to village poultry and aquaculture farmers. In addition a universal poultry concentrate suited for village poultry, commercial layers and broilers was formulated to blend with local feed ingredients.

Proof of concept trials on village farms were conducted using crossbred village layers in the Madang Province and commercial layers and broilers in the Jiwaka Province in PNG. The birds were fed either a commercial poultry diet or a Universal Concentrate blended with cassava. The blended poultry diets were prepared using the mini feed mill facilities at the Domil Cooperative mini mill and the Labu mini mill. Egg farmers from the Domil cooperative and from the Banz region participated in the layer trials. Feed intake, egg production and egg weight were higher for the commercial hens fed the commercial layer diet compared with hens fed the Universal Concentrate blended with cassava but cost of production was higher for the birds fed the commercial feed. Egg farmers at Transgogol and Amele in the Madang Province used village crossbred hens to compare the commercial layer diet with the mini feed mill Universal Concentrate blended with cassava. Feed intake, egg production and egg weight were superior for hens fed the commercial diet but as found previously the cost of egg production was higher for birds fed the

commercial feed. For the broiler feeding trials conducted on village farms from the Jiwaka Province a 3% higher body weight gain was noted for birds fed the Universal Concentrate blended with cassava compared to the commercial ration.

Proof of concept aquaculture feeding trials at Yalu and Kefamo were conducted using earthen ponds and at Yonki using cage culture. The aim was to assess the growth of GIFT Tilapia growers fed with diets made with sweet potato or cassava combined with a fish feed concentrate compared to a control diet. The blended aquculture diets were prepared using the mini feed mill facilities at the Labu and Goroka mini mill. The three diets tested comprised cassava mixed with a fish concentrate; sweet potato mixed with a fish concentrate and a standard diet. In the trial conducted at Yalu fish fed with the cassava based diet had poorer growth and FCR than the control diet but at Yonki and Kefamo fish fed the with sweet potato based diet had better growth and FCR than the standard diet. Use of the feed concentrate technology mixed with sweet potato resulted in in promising growth of tilapia. The cost of the feed concentrate and manufacturing of the diet at the Labu Mill is cheaper than cost of producing a standard fish diet.

The third focus of the project was to facilitate the adoption of feed mills in PNG. Staff from the Entrepreneurship, Commercialisation and Innovation Centre at the University of Adelaide brought their business experience and teaching skills to run a business planning workshop in Lae, PNG from July 28-30, 2015 for 30 participants including farmers, NGO's and representatives from the PNG National Agricultural Research Institute and PNG University of Technology. The workshop participants were trained to develop a draft of a real-world business plan for their feed mill incorporating market research, SWOT analysis, business governance, capital purchases, fixed and variable costs, profit and loss forecasting, budget and cash flow statements, costing and pricing strategy, financial projections and risk analyses. The participants created a basic draft of a business plan for their own circumstance, using actual figures or estimates as appropriate. At the end of the workshop oral reports were given on the business plans. The participants reported the business workshop had increased their understanding of the business tools that are available and how it can be applied in their business.

An ACIAR monograph of 29 project papers were prepared by PNG and Australian research scientists to report results on feeding trials with growing pigs, meat chickens, laying hens and tilapia using local feed resources blended with a concentrate produced by a mini mill or a commercial feed mill. Recommendations on the most profitable feeding system to adopt were highlighted and papers on the socio-economic and market aspects that influence the uptake of feeding systems and adoption of mini mills were published in the monograph.

On the basis of the benefits obtained from using mini mills and the results obtained from feeding trials with pigs, poultry and inland aquaculture a communication strategic plan was implemented. The plan aimed to ensure that the PNG central government and provincial government, research institutes, universities, rural banks, agriculture aid donors including the international fund for agriculture development were made aware of the benefits of mini mills and the concentrate feeding systems for pigs, poultry and inland aquaculture. In addition a plan was implemented to communicate more widely the benefits of the adoption of the use of mini mills and feeding systems to semi commercial and smallholder farms using demonstration activities and multimedia.

Promotion of the feeding system using local ingredients and the role of mini mills in monogastric sector in PNG and other Pacific countries has involved about 1,500 farmers (about 30% females) who have participated in the feed mill project through training and on- farm trials. Farmers who have been trained to mix feed, feed poultry, pigs and fish have been associated with the current ACIAR project and also through the ADRA, Oxfam, World Vision projects in PNG and EU-ARD project in PNG, Solomon Islands and Vanuatu. In some sites there have been more women than men and for some communities women tend to take lead in applying the knowledge and technology more so than men.

3 Background

Pig and poultry are the most favoured meat protein sources in PNG, while there have been increased demands for fish from inland aquaculture. Total livestock production in PNG is 57,000 tons per year (Bourke and Harwood 2009) with pig and poultry products making up 95% of domestic production. Based on indicative figures of the 2000 PNG National Census data (NSO 2002), half of the rural households and 10% of urban households in PNG are engaged in some kind of livestock production; which includes about 360,000 pig farmers, 220,000 poultry farmers and about 20,000 fish farmers (Ayalew 2011).

Most fish farmers currently have small ponds and produce about 55 kg of fish/annum. Pig production at village level (Hide 2003) is the main livestock species kept by most villagers for food and cash sales. The average number of pigs farmed is between 1 and 5. Pork is the most consumed meat in PNG with an estimated 5 kg eaten per person each year. The owning of pigs gives a higher social standing and is always a part of the bride price payment and ceremonial festivals. The poultry sector comprises a village broiler market growing 50 birds in 5-6 batches/year producing about 7 million birds per year (Glatz, 2007), an emerging layer sector using commercial hybrids at the village level in 50-100 bird lots and the traditional indigenous sector with about 10 birds per family unit. There is a great opportunity for village farmers to 'cash in' on the huge demand for animal protein, improve their food security and reduce poverty.

The major cost associated with farming fish, pigs and poultry is feed. It accounts for up to 80% of the cost of production. Most of the feed ingredients used in semi commercial production in the monogastric sector is imported which has resulted in a continual increase in feed costs. The sustainability of the monogastric sectors can be improved if cheap feed can be provided to farmers using mainly local feeds manufactured by mini mills. Improving the profitability of the smallholder and semi commercial aquaculture, pork and poultry farming sector through the use of locally available feed resources has been identified as a high priority by the PNG government, NFA and NARI.

The major constraint to the expansion of the monogastric enterprises in the semi commercial and village sectors is the availability of cheaper feed. A previous ACIAR project, FIS/2006/001 'Increasing capacity for regional fish feed manufacture in PNG', recognized the feed availability and cost of feed issue and established pilot mini feed mills. PNG commercial mills are well established in Lae but promotion of small mills only started a few years ago with an ACIAR SRA aquaculture activity in collaboration with PNG equipment suppliers and PNG government agencies. A number of NGO's and Institutes in PNG have small mills. In project ASEM/2005/094 "Improving the profitability of village broiler production in PNG" an economic assessment verified that locally milled broiler concentrate was 30-40% cheaper than commercially available alternatives at several key sites in PNG (Black and Yalu, 2010).

Therefore the current project was developed to link mini feed mill enterprises with the village aquaculture, pork and poultry farmers. There are a number of sites in PNG where business, market and social research can be undertaken to gain a better understanding of the issues that need to be resolved before full scale adoption on feed milling plants can be promoted. The emphasis was on mini mills producing 5-10 tonne of concentrate each week which would service about 5000-10000 poultry in a district, as an example. The main activity of the small mills is to produce the supplement for pigs and poultry and make the complete fish diet. The fish diets can be sold direct to the farmers with an emphasis of using mainly local ingredients in the diet where possible.

This project aimed to develop, test and disseminate diets that are best-bet feeding options for tilapia, poultry and pigs based on availability of feed resources near feed mill sites. The concentrate feed ingredients comprising the major portions of protein, vitamins and minerals will be sourced by mini mills where they available. The mini mill target groups in

PNG are producing a limited range of diets mainly for aquaculture. These mill sites are working models which the partners in this proposed project consider suitable for promoting the small scale feed mill activity in PNG. However data needs to be gathered from each of these enterprises to develop the business models to evaluate the real world costs, management, operational issues and constraints.

The preliminary work undertaken in PNG (FIS/2006/001) and Tonga (LPS/2006/149) with the establishment of small scale feed milling plants resulted in some issues which require further investigation before adoption can proceed on a wide scale in PNG. These include establishing regional availability of suitable local feeds, power requirements of equipment, internal finance issues and ownership of equipment, micro finance facilities, lack of staff confidence when using equipment, maintenance of plant and lack of knowledge on local marketing of feed.

The development of a manual for feed mill set up and operation is needed by operators of new feed mill plants and for staff operating mills and based on the 'HACCP-based quality assurance system.' In addition fundamental social questions need to be addressed in village communities where aquaculture, pig and poultry production is being promoted. Is it socially acceptable to introduce mini mill enterprises and expand the fish, pig and poultry market? Personnel who intend to get involved in the smallholder feed industry would benefit from training to manufacture the diets. Most lack the necessary skills and experience to make high quality farm made feeds suitable for feeding fish, pigs and poultry. Knowledge on the infrastructure required to produce and store dried feed and ingredients is also limited.

This project aligned with the vision of the PNG National Agricultural Development Plan (2007-2016) published by the Papua New Guinea Ministry of Agriculture and Livestock (2007) to transform the agriculture sector into a vibrant and productive economic sector that contributes to economic growth, social wellbeing, national food security and poverty alleviation. The development of the local feed mill industry is likely to encourage employment opportunities for allied sectors providing resources and services to the feed mill and monogastric farm sector including multiplier effects for the local economy.

4 Objectives

The aims of the project were to improve the profitability of smallholder and semi commercial aquaculture, pig and poultry production in PNG by at least 25% over 5 years for those that adopt the technologies and to increase smallholder aquaculture, pig and poultry production by 5% per annum over the same period. This could be achieved by promoting existing and new monogastric enterprises to use lower-cost feed manufactured by mini mills and to market feed and livestock products through organized markets.

4.1.1 Objective 1. Determine the factors affecting the development of mini feed mills for the monogastric industries in PNG

Activity 1: Use surveys to evaluate social acceptability and attitudes to use of locally milled feeds in monogastric enterprises.

Activity 2: Establish the market segments using a market chain approach for locally milled feeds, farmed fish, pigs and poultry and supply chains in remote and town areas.

Activity 3: Examine the potential for integration of feed supply, feed manufacturing, fish, pig and poultry production and sales in regional areas.

Activity 4: Develop the business models and user briefs for establishing mini mills in a range of locations.

4.1.2 Objective 2. Formulate a range of least cost diets using local feed resources that can be produced by mini mills which meet the nutritional requirements of the most popular farmed fish, pigs and poultry in PNG.

Activity 1: Develop a range of least cost diets using feed formulation which can be manufactured by mini mills based on local feed ingredients for various sites in PNG.

Activity 2: Test a range of diets for fish, pigs and poultry using on-station trials at Institutional partner sites.

Activity 3: Undertake region-specific feeding trials with NGO's to develop local knowledge and refine feeding options for testing on-farm.

Activity 4: Determine best-bet feeding options on-farm for fish, poultry and pigs based on regional availability of feed resources.

4.1.3 Objective 3. Facilitate the adoption of mini feed mills in the monogastric industry in PNG to improve smallholder and semi commercial farm profitability.

Activity 1: Conduct workshops with partners, stakeholders and entrepreneurs at feed mill sites and provide information about on-station and on-farm activities and feedback on-farmer experiences with local diets.

Activity 2: Distribute updated leaflets and village training materials widely across PNG to promote the adoption of the diets and feeding systems for aquaculture, pig and poultry production.

Activity 3. Run a coordinated campaign to promote the use of lower-cost feeding regimes in monogastric enterprises building on the outcomes of the farmer demonstration trials.

Objective 4. Consolidate research outcomes with project partners;

Activity 1. Involve SARDI junior scientists in the project.

Activity 2. Interact with a broader range of PNG stakeholders.

5 Methodology

5.1 Objective 1. Determine the factors affecting the development of mini feed mills for the monogastric industries in PNG

The rationale for the first stage of the methodology was to understand the factors which influence the establishment of mini mills and the future development of the monogastric sector by undertaking socio-economic and market surveys in the pig, poultry and aquaculture market chain. The project inception meeting was held early in year 1. Key project partners and other stakeholders developed the survey questions and a student project activitiy was associated with the survey.

Two surveys were undertaken; the first survey was undertaken at four sites in PNG while the second survey involved a more detailed investigation of farmers attached to one of these sites, namely the Domil Cooperative in the Jiwaka province.

The first survey aimed to evaluate and identify the socio-economic issues affecting small holder livestock and aquaculture farmers that were located close to mini feed mills in PNG. There were more than 20 sites where farmers were located close to mini mills. The initial survey sites chosen were the Keripia and Mount Hagen site in the Western Highlands, Domil cooperative site in the Jiwaka Province, Pikosa village and Goroka sites in the Eastern Highlands and the Kiunga site in the Western Province.

The sites selected for the first survey were representative of pig, poultry and aquaculture enterprises close to where the mini mills had been established. The aim was to gather baseline information on-farmer constraints such as access to feed, costs of inputs, product, market access and level of training that affected the operation of existing and potential poultry, aquaculture and piggery farms.

5.1.1 Socio-economic survey

Survey at four sites

The first survey collected qualitative and quantitative data. The qualitative data was obtained from a conversation with farmers while the quantitative data involved asking questions and recording the answers provided by farmers. To obtain qualitative data farmers were asked to provide views on their enterprise. To obtain the quantitative data, farmers were interviewed to identify the constraints that they faced in their enterprise.

Survey at the Domil site

The second survey was undertaken with farmers who were members of the Domil Cooperative farming 12,000 meat birds per annum. The specific objectives of the second survey was to determine the farmers attitude to mini feed mills; determine farmers knowledge about the mini feed mill set up and determine the constraints faced by the farmers using feed from the mill.

Fifty farmers were selected to participate in the Domil Cooperative survey. Data was collected on socio-economic attributes that influence attitude, knowledge and constraints. Section one of the survey had questions on socio-economic attributes of farmers. Section two included statements relating to attitude which was measured using the Likert Attitude Scaling approach (Trochim, 2006). The knowledge of farmers was scored using the constraints facing index (CFI) using scores on the extent of difficulty each farmer faced (Rahman, 2000).

The qualitative approach involved focus group discussions with key stakeholders. For example, 15 Domil farmers were asked key questions to stimulate discussion, and other questions to obtain detailed information on issues relating to the mini feed mill, spin-off

effects of the mini feed mill, poultry feed, feed formulation, sources of raw materials, constraints faced and value added options.

Categories at the Domil site

Low, medium and high categories were created for attitude and knowledge and constraints variables. To determine the categories within each variable, variables that fell between 1-50% of the score range received a low rating (1- 50% = first category), scores between 50% plus one to the mean plus one standard deviation fell in the second category (upper limit). Any scores that were above the upper limit were included in the third category.

Measure of farmer's attitude

The attitude of broilers farmers were measured using Likert Attitude Scaling (LAS) with 18 statements. Response to statements were strongly agree, agree, uncertain, disagree and strongly disagree. In this survey, strongly agree achieved a score of five, whilst the other extreme, strongly disagree scored one, and the reverse for negative statements was applied. Possible attitude score of the respondents varied from 0-90 for the 18 statements; 0 being a highly unfavourable attitude, whilst 90 was a highly favourable attitude.

Measure of farmer's knowledge

Each of the respondents responded to 10 statements relating to their knowledge on feed ingredients, feed formulation, processing and use of the mini mill feed. The knowledge of farmers on local feed and use of the mini feed mill were measured using a scoring system. A correctly answered statement was allocated a score of three points; two points for a partially answered question and one point for an incorrect statement. Possible knowledge score ranged from 1-30; 1 being less knowledgeable on the feed mill technology, and 30 being more knowledgeable on the feed mill technology.

Measure of farmer's constraints

Constraints faced by farmers using mini feed mill diets were regarded as a dependent variable in the study. This was measured on the basis of nine selected constraints, which relate to aspects of the mini feed mill diet, production of feed and mill utilisation. The independent variables of the study included; 1) poor extension services and lack of information; 2) lack of marketing; 3) low market value; 4) non-availability of inputs (feed ingredients); 5) lack of training; 6) lack of credit or capital to invest; 7) complexity of practice; 8) criticism by family and/or relatives and 9) poor access to day-old chickens. Each respondent was asked to indicate the extent of difficulty caused by each constraint and record responses ranging from very high, high, little, not at all, with weights assigned to each responses from 3, 2, 1 and 0. Scores from all nine selected aspects were summed together to get the individual constraint score. Survey data was analysed using the Statistical Package for Social Scientist (SPSS 20).

5.1.2 Value chain analyses

Value chain methodology

To analyse the value chains in PNG all the production, processing, packaging, transporting, marketing and selling activities to get the product to the consumer were assessed in the pig, poultry and aquaculture sectors. These included all inputs, genetics, products, feed, processing and markets. The focus of the supply chain activity was to assess how to get the product from the producer to the consumer as cheaply as possible, reduce the production costs and avoid wasteful activities and make the supply chain more efficient. To analyse the value chain, an effort was made to examine the structure of the industry, links in the chain, number of customers in the chain, flow of the product, value adding occurring, flow of information between links, economic value from farmer to customer and consumer and the level of trust, sharing and collaboration.

The market participants and businesses examined along the chain included farmers, middle men and traders or collectors, brokers, wholesalers, processors and retailers.

Value chain workshop

Theo Simos (value chain analyst) led 2 sessions at a workshop with project participants to map the egg, chicken meat, pork and aquaculture sectors including the supply of feed ingredients to feed mills and rations prepared by feed mills. Market chains analysis in the PNG monogastric sector aimed to identify major players along the chain; improve the efficiency and the effectiveness of these players; identify blockages along the chain and reduce the costs of production.

Mapping of the pig, poultry and aquaculture value chains

The value chain research methodology was used to investigate the overall commercial and small holder sector nominated mills including aspects across the value chain such as; feed and other inputs, operations, flow of products, distribution of feeds to farmers, farmer use of feeds, sales and marketing of live animals, slaughtering/processing and sales pathways to consumers.

Value chain maps were developed for the overall commercial and small holder sector in the pork, egg and aquaculture industries to get an initial understanding of the structure of the industry and where the mini mills fit and then to follow with mapping of the value chain at 3 mini mill sites.

Mapping of Domil mill, Goroka mill, Pikosa mill and Tambul mill

The value chain analysis for individual mills was undertaken at the Domil mill with a focus on broilers; at the NFA Goroka mill and Pikosa Community Mill with a focus on inland fish and the Tambul private mill with a focus on pork.

5.1.3 Strategic Plan for mini mills

On the basis of the findings in the value chain analysis a strategic plan for the mini mill industry in PNG was developed to improve operation of mills and business and marketing skills of mini mill enterprises.

5.1.4 Business Models

The previous ACIAR project “Improving the profitability of village broiler production in Papua New Guinea “ (ASEM/2005/094) developed recommendations for feeding meat chickens using protein concentrates mixed with sweet potato in the highlands or cassava in the lowlands. This current project aimed to develop cost and profit models of mini mills producing pig, poultry and aquaculture diets and for pig, poultry and aquaculture enterprises purchasing the feed from the mini mills. The model also examined use by mini mills of a Universal Concentrate manufactured by commercial mills and use of sweet potato silage and cassava silage as a substitute for sweet potato tubers and cassava tubers in hybrid pig village enterprises in the highlands.

Model format

The models were developed on XL spreadsheets. The detailed assumptions for items and explanations of each of the cell calculations for each item are contained in the electronic versions, as notes.

Major sources of information were obtained as follows:

- Fresh Produce Development Agency statistics for sweet potato and cassava market prices.
- PNG generalised grouping price indices to update initial price estimates.
- Kaliber, Indonesia – equipment and machinery costs.

- Expert opinion provided by participants at project workshops and
- "Commercial in confidence" price data for micro-ingredient and protein sources.

An important assumption used in the models was the application of a 30% discount to the market prices of sweet potato. This is thought to be justified because time is saved by avoiding selling individual tubers in markets, and the use of sub-standard tubers that are acceptable when used in bulk in mini mill mixes or in village enterprises.

The modelling reflects prices and assumptions made in August 2015. Such assumptions and prices, and therefore modelling results, may not apply accurately at times later than this.

5.1.5 Feed Mill User Brief

The user brief was an essential resource to provide mini feed mill managers, staff, researchers and industry people with a resource when establishing mini mills. The brief was aimed to outline best practice protocols and solutions to problems for mini mill enterprises. The user brief aimed to present the information in an easy to read style, so that the main issues associated with mini mills are easily understood.

5.2 Objective 2. Formulate a range of least cost diets using local feed resources that can be produced by mini mills which meet the nutritional requirements of the most popular farmed fish, pigs and poultry in PNG.

5.2.1 Formulate Diets

Formulation of the pig and poultry diets was developed by Carey Nutrition in consultation SARDI and NARI scientists. Dr Mark Booth, NSW Department of Agriculture developed the aquaculture diets in consultation with NARI scientists.

Pig grower diets

A pig grower concentrate was formulated from imported ingredients to mix with sweet potato, cassava, sweet potato silage and cassava silage. In addition a pig grower concentrate was formulated from local ingredients (fish meal, copra meal and mill run) and an imported premix to mix with sweet potato or cassava. It is common in PNG for village farmers to dilute commercial pig grower diet with sweet potato silage. The nutrient value of the resulting mix was evaluated using feed formulation software.

The composition and calculated nutrient specifications of the pig diets were as follows:

Composition of pig grower concentrate using mainly imported ingredients.

Wheat (12%); Meat meal (13%); Blood meal (5%); Fish meal (10%); Tallow (4%); Soybean meal (18%); Mill run (35.8%); Salt (0.3%); Choline chloride (0.1%); Rhodimet-88 (Meth) 0.4%; Lysine (0.1%); Lae premix (1%); Mycostat (0.1%); Sorbasafe (0.2%); MJ/kg = 13.9

Pig grower concentrate specifications

Protein (32%); Fat (8.6%); Fibre (4.5%); Ash (9.9%); Ca (0.6%); P (0.2%); Methionine (0.6%); Methionine + Cysteine (1.3%); Tryptophan (0.3%); Arginine (2.0%); Threonine (1.2%); Valine (1.7%); Lysine (2.0%); D Lysine (1.8%); Histidine (0.9%); Glycine (2.2%); MJ/kg = 13.9

Specification of 45% pig grower concentrate mixed with 55% cooked sweet potato

Protein (15.7%); Fat (4.2%); Fibre (4.2%); Ash (7.2%); Ca (0.9%); P (0.5%); Methionine (0.4%); Methionine + Cysteine (0.6%); Tryptophan (0.2%); Arginine (1.0%); Threonine (0.6%); Leucine (1.1%); Iso leucine (0.6%); Phenylalanine (0.8%); Valine (0.7%); Lysine (1.0%); D Lysine (0.9%); Histidine (0.6%); Glycine (1.1%); MJ/kg = 14.8

Specification of 43% pig grower concentrate mixed with 57% cooked cassava

Protein (16.3%); Fat (4.0%); Fibre (8.9%); Ash (5.7%); Ca (0.9%); P (0.5%); Methionine (0.4%); Methionine + Cysteine (0.6 %); Tryptophan (0.2%); Arginine (1.0%); Threonine (0.7%); Leucine (1.2%); Iso Leucine (0.6%); Phenylalanine (0.8%); Valine (0.7%); Lysine (1.0%); D Lysine (0.9%); Histidine (0.6%); Glycine (1.1%); MJ/kg = 14.8

Specification of 40% pig grower concentrate mixed with 15% sweet potato silage vine and leaves and 45% sweet potato tubers

Protein (15.7%); Fat (3.8%); Fibre (8.0%); Ash (5.4%); Ca (0.8%); P (0.5%); Methionine (0.4%); Methionine + Cysteine (0.6%); Tryptophan (0.1%); Arginine (0.9%); Threonine (0.6%); Leucine (1.1%); Iso Leucine (0.6%); Phenylalanine (0.7%); Valine (0.7%); Lysine (0.9%); D Lysine (0.8%); Histidine (0.6%); Glycine (1.0%); MJ/kg = 13.5

Specification of 50% standard pig grower diet diluted with 50% sweet potato silage

Protein (11.3%); Fat (2.3%); Fibre (5.1%); Ca (0.5%); P (0.3%); Methionine (0.1%); Methionine + Cysteine (0.3%); Tryptophan (0.1%); Arginine (0.9%); Threonine (0.3%); Leucine (0.7%); Iso Leucine (0.3%); Phenylalanine (0.4%); Valine (0.4%); Lysine (0.5%); D Lysine (0.4%); Histidine (0.3%); Glycine (0.6%); Phenylalanine + Tyrosine (0.7%); Salt (0.2%); MJ/kg = 9.5

Composition of pig grower concentrate using mainly local ingredients.

Sweet potato (20%); Fish meal (13%); Palm oil (3.5%); Copra meal (7.5%); Mill run (55%); Limestone (0.25%); DL Methionine (0.1%); Lysine (0.15%); Threonine (0.15%); Lae premix (0.5%); Mycostat (0.05%); Sorbasafe (0.1%); MJ/kg = 13.0

Specification of pig grower concentrate using mainly local ingredients

Protein (17.3%); Fat (7.7%); Fibre (6.0%); Ca (0.9%); P (0.6%); Methionine (0.4%); Methionine + Cysteine (0.7%); Lysine (1.1%); DL Lysine (0.9%); Tryptophan (0.2 %); Arginine (1.1%); Threonine (0.8%); Leucine (1.0%); Iso Leucine (0.6%); Phenyalanine (0.7%); Valine (0.8%); Histadine (0.4%); Glycine (1.0%); MJ/kg = 13.1

Poultry diets

The previous ACIAR project, “Improving the profitability of village broiler production in Papua New Guinea” (ASEM/2005/094) formulated a broiler protein concentrate using mainly imported ingredients. The ingredients for the broiler concentrate diet used in this project focused on using mostly local ingredients to mix with sweet potato and cassava. The composition and calculated nutrient specifications of the broiler diets were as follows:

Composition of broiler grower diet using mainly local ingredients including cooked sweet potato

Sweet potato (65%); Fish meal (7%); Palm oil (2.4%); Copra meal (7.0%); Mill run (9.2%); Soybean meal (8.8%); DL Methionine (0.15%); Lysine (0.12%); NARI broiler premix (0.23%); Mycostat (0.03%); Sorbasafe (0.06%); Rovabio-T-flex (0.012%); MJ/kg = 7.2

Specification of broiler grower diet formulated using local ingredients mixed with sweet potato

Protein (12.3%); Fat (4.1%); Fibre (2.9%); Ca (0.4%); P (0.3%); Methionine (0.3%); Methionine + Cysteine (0.5%); Lysine (0.7%); Threonine (0.4%); Linoleic acid (0.5%); Iso Leucine (0.5%); Salt (0.2%); Moisture (47%); MJ/kg = 7.2 [Note that this diet is fed as wet mash; hence the lower protein content]

Composition of broiler grower diet using mainly local ingredients mixed with cooked cassava.

Cassava (65%); Fish meal (7%); Palm oil (2.4%); Copra meal (7.0%); Mill run (9.2%); Soybean meal (8.8%); DL Methionine (0.15%); Lysine (0.12%); NARI broiler (0.23%); Mycostat (0.03%); Sorbasafe (0.06%); Rovabio-T-flex (0.012%); Moisture (47%); MJ/kg = 7.2

Specification of broiler grower diet using mainly local ingredients mixed with cooked cassava

Protein (11.8%); Fat (4.1%); Fibre (2.8%); Ca (0.4%); P (0.3%); Methionine (0.4%); Methionine + Cysteine (0.5%); Lysine (0.8%); Tryptophan (0.1%); Threonine (0.4%); Linoleic acid (0.6%); Iso Leucine (0.5%); Salt (0.2%); Moisture (47%); MJ/kg = 7.1 [Note that this diet is fed as wet mash; hence the lower protein content]

Layer concentrate diet comprising mainly imported ingredients blended with a greater range of local ingredients including fish meal, palm oil and copra meal.

The Layer concentrate was formulated from imported feed ingredients; Wheat, meat meal and soybean meal blended with sweet potato or cassava plus an imported layer premix.

Layer concentrate diet composition (g/kg); Wheat (580); Meat meal (200); Soybean meal (200); NARI layer premix (15); Mycostat (2); Sorbasafe (3).

The Layer concentrate can be mixed with local ingredients and sweet potato (g/kg); Sweet potato (600, 68% moisture); Fish meal (90); Palm oil (30); Copra meal (140), Shell grit (40), Layer concentrate (100).

Specification of layer concentrate mixed with 60% of cooked sweet potato (g/kg)

Protein (116), Fat (49), Fibre (25), Ca (21), P (4), ME = 1818 kcal/kg, methionine (2.1); Methionine + Cysteine (3.7); Lysine (6.8), Tryptophan (1.2); Choline - mg/kg (656); Threonine (4.5); Linoleic acid (5.2); Isoleucine (4.5); Salt (2.4), Na (1.1); Cl (1.3); moisture (44%).

The layer concentrate can also be mixed with local ingredients and cassava as follows (g/kg); Cassava (600, 68% moisture); Fish meal (90); Palm oil (30); Copra meal (140), Shell grit (40), Layer concentrate (100).

Specification of layer concentrate mixed with 60% of cooked cassava (g/kg)

Protein (113), Fat (49), Fibre (25), Ca (22), P (4), methionine (2.1); Methionine + Cysteine (3.6); Lysine (6.5), Tryptophan (1.2); Choline-mg/kg (786); Linoleic acid (5.9); Isoleucine (4.2); Salt (2.7); Na (1.1); Cl (1.3); moisture (44%)

Layer concentrate diet comprising mainly imported ingredients blended with sweet potato and cassava.

A low energy protein concentrate suited for mixing with sweet potato and high energy concentrate suited for mixing with cassava were formulated. The layer concentrate was formulated from imported feed ingredients; Wheat, meat meal and soybean meal and an imported layer premix.

Composition and specification of the high energy layer concentrate (g/kg):

Composition: Wheat (27%); Meat meal (15.67%); Tallow (4.17%); Sunflower oil (1.17%); Soybean meal (12.67%); Mill run (30.83%); Limestone (7.33%); Salt (0.06%); Choline chloride (0.03%); Rhodimet-88 liquid methionine (0.33%); NARI layer premix (0.41%) and Sorbasafe (0.17%)

Specification (g/kg); Protein (219), Fat (88), Fibre (45), Ca (44), P (8), ME = 2610 kcal/kg, methionine (5.6); Methionine + Cysteine (9.0); Lysine (10.8), Tryptophan (2.2); Choline mg/kg (1286); arginine (14); Threonine (7.3); Linoleic acid (17.6); Isoleucine (7.9); Salt (3.7), Na (1.6); Cl (1.9); moisture (9.5%).

The high energy Layer concentrate was mixed with 40% of sweet potato to give a diet with the following specifications

Protein (14.4%); fat (5.8%); fibre (3.9%); ME = 2072 kcal/kg; ash (9.3%); Ca (2.7%); available P (0.5%); methionine (0.38%); Methionine + Cysteine (0.58%); Tryptophan (0.14%); Choline (mg/kg) 1007; Arginine (0.9%); Threonine (0.46%); Leucine (0.9%); Linoleic acid (1.08%); Isoleucine (0.51%); Valine (0.63%); Salt (0.24%); Na (0.1%) and Cl (0.13%).

Composition and specification of the low energy layer concentrate (g/kg):

Composition: Wheat (31.8%); Meat meal (15.83%); tallow (5%); sunflower oil (1.4%); Soybean meal (16.67%); millrun (20.5%); limestone (7.7%); Salt (0.1%); Choline chloride (0.08%); rhodimet-88 liquid methionine (0.4%); layer premix (0.42%); and Sorbasafe (0.17%)

Specification (g/kg); Protein (229), Fat (96), Fibre (35), Ca (45), P (7), ME = 2737 kcal/kg, methionine (6.3); Methionine + Cysteine (9.8); Lysine (11.5), Tryptophan (2.3); Choline mg/kg (1678); Arginine (15); Threonine (7.7); Linoleic acid (18); Leucine (15.3); Isoleucine (8.5); Valine (10.6); Salt (4.1), Na (1.8); Cl (2.2); moisture (9.3%).

The low energy layer concentrate was mixed with 40% of cassava to give a diet with the following specifications;

Protein (13.5%); fat (5.3%); fibre (3.3%); ME = 1997 kcal/kg; ash (9.6%); Ca (2.6%); available P (0.48%); P (0.75%); methionine (0.34%); Methionine + Cysteine (0.55%); Lysine (0.66%); Tryptophan (0.13%); Choline (mg/kg) 858; Threonine (0.45%); Leucine (0.9%); Linoleic acid (1.1%); Isoleucine (0.48%); Salt (0.24%); Na (0.1%) and Cl (0.1%).

Development of a Universal Concentrate for pig and poultry diets

Use of a single Universal Concentrate that can be used by mini mills to blend with local ingredients and some purchased supplements offers a cost effective method for mini mills to prepare pig and poultry diets for smallholder farmers. The large commercial mill have the bulk buying power to provide the protein based concentrate at cheaper price than what the mini mills can purchase. However this may not apply to all mini mill operators and mill cost models for diets need to be undertaken. The mini mills can use a Universal Concentrate purchased from a commercial mill to mix with dried cassava or dried sweet potato prepared at the mini mill site. For mixing the various rations the mini mill operator can purchase the following ingredients to mix with the Universal Concentrate.

- Layer ration-palm oil; sunflower oil, limestone (or crushed shells); salt and a layer Premix.
- Broiler ration-palm oil, broiler premix
- Pig Grower ration-Pig Premix

Universal Concentrate diet composition (g/kg); Meat meal (140.6); Blood meal (96.5); Fish meal (105.3); Tallow (43.8); Soybean meal (219.3); Mill run (384); Choline chloride (1); Rhodimet-88, liquid Methionine (6.3); Avizyme (0.7); Mycostat (0.855); Sorbasafe (1.75); Total 1000.15.

The Universal Concentrate diet specifications (g/kg); protein (377); fat (92); fibre (47); Ca (21); P (10); Methioinine (11); Lysine (24); D-Lysine (22); Choline 2234 (mg/kg); Phenylalanine + Tyrosine (29); Salt (5.8); MJ/kg = 14.2; dry matter = 90.3%

The ingredients of the layer ration (g/kg) are as follows; Cassava or Sweet potato (500); Palm oil (10); Sunflower oil (10); Limestone or Crushed Shell (80); Salt (1); Layer Premix (2.5); Universal Concentrate (400).

The ingredients of the broiler ration (g/kg) are as follows; cassava or sweet potato (400); Palm oil (30); broiler premix (4.0); Universal Concentrate (570).

The ingredients of the pig grower ration (g/kg); Cassava or sweet potato (500); pig premix (5.0); Universal Concentrate (500).

Tilapia aquaculture diets

In the first tilapia feeding trial diets were developed which used the broiler concentrate to mix with sweet potato, cassava and bran followed by formulation of a tilapia diet using the pig and poultry Universal Concentrate. Finally concentrate diets specifically formulated for tilapia to mix with local ingredients were developed.

Tilapia diets made using broiler concentrate mixed with local ingredients

Composition of tilapia diet using high energy broiler concentrate (75%); dried cassava (20%) and Palm oil (5%).

Specification of the tilapia diet using the high energy broiler concentrate was; dry matter (89.3%); crude protein (35.5%) and GE = 16.9 MJ/kg

Composition of tilapia diet using the low energy broiler concentrate was; dry matter (89.6%); low energy concentrate (75%); dried sweet potato (20%) and Palm oil (5%).

Specification of the tilapia diet using the high energy broiler concentrate was; dry matter (89.6%); crude protein (35.5%) and GE = 15.1 MJ/kg

These diets were compared to a benchmark diet prepared by the National Fisheries Authority (NFA) mill in Goroka, which is the only mini feed mill supplier of fish feed in PNG.

Specification of the NFA fish standard diet; dry matter (92.4%); crude protein (36.8%) and GE = 17.6 MJ/kg

Tilapia diets made using the Universal Concentrate mixed with local ingredients based on rice bran

Composition of the tilapia Universal Concentrate diet was; Universal Concentrate (64.2%); cassava meal (30.8%) and cooking oil (5%).

Specification of the tilapia Universal Concentrate; protein (23.6%); GE = 16.8 MJ/kg; fat (10.7%); ash (6.4%); NFE (49.2%); CP/GE ratio (g/MJ) = 14.0

Composition of the 20% rice bran diet was; Rice bran (20%); Fish meal (32.0%); Cassava meal (23%); Wheat mill run (23.0%); Tallow (2.0%).

Specification of the 20% rice bran diet was; crude protein (27.8%); GE = 16.9 MJ/kg; fat (8.7%); ash (8.6%); NFE (45.4%); CP/GE ratio ((g/MJ) = 16.4

Composition of the 40% rice bran diet was; rice bran (40%); Fish meal (30.0%); cassava meal (5%); Wheat mill run (23.0%); tallow (2.0%).

Specification of the 40% rice bran diet was; crude protein (28.6%); GE = 17.7 MJ/kg; fat (11.8%); ash (9.6%); NFE (40.9%); CP/GE ratio ((g/MJ) = 16.2

Tilapia diets made using a tilapia concentrate mixed with local ingredients

Composition (%) of the tilapia concentrate

Fish meal (20%); Meat meal (40.75%); Soybean meal (25%); tallow (2.24%); DSM premix (0.80%); blood meal (10.04%) and corn gluten (1.16%).

Specifications of the tilapia concentrate

Dry matter (92.97%); ash (17.39%); crude protein (48.00%); fat (10.00%); NFE (11.62%); gross energy (MJ/kg) = 17.00

Composition of the tilapia diet blended with local ingredients

Dried cassava (20%); dried sweet potato (20%); tilapia concentrate (60%)

Specifications of the Tilapia feed (concentrate blended with local ingredients)

Dry matter (90.56%); ash (11.41-12.60%); crude protein (29.83-32.94%); fat (6.23-6.88%), NFE (39.51-43.63%) and gross energy (MJ/kg) = 16.14-17.83

5.2.2 Test a range of diets for pigs, poultry and tilapia using on-station trials

Feeding trials with pigs

Pig grower trials with protein concentrate blended with sweet potato roots either boiled or ensiled with or without vines

The experiment was conducted on-station at the Livestock Research Station at NARI. Four Large White–Landrace×Duroc grower pigs (25.5 kg) nine weeks-of-age housed in metabolic crates were used in a 4×4 Latin Square experimental design, with four diets (control vs. sweet potato diets) interchanged over consecutive 8-day feeding periods with total collection of faeces and urine. ANOVA in GenStat 15th Edition (VSN Ltd) was used for the analysis of the Latin Square design and means were separated by Least Significant Differences.

Total fresh faeces were weighed, oven dried (105°C) and milled. Urine was collected over 24 hours. Dried faeces and urine were pooled for each period and duplicate samples stored at <0°C until analysis. Chemical tests were completed at the National Analytical and Testing Services Laboratory Ltd (Lae, PNG). Dry matter, ash, fat, protein and urine-N (by modified Kjeldahl), Ca and Total P were analyzed by AOAC (1990) methods. Nitrogen Free Extract was calculated. Lysine, Methionine and Methionine-Cysteine were estimated from the pig concentrate. Data were collated in MS Excel and ANOVA was conducted using GenStat 15th Edition (VSN Ltd) to analyse the Latin Square design and means were separated by Least Significant Differences.

The specifications of the diets were as follows;

Commercial pig grower diet; dry matter (88%); ash (6.4%); EE (3.8%); crude fibre (5.6%); crude protein (16.5%); NFE (55.7%); lysine (0.86%); methionine (0.24%); methionine + cysteine (0.53%); DE (MJ/kj DM) = 14.5; lysine:DE (g/MJ) = 0.58

Pig concentrate (57%) mixed with boiled sweet potato roots (43%); i.e. SPBR

SPBR; dry matter (50.2%); ash (4.3%); EE (2.2%); crude fibre (2.3%); crude protein (14.9%); NFE (35.9%); lysine (0.89%); methionine (0.36%); methionine + cysteine (0.55%); DE (MJ/kj DM) = 16.3; lysine:DE (g/MJ) = 0.54

Pig concentrate (57%) mixed with ensiled sweet potato roots (43%); i.e. SPER

SPER; dry matter (55.3%); ash (4.7%); EE (2.2%); crude fibre (2.4%); crude protein (14.7%); NFE (38.3%); lysine (0.86%); methionine (0.35%); methionine + cysteine (0.53%); DE (MJ/kj DM) = 16.1; lysine:DE (g/MJ) 0.53

Pig concentrate (60%) mixed with ensiled sweet potato roots and vine (40%); i.e. SPERV

SPERV; dry matter (36.8%); ash (4.3%); EE (1.9%); crude fibre (3.0%); crude protein (13.9%); NFE (27.6%); lysine (0.79%); methionine (0.32%); methionine + cysteine (0.49%); DE (MJ/kj DM) = 16.0; lysine:DE (g/MJ) = 0.49

Pig grower trials with protein concentrate blended with cassava roots either boiled or ensiled with or without vines

The experiment was conducted at the PNG National Agricultural Research Institute (NARI) Livestock Station, Morobe Province. The experiment design was 4x4 Latin Square with four diets (control vs. cassava based diets) as interchanged treatments fed to four grower pigs on four consecutive 8-day feeding periods. Four commercially sourced pigs, (Landrace x Large White) x Duroc, (28.0 kg) were placed into metabolic cages at nine weeks-of-age. Cages were equipped with trays for separation of faeces and urine. Each

feeding period included five days for adaptation to the test diets and three days feeding for collection of faeces and urine. Feed was offered ad libitum (remaining feed weighed as refusal) and water was available at all times.

Total fresh faeces were weighed, oven dried (105°C) and milled. Urine was collected over 24 hours. Dried faeces and urine were pooled for each period and duplicate samples stored at <0°C until analysis. Chemical tests were completed at the National Analytical and Testing Services Laboratory Ltd (Lae, PNG). Dry matter, ash, fat, protein and urine-N (by modified Kjeldahl), Ca and Total P were analysed by AOAC (1990) methods. Nitrogen Free Extract was calculated. Lysine, Methionine and Methionine-Cysteine were estimated for the pig concentrate. Data were collated in MS Excel and ANOVA conducted using GenStat 15th Edition (VSN Ltd).

The specifications of the diets were as follows;

Commercial pig grower diet; dry matter (88%); ash (6.4%); EE (3.8%); crude fibre (5.6%); crude protein (16.5%); NFE (55.7%); lysine (0.86%); methionine (0.24%); methionine + cysteine (0.53%); DE (MJ/kj DM) = 14.5; lysine:DE (g/MJ) = 0.58

Pig concentrate (55%) mixed with boiled cassava roots (45%); i.e. CABR

CABR; dry matter (51.5%); ash (4.6%); EE (2.2%); crude fibre (2.2%); crude protein (15.4%); NFE (37.4%); Lysine (0.89%); methionine (0.36%); methionine + cysteine (0.56%); DE (MJ/kj DM) = 16.3; Lysine:DE (g/MJ) = 0.57

Pig concentrate (55%) mixed with ensiled cassava roots (45%); i.e. CAER

CAER; dry matter (48.1%); ash (4.5%); EE (2.1%); crude fibre (2.1%); crude protein (15.4%); NFE (35.7%); lysine (0.9%); methionine (0.36%); methionine + cysteine (0.56%); DE (MJ/kj DM) = 16.3; lysine:DE (g/MJ) = 0.57

Pig concentrate (55%) mixed with cassava milled roots (45%); i.e. CAMR

CAMR; dry matter (88.4%); ash (5.2%); EE (2.3%); crude fibre (2.6%); crude protein (15.9%); NFE (63.2%); lysine (0.89%); methionine (0.36%); methionine + cysteine (0.55%); DE (MJ/kj DM) = 15.9; lysine:DE (g/MJ) = 0.58

On-farm pig feeding trial using ensiled sweet potato roots fed to local mixed genotype pigs in the Western Highlands Province

The trial was conducted at Robinson Kale's pig farm at Kindeng in the Western Highlands Province farm. The aim was to test the performance (feed intake, growth rate and feed efficiency) of local mixed genotype grower pigs fed ensiled sweet potato roots blended with a Pig Concentrate (SPER43) compared to pigs fed a commercial pig grower standard feed (STDPG) under restricted feeding. Due to the severe drought and shortage of sweet potato the diets could only be provided to pigs on a restricted basis.

A randomized complete block design was used for the trial comprising two diets (SPER43 vs. STDPG) with each dietary treatment replicated in six pens (2.25 x 3.65 m) with eight pigs per pen. An equal number (48) of barrows and gilts about 7-10 weeks-of-age were used in the trial with body weight ranging from 10-40 kg. Pigs were randomly allocated to pens and balanced for sex and weight. Pens comprised a concrete floor and walls and a tin roof.

The trial was conducted for 80 days over the period November 2015 to January 2016. The sweet potato roots were sourced from local markets, washed and grated using a modified flake mill. Table salt was added at 0.5% w/w mixed and packed and compressed into polyethylene air-tight garbage bags inside large 80 L plastic bins. Fermentation was allowed for 14 days before mixing and feeding once daily (0900-1000 h). The Pig Concentrate was purchased from Associated Mills Ltd (PNG) using a formulation supplied by Carey Animal Nutrition (Australia).

Specifications of the two treatment diets fed as pellets (STDPG) or blended meal (SPER43) to local mixed genotype grower pigs were as follows;

Pig concentrate (57%) mixed with 43% sweet potato ensiled roots (i.e. SPER43).

Moisture (50.8%); DM (49.2%); ash (4.5%); fibre (2.3%); fat (2.1%); protein (14.7%); NFE (32.3%); calcium (0.83%); total P (0.47%); total N (2.4%); DE (MJ/kg) 16.3; lysine (0.87%); methionine (0.47%); methionine + cysteine (0.72%); lysine: DE ratio (0.53); Ca:P ratio (1.76).

Commercial grower pellets (ie.STDPG)

Moisture (12%);DM (88%); ash (6.4%); fibre (5.6%); fat (3.8%); protein (16.5%); NFE (60.4%); calcium (0.92%); total P (0.97%); total N (2.6%); DE (MJ/kg) 14.8; lysine (0.86%); methionine (0.24%); methionine + cysteine (0.53%); lysine: DE ratio (0.58); Ca:P ratio (0.94).

Feed offered was restricted to 1.0 kg DM/day/pig for the SPER43 diet due to sweet potato shortage as a result of the drought and 1.5 kg DM/day/pig for the STDPG diet.

The mixed genotype pigs were bred by the Robinson Kale Family Piggery using multiple crossings of indigenous pigs with various exotic breeds. The pig shed was all-concrete, naturally ventilated shed with tin roofing covering 75% of the pen area. Water was provided ad libitum using two steel drinkers per pen.

Body weight, feed offered, average daily gain (ADG) and feed conversion ratio (FCR) were measured and data analysed using student ‘T’ test and ‘F’ tests. Pigs were processed by a licensed butcher with carcass measurements made on three pigs from each diet.

Feeding trials with poultry

Production performance of a Hyline Brown, a Hyline Brown x Australorp crossbred and Indigenous layers fed on a sweet potato or cassava based Layer concentrate diet.

The experimental work was conducted at the PNG National Agricultural Research Institute (NARI), Livestock Research Station at Labu located near to the Lae Township. The climate is typically warm and wet with an average temperature of 32°C and relative humidity of 88-90% during the experimental period.

Day-old Hyline Brown chicks were obtain from Christian Leaders Training College (CLTC) hatchery in Banz and raised on starter crumbles (12.13 MJ/kg, 21% protein, 7.7% fat and 4.1% fibre) during the first ten weeks and thereafter were fed on a pullet grower diet (10.95 MJ/kg, 17.5% protein, 4.6% fat and 4.8% fibre) until they reached week 18 weeks-of-age when commercial layer pellets (10.97 MJ/kg, 16% protein, 6.9% fat and 4.4% fibre) were fed up to the point of lay at 24 weeks. A similar feeding regime was provided to F1 crosses of a Hyline Brown (female) x Australorp (male) (HBX) which were bred and hatched in a Multiquip (Model E3) incubator at Labu Research Station. The village chicks were sourced in villages around Lae and their ages were estimated between 4- 7 weeks with a body weight of 150 g. The chicks were fed on starter crumbles until they were between 8-11 weeks-of-age and switched to pullet grower diet until 18 weeks-of-age and then fed on commercial layer pellets to 24 weeks-of-age.

Experimental diets

Birds were fed 3 diets;

- High Energy Layer concentrate mixed with boil-mashed sweet potato (HELC+BMSP),
- Low Energy Layer concentrate blended with boil-mashed cassava (LELC+BMC),
- Commercial layer pellet (Con) as the control diet.

Housing and experimental design

A shed (30 x 6m) with a concrete floor, iron roof and wire mesh sides facing in a north-easterly direction was used. The shed was naturally ventilated shed with two blocks of 10 similar pens each measuring 3 x 2.5 m in dimension. The trial was conducted for 10 weeks starting at 25 weeks-of-age. Wood chips were used as litter material and each pen had a bell drinker and tube feeder. Artificial fluorescent light (17 lux intensity) was switched on at 1700h and switched off at 0600h in the morning to provide a photoperiod of 13h L : 11h D. Ambient temperature was monitored daily and ranged from a minimum of 23.4°C to a maximum of 37.7°C.

Fourty two birds from each strain (Hyline Brown, Hyline Brown x Australorp crossbred and Indigenous layers) were used for the trial. These were allocated into 18 feeding pens arranged in two rows of nine pens in a 3 x 3 x 2 experimental layout with two replications, and seven hens per replicate.

Variables measured

Feed intake, egg production and egg weight were recorded. Body weight of pullets was recorded at the start of the trial and at monthly intervals thereafter until the trial was completed.

Statistical analyses

Microsoft Excel spreadsheets were used to compile data and then transfered to the GENSTAT® software for Analysis of Variance (VSN, I 7th Edition, 2012). Two-way ANOVA was used to analyse diet and genotype effects.

Production performance of Hyline Brown hens fed on a poultry concentrate blended with sweet potato or cassava in the highlands of PNG.

This trial was conducted at the CLTC farm in Banz, Jiwaka Province. The average temperature ranged from 13-25°C during the trial. Hyline Brown chickens hatched at CLTC were raised on broiler starter feed (12.13 MJ/kg ME, 21% protein, 7.7% crude fat and 4.1% crude fibre) from day 1-70; pullet grower (10.95 MJ/kg ME, 17.5% protein, 4.6% crude fat and 4.8% crude fibre) from day 71-126. Thereafter birds were fed egg layer crumbles (10.97 MJ/kg ME, 16% crude protein, 6.9% crude fat, 4.4% crude fibre).

Housing and husbandry

The trial was carried out in a naturally ventilated shed (12 x 5 m dimension) covered on the sides with wire mesh. The shed had 12 pens (2 x 1m) which were assigned to two blocks; each block having two replicates for each of the three treatment diets. A total of 120 Hyline Brown hens 21 weeks-of-age were allocated randomly, ten each to the 12 pens. The litter comprised wood shavings and each pen had a bell drinker and a tube feeder. Artificial fluorescent light (17 lux intensity) was switched on at 1700h and switched off at 0600h in the morning to provide a photoperiod of 13h L : 11h D. Birds were fed ad libitum. Eggs were collected daily, feed intake and body weights were determined weekly. Eggs were sampled for egg shell thickness.

Experimental diets

There were three dietary treatments in this trial.

- The first treatment (sweet potato based diet) consisted of a high energy Layer concentrate (HELC) mixed with boiled and mashed sweet potato (BMSP) tubers.
- The second treatment (cassava based diet) consisted of a low energy Layer concentrate (LELC) mixed with boiled mashed cassava (BMC) tubers.
- The third treatment (commercial diet) consisted of a standard commercial layer diet prepared by a commercial feed mill.

Both the sweet potato (*Waghi Besta*) and cassava (various local varieties) were bought from a local market near the site of the trial. The sweet potato and peeled cassava tubers were washed in cool water, boiled for 25 minutes in separate bowls half-filled with water over a wood-fired stove. The cooked cassava and sweet potato tubers were then mashed by hand in different bowls and mixed with HELC and LELC.

Production variables

Eggs were collected daily and weighed. Feed intake and body weight was determined weekly. Cost of feeding the hens for all diets was calculated as the cost of dry matter feed consumed divided by weight of egg produced. Nine eggs from each pen were randomly chosen from the eggs laid in week 5 of the trial and used for egg shell thickness. Four readings were of the egg shell thickness. The thickness of the egg shells were measured using a micrometer screw thread gauge (accurate to 0.001g).

Statistical analysis

Single factor analysis of variance (ANOVA) was carried out on each variable measured to compare treatment means using SPSS (2012) software, version 17.0. Where the treatments were found to have significant effect on the variable, mean separation was carried using the least significant difference method (LSD, P=0.05).

Production performance of village hens fed concentrates blended with sweet potato or cassava in PNG.

The experiment was conducted at the village chicken breeding and distribution facility at the Lutheran Development Service Centre in Malahang, Lae. The trial was conducted for 7 weeks.

Birds and housing

A total of 40 village hens (approximately 28 weeks-of-age) with body weight of approximately 1.3 kg were randomly allocated to 8 pens with 5 hens in each pen. The birds were an indigenous strain with mixed colour plumage and feathers. The shed used was naturally ventilated (18 x 7m) with wire mesh walls and a corrugated iron roof. Each pen (3 x 3m) had wood chips as deep litter, a bell drinker and a tube feeder. Fluorescent lights (17 lux intensity) was switched on 1700h switched off at 0700h in the morning to provide a light regime of 13h L:11h. The natural daylight hours in Lae are between 0530h 1830h.

Diets

There were three dietary treatments in this trial.

- The first treatment (sweet potato based diet) comprised 60% of a high energy Layer concentrate (HELC) mixed with 40% of boiled and mashed sweet potato (BMSP) tubers.
- The second treatment (cassava based diet) comprised 50% of a low energy Layer concentrate (LELC) mixed with 40% of boiled mashed cassava (BMC) tubers.
- The third treatment (commercial diet) consisted of a standard commercial layer diet was supplied by a commercial feed mill.

Both the sweet potato (*Waghi besta*) and cassava (*local variety*) were bought from Lae market. The sweet potato and peeled cassava tubers were washed in cool water, boiled

for 25 minutes in separate bowls half filled with water over a wood-fired stove. The cooked cassava and sweet potato tubers were then mashed by hand in different bowls and mixed with the HELC and LELC respectively.

Chemical Analysis

Proximate analysis was carried out on duplicate samples of each test diet using the methods of AOAC (1990) at the University Analytical Services Laboratory (UASL) of the PNG University of Technology, Department of Agriculture.

Experimental design and protocol

Use was made of 8 pens with 3 replicates of each treatment diet except for the control diet which had 2 replicates. The treatment feeds (wet mash) were prepared each day and fed ad libitum to birds. The control feed was fed to hens in pellet form. Feed intake was calculated daily, hens were weighed at the commencement of the trial and monthly thereafter. Eggs were collected daily.

Cost of feeding hens on treatments HELC+BMSP and LELC+BMC and control was calculated as cost of the dry matter consumed divided by weight of egg produced. Nine eggs from each pen were randomly chosen from the eggs laid in week 5 of the trial and used for egg shell thickness and egg yolk colour measurements. The eggs were weighed, then cracked open and the shells were separated from its contents. Four readings were taken from the equatorial sides of the egg shell and used to calculate mean egg shell thickness. The thickness of the egg shells were measured using a micrometer screw thread gauge (accurate to 0.001g).

Feed costs

The commercial egg layer feed was bought from Farmset distributors in Lae at K95.20 while sweet potato (*Waghi besta variety*) and cassava (various local varieties) were sold at K0.75/kg and K0.61/kg at the Lae Main Market as shown in Table 1 excluding the freight cost, overhead cost and other associated production costs. The unit cost of the complete ration is shown in Table 2. Based on this estimation, the feed cost per kilogram egg weight was calculated.

Table 1. Unit cost of sweet potato, cassava, layer pellets and Layer concentrate

Feed	Quantity (kg)	Price (Kina)	Total cost/kg
Sweet potato (bag)	80	60	0.75
Cassava (bag)	24	16.8	0.61
Comm (bag)	40	95	2.38
HELC/LELC (bag)	40	100	2.50

Table 2. Estimated unit cost of dietary treatments on a as fed basis and dry matter basis (dm)

Diet	Ingredients	Boiled mashed ratio	Qty/kg feed		Cost/kg (as fed basis) (K)	Cost/kg (dm basis) (K)
			*Conc.	SP/Cass		

I	HELC+BMSP	1: 2.2	0.3125	0.6875	1.30	2.51
II	LELC+BMC	1: 2	0.333	0.667	1.24	2.21
III	Comm	-	-		2.38	2.65

*Conc. = Concentrate

Data analyses

The live body weight, feed weights, feed refusal weights and the environmental temperature were all monitored over the experimental period. Feed intake, feed conversion ratio and weight gain were calculated. SPSS Software (Version 17.0, 2008) was used to conduct a one-way ANOVA with significant effects determined using least significant difference (LSD, P=0.05).

Use of a Universal Concentrate in poultry feeding trials

Performance of broiler chickens fed cassava blended with a Universal Concentrate in an on-farm study

Six farms from the Domil Cooperative in the highlands region of the Nondugl Rural Local Level Government District were used in this study. The minimum and maximum temperatures during the study period were 24°C and 28°C respectively. The annual rainfall varies between 2200 mm and 4000 mm with average relative humidity ranging from 80 to 86%.

Experimental animals

A total of 312 Ross 308 broiler day-old chicks of mixed sex were obtained from the hatchery at the Christian Leaders Training College (CLTC) in Banz for this study. The birds were then transported to Domil and distributed to the six farms. These farms had experience in similar research efforts with NARI and its collaborating partners.

Housing and experimental design

The study was conducted on six different farms with similar broiler sheds. Each farm had a naturally ventilated shed with a thatched roof made from grass (*Imperata cylindrica*). Pit-pit grasses (*Miscanthus floridulus*) were split and woven together to construct the walls of these sheds. Each shed had two experimental pens measuring 2m x 2m and housed a total of 52 birds with 26 birds per pen. The study used two treatment diets with each farm being considered a replicate of the treatment diets. Natural daylight was supplemented with artificial light provided from 1800h to 0800h using large hurricane lanterns.

The dietary treatments as outlined previously were

- Universal Concentrate, Palm oil and Broiler Premix blended with cassava flour
- Standard finisher ration.

The Universal Concentrate was blended with cassava roots sourced locally. The cassava roots were cleaned and chipped, sun-dried and milled into powdered form using a hammer mill at Domil's community mini-mill. The commercial starter and finisher rations were obtained from Lae Feed Mills.

Each pen was equipped with a hanging tube feeder and a bottle drinker. Wood chips were used as deep litter. Day-old birds were raised on a starter ration from day 0-21 in a brooder. Lighting and heat was provided throughout the brooding-phase via hurricane lanterns. On day 22, the birds were weighed and 26 birds were randomly allocated to each of the two pens in each of the six individual sheds on each farm. The birds were introduced to the experimental diets after allocation to individual pens.

All diets were offered ad libitum in mash form. The test and control diets were fed from day 22-42; one group was fed a standard broiler finisher diet while the other group was fed the Universal Concentrate ration. Feed costs were calculated for each diet. The cost of producing a chicken on each diet was then calculated based on the 2014 selling price of stock feed and live meat birds in Banz.

Data collection and analysis

Data on feed intake, body weight gain and cost of feeding each diet were recorded over 20 days commencing on day 22. Group body weights for birds in each pen were measured weekly. Feed offered and refusals were recorded daily. Data on all parameters; dry matter feed intake (DMI), feed conversion ratio (FCR), average daily weight gain (ADG), final body weights (FBW) and feed costs were recorded. DMI was calculated based on feed intake of broilers while body weight gain (BWG) and FBW were derived as weekly weight differences of birds and end weights on day 42 accordingly. FCR was calculated as amount of feed converted to body weight. The data collected were then analysed using an analysis of variance (one-way ANOVA) in GenStat® discovery edition 3 to determine the main effects of diets on production variables. Least significant difference (LSD) was then used to separate differences between means where significant dietary effects were detected in the ANOVA.

Performance of local chickens and Shaver Brown crossbred layers fed on the Universal Concentrate blended with cassava

The study took place in two villages, Amela and Amarub in the Trans-Gogol area of Madang Province situated in the Central North of the PNG mainland. Nine farmers were selected given their interest in the project. Two trials were undertaken; the first involved 5 farmers; and in the second trial 4 farmers participated.

Birds, housing and management

Ninety crossbred hens (local chicken crossed with a Shaver Brown) at 43 and 47 weeks-of-age were obtained from NARI livestock research station in Lae and distributed to the farmers. Each farmer was allocated 10 birds (5 birds per treatment). The trial was conducted in locally built shelters with approximate dimension of 2 x 3 x 1.5 m containing two pens (1 x 1.5 m). Four of the shelters had a tin roof while the other five used woven sago palm leaves as the roof. Split bamboo was used for the walls of the shelter allowing enough space for air circulation and natural light to enter the shed. Four farmers used a raised floor made of split palm while the other five used grass cuttings or wood shavings as litter. The hens were fed the commercial diet for 4 weeks before the trial commenced. At 43 (trial 1) and 47 weeks-of-age (trial 2) the hens were weighed and randomly allocated to experimental pens on each farm. There were a total of 18 experimental units each having 5 hens. These hens were then introduced to the experimental diets (a commercial layer vs. the Universal Concentrate cassava based diet). Both experimental diets and clean water were offered *ad libitum.* No additional light was provided during the night.

The Universal Concentrate was mixed with 50% cassava flour and supplemented with 10.35% of Palm oil, Sunflower oil, Limestone, Salt and Layer Premix to produce a complete layer diet. The cassava flour was made from locally grown cassava. Fresh cassava roots were peeled and grated using a manual grater and later sundried until approximately 80-90% of the moisture content was removed. The sundried cassava was then milled into flour form using a hammer mill at the NARI Labu mini mill.

Experimental design

The experiment used a completely randomized design with 2 dietary treatments and 9 replicates. Each farm was considered to be a replicate.

Variables measured

The variables measured were feed intake (g/bird/day), egg weight (g), hen-housed egg production (%), feed conversion ratio (FCR), cost of feed per hen per day, feed cost to produce a dozen eggs and the total feed cost over the experimental period. All data obtained over the experimental period were aggregated in MS Excel 2007 and analysed using ANOVA in GenStat discovery edition 4. Data from all farms were pooled.

Aquaculture Diets

Comparative performance of juvenile gift tilapia fed on a broiler concentrate mixed with sweet potato or cassava meal

The experiment was conducted at the Inland Aquaculture Research Facility at NARI's Labu Livestock Research Station in Lae, PNG. The average daily temperature was 27^0C during the trial.

Experimental facilities

The experimental shed allowed limited control of most environmental variables. Twelve experiment tanks were assembled in rows of three and four columns. The tanks were uniform in cylindrical shape and size (fibre glass tanks) and held up to 100 litres of water at a depth of 70cm. All experiment tanks were filled with fresh rain water (constant depth) using buckets. The fresh rainwater used in the experiment was collected from rainwater through the roof gutter and stored in a 9,000 litre tank. Once every week, water from the storage tank was used to replace the water in the 12 experiment tanks. The experiment tanks had an outlet valve that allowed the tank water to be emptied. Each experimental tank was allocated a single dissolved oxygen aerator that supplied constant oxygen to the fish.

Fish

A total of forty-eight (48) mixed-sex juvenile GIFT tilapia fingerlings were used in the experiment. The fingerlings were taken from a naturally spawned pond at integrated fish and duck farming facility at the research station. Groups of four fish (35g) were randomly selected and allocated to each of the twelve (12) experimental tanks.

Dietary treatments

The benchmark feed used in the experiment was supplied by the National Fisheries Authority (NFA) mill in Goroka, PNG. The ingredient and nutrient composition of the HEC and LESP dietary treatments were presented previously.

Diet preparation, feeding and experimental procedures

Ten kg each of sweet potato and cassava dried milled tubers were produced by grating, boiling, sun drying, oven drying and hammer milling to produce the final meal. The technique involves harvesting or purchasing cassava and sweet potato root tubers from local markets, washing and cleaning of decayed or pest ridden material, chopping and grating with a kitchen grater or a chipper machine. The grated chips were boiled for 15 min and were sun and oven dried for 5 days and 2 days respectively. The sweet potato

dry milled tuber was mixed with LE broiler concentrate (LESP) and cassava was mixed with the HE broiler concentrate (HEC). The diets were made into pellets (Gonzales and Allan 2007) using a manual hand mincing machine (4mm pellet size) and sun dried for 5 days at a temperature of 28-32°C and oven dried at temperature of 55°C for 2 days. Prior to commencing the feeding trial each of the three diets (i.e. LESP, HEC and FishSTD) was randomly allocated to 12 of the experiment tanks. The fish were then given the FishSTD diet for 14 days for adaptation. The group fish (each tank) were weighed at the end of each week in order to adjust to the feed delivered. The amount of feed provided was 7% of their bodyweight daily and fed to the fish every morning between 0900 and 1000 h and in the afternoon between 1600 and 1700 h. Daily procedures included checking temperature (^{0}C) and dissolved oxygen (DO) levels while changes in body weight were checked every week. Water in experiment tanks was replaced once every week with all the faeces and waste feed washed out.

Statistical analysis

Data from each dietary treatment (HEC, LESP or FishSTD) was statistically analysed using one-way ANOVA based on a completely randomised design (CRD) with four replicates per diet group. Performance variables analysed included weekly feed intake, body weight and feed conversion ratio (FCR; FCR = feed intake/weight gain). Analysis of raw data was done using the Genstat Software (Lawes Agricultural Trust 2005). Where ANOVA indicated significant differences among treatment means, means were separated using Fisher's LSD post-hoc test.

Growth Performance of Juvenile GIFT Tilapia (Oreochromis niloticus) fed two levels of Rice Bran and a High Energy Universal Concentrate mixed with Cassava Meal

The experiment was conducted at the Inland Aquaculture Research Facility at NARI's Labu Livestock Research Station in Lae, PNG. Ambient air temperature in the facility ranged from 20-32^{0}C.

Experimental facilities

The aquaculture facility as described for the previous trial contained 12 independent 100 L circular fibreglass tanks arranged in 2 rows of six. Rainwater collected in a 9000 L holding tank was used to fill experimental tanks at the start of the study as well as exchange tank water on a weekly basis as the experiment progressed. Each tank was stocked with 4 fish equivalent to a stocking density of 100 fish per m^2.

Feeds and feeding

Three experimental feeds were prepared.

- Two isoproteic (28% crude protein) and isoenergetic (17 MJ/kg) feeds were formulated using fishmeal; cassava meal and mill run to contain either 20% or 40% rice bran (known as RB20 and RB40).
- These diets were compared to a high-energy Universal Concentrate blended with 31% cassava meal (known as HEC+CAS; 24% crude protein, 17 MJ/kg) as presented in previous section on aquaculture diets.

The ingredients were purchased locally and ground to flour using a hammer mill. Formulated mixtures were then placed on a canvas sheet and thoroughly mixed by hand before the addition of wet ingredients. Tallow was warmed to 60-65 ºC and added to the RB20 and RB40 mixtures as an energy source and binding agent. Vegetable cooking oil was also warmed to 60-65 ºC and used in the HEC+CASS mixture rather than tallow.

Warm water (65-70 ºC) was then added to each mash and the resulting dough was passed through a 4mm mincing machine to form pellets. The pellets were sun dried from 1100h-1600h at ambient temperatures of 27-34ºC for 3 days (total of 12 h of sun drying). Prior to use in the experiment the 4 mm pellets were ground to a small crumble size of <2mm.

All fish were fed according to a restrictive feeding regime. Fish were hand fed during the first week at a rate of 12% live body weight per day (i.e. 2 g feed/tank/day). Feeding rations were increased from 2-3 g/tank/day (week 2 and 3) and then to 4 g/tank/day (week 4) as the experiment progressed. Feed was delivered by carefully broadcasting 50% of the ration in the morning (0800-0900 h) and 50% of the ration in the evening (1600-1700 h) except the day preceding weighing of fish, when feeding was delayed until sampling was completed.

Fish stocking and sampling

Mixed sex, unpaired juvenile GIFT tilapia (*Oreochromis niloticus*) were sourced locally from Potsi Inland Fish Farming Ltd near Lae. They were initially kept for 1 week in a large tank for acclimation and to ensure the fish were healthy before stocking. During this time they were fed the high energy concentrate mixed with cassava. After acclimatization, healthy fish with body weights ranging from 3.8-3.9 g were selected and 4 fish were randomly assigned to each of the 12 experimental tanks. These fish were allowed to acclimatize to tank conditions for 7 days before test feeds were introduced. No mortality was observed during this period. The average biomass and individual weight of fish across all tanks was 15.21g and 3.80g, respectively. Weight assessment was done on a weekly basis allowing the tanks to be drained, cleaned and refilled with fresh rain water. At this time fish from each tank were bulk weighed with no anaesthetics applied. Water temperature (°C), pH, ammonia levels and dissolved oxygen levels were monitored throughout the trial. Survival, feed intake, weight gain and biological feed conversion ratio (bFCR) were calculated.

Statistical analysis

Response data was analysed using one-way ANOVA of GenStat Software® after checking data for normality and homogeneity of variances. Upon detection of statistically significant ($P<0.05$) differences, a Duncan's multiple range test was used to rank the test diets.

Comparative evaluation of locally formulated fish concentrate combined with sweet potato and cassava as a feed source for juvenile GIFT Tilapia

The experiment was conducted at the Inland Aquaculture Research Facility at NARI's Labu Livestock Research Station in Lae, PNG.

Experimental facilities

The aquaculture facility as described for the previous trial contained 12 independent 100 L circular fibreglass tanks arranged in 2 rows of six. Rainwater collected in a 9000 L holding tank was used to fill experimental tanks at the start of the study as well as to exchange tank water on a weekly basis as the experiment progressed.

Feeds and feeding

Diets tested as described previously were a fish concentrate mixed with sweet potato; fish concentrate mixed with cassava; fish concentrate mixed with cassava leaf and sweet potato compared with a standard control diet.

Fish stocking and sampling

GIFT tilapia (*Oreochromis niloticus*- F1 offspring) were sourced locally and kept for 1 week in a large tank for acclimation and to ensure the fish were healthy before stocking.

During this time they were fed the standard diet. After acclimatization, healthy fish were selected and 20 male fish were randomly assigned to each of the 12 experimental tanks. These fish were allowed to acclimatize to tank conditions for 7 days before the 4 test feeds were introduced with 3 replicates for each dietary treatment. Weight assessment was done on a weekly basis allowing the tanks to be drained, cleaned and refilled with fresh rain water. Water temperature (°C), pH, ammonia levels and dissolved oxygen levels were monitored throughout the trial. Survival, feed intake, weight gain and biological feed conversion ratio were calculated.

Statistical analysis

Response data was analysed using a one-way ANOVA of GenStat Software after checking data for normality and homogeneity of variances. Upon detection of statistically significant ($P<0.05$) differences, a Duncan's multiple range test was used to rank the test diets.

On-farm proof of concept grower tilapia fish experiment

Objectives

- To assess growth performance of GIFT Tilapia grower fed with the formulated test diets of sweet potato or cassava combined with a fish feed concentrate and a formulated alternative control diet.
- To assess the cost involved in producing the feed concentrate and the test diets of sweet potato and cassava
- To produce and promote feed concentrate as an alternative protein source to combine with sweet potato and cassava in rural inland fish farming

The fish feed concentrate comprised 28.5% poultry offal meal, 36.2% fishmeal, 26.6% soybean meal, 2.4% tallow, 4.2% cassava meal, 1% vitamin premix and 1.1% methionine.

The chemical composition of the fish feed concentrate was 92.3% DM, 51% crude protein, 13% crude fat, 12.9% ash, 2.1% crude fibre, 20.1 GE MJ/kg and 17.6 DE.

The three diets comprised;

1) 50% cassava mixed with fish concentrate (CAFC) with 25.5% crude protein, 8.2% crude fat, 5.7% ash, 1.9% crude fibre, 17.2 GE MJ/kg

2) 50% sweet potato mixed with fish concentrate (SPFC) with 29.2% crude protein, 8.5% crude fat, 5.6% ash, 2.6% crude fibre, 18.2 GE MJ/kg

3) Fish standard diet (FSTD) as previously described 26.8% crude protein, 10.1% crude fat, 5.4% ash, 4.78% crude fibre, 18.8 GE MJ/kg

The three diets were tested in a 12 week on-farm feeding trials at Yalu and Kefamo using earthen ponds and at Yonki using cage culture. Four replicates of 20 fingerlings (GIFT tilapia) were weighed and then placed into ponds and cages and fed daily using pellets manufacutured at Labu's mini mill. Fish were weighed 12 weeks after being placed in the ponds and cages.

5.3 Objective 3. Facilitate the adoption of mini feed mills in the aquaculture, pork and poultry industry in PNG to improve smallholder and semi commercial enterprise profitability.

To achieve objective 3, annual, six monthly, mid term review and final review meetings were held with project partners to provide information on surveys, feeding trials, feed mill equipment, operation protocols, and business models for running a feed mill. All partners

were invited to a business planning workshop. In the latter phases of the project, extension material prepared in the project were made available to the farming community and feed mill resource information provided to Unitech for use in their teaching program. Finally a media campaign to promote the research activities and encourage widespread adoption of establishment of mini mills and use of locally manufactured feeds was initiated.

5.3.1 Review meetings

The year 1, 2, 3 and 4 six monthly review, annual meetings and midterm review meetings were completed with representatives from all partner organisations attending each meeting. The final review meeting was held from 21-22 March 2016.

5.3.2 Business Planning

Business planning workshop for Feed Mill Managers in PNG was held at the PNG National Agricultural Research institute, Lae, PNG from 28-30 July 2015.

Training team

Staff and consultants from the Entrepreneurship, Commercialisation and Innovation Centre (ECIC) at the University of Adelaide brought their business experience and teaching skills to run a business planning workshop for the ACIAR feed mill project. Engagement of the ECIC team to run the workshop added considerable value to the ACIAR project and enabled completion of a key project milestone of training project partners and key farmers on how to develop a feed mill business plan.

PNG participants and resources provided

The workshop was attended by farmers, entrepreneurs and representatives from PNG National Agricultural Research Institute (NARI) and PNG University of Technology (UniTech) who were establishing or intending to develop their mini mills. In addition to the workshop materials, participants received electronic copies of the presentations and a template of the business plan. The workshop participants developed a first draft of a real-world business plan for their proposed feed mill. After the ACIAR feed mill project is completed on June 30, 2016 there will be on-going business support to the feed mill sector by staff from NARI and Unitech. The workshop participants will also receive advice from the ECIC team as the feed mill business plans were finalised.

5.3.3 Updating of existing extension materials and development of new extension materials

Updating of extension materials was undertaken by SARDI and NARI as new information emerged from the project. Resource information from the project was provided to PNG University of Technology and NGO's involved in the project.

5.3.4 Media campaign

During the project the findings of the project were promoted across PNG via the media, other NGO's and provincial governments based on a communication strategic plan developed for the project. To get the message out to smallholder farmers there were road shows at village markets, radio, newspaper articles, reports on the internet and TV broadcasts.

5.4 Objective 4. Consolidate research outcomes with project partners; involve SARDI junior scientists and interact with a broader range of PNG stakeholders.

5.4.1 Include SARDI junior research scientists in the project

The project provided funds to employ a junior scientist to work with Dr Phil Glatz as part of his succession plan. SARDI was unable to fill the position. However SARDI appointed 5 new pig and poultry staff in 2015 who have made a contribution to the project. Carry over funds set aside for the position were used to fund the contribution of the 5 staff toward the project over the period July 1, 2015-30 June 2016. Dr Kelly Drake replaced Dr Phil Glatz as project leader in July 2015. When Dr Drake left SARDI in January 2015, Dr Carolyn Dekoning was appointed project leader.

5.4.2 Consolidate research outcomes by having additional meetings with a broader range of stakeholders through the annual review meeting and the final review meeting.

SARDI staff were given the opportunity to interact with a broader range of stakeholders in PNG in a new project “Improving opportunities for economic development for women smallholders in rural Papua New Guinea” managed by Professor Barbara Pamphilon and Associate Professor Katja Mikhailovich from the Australian Institute for Sustainable Communities, University of Canberra.

6 Achievements against activities and outputs/milestones

Objective 1. Determine the factors affecting the development of mini feed mills for the monogastric industries in PNG

No.	Activity	Outputs/ Milestones	Due date of output	Comments
1.1	Undertake a socio-economic survey of feed mills and village farms	Meeting held of project partners to develop survey questions (PC,A)	Yr1, m3	Survey questions developed
		Pilot survey conducted in Lae (PC)	Yr1, m4	Pilot survey completed
		Major survey conducted around mini mill sites in PNG (PC). Student projects developed	Yr1, m7	Socio-economic survey work completed in Yr 2 for farms located close to Domil, Tambul, Goroka, Pikosa and Oktedi mills Eleo Dowa completed MPhil study at Unitech.
		Survey results analysed (PC,A)	Yr1, m12	Results analysed and presented at midterm review meeting and published in thesis by Eleo Dowa on "Socio-economic characteristics of farmers and their relationship to attitude, knowledge and constraints associated with mini feed mills in PNG".
1.2	Undertake market chain analysis of feed mills and farms	Meeting held of industry stakeholders to map the market chains (PC, A). Student projects developed	Yr1, m3	Draft of market chains of PNG poultry, pig and aquaculture industries completed at inception meeting.
		Market chains completed by value chain analyst (A)	Yr1, m9	Value chain analysis of Domil, Tambul, Goroka and Pikosa mini mills completed in Yr 2.
1.3	Develop strategic plan integrating supply of local feed ingredients with feed milling, feed sales, monogastric farming and livestock and fish sales	Annual review meeting to develop strategic plan completed (PC,A)	Yr2, m3	Workshop held at annual review meeting in Yr 1 to discuss the strategic plan.
		Strategic plan completed by value chain analyst and key project partners (PC,A)	Yr2, m3	Strategic plan completed at workshop held at midterm review meeting. The vision is "To ensure training in operational, business and marketing skills and greater use of local feeds in mini mill enterprises will lead to an expansion and improvement of profitability in the smallholder monogastric sector in PNG"
1.4	Develop the business models and user briefs for establishing mini mills in a range of locations	Feed mill stakeholders meeting to discuss user briefs (PC,A)	Yr1, m3	Meeting of stakeholders held. User brief titled “Mini feed milling in Papua New Guinea” comprises two parts; 1) Mill management and 2) Feed ingredients and species formulations. The document could be released as an ACIAR monograph but in the

				first instance is included as an appendix in this report.
		Draft of feed mill user briefs developed (PC, A). Student projects developed	Yr1, m8	Draft of feed mill user brief prepared. It was recommend at the Yr 1 annual review meeting that the feed mill brief be prepared as an ACIAR monograph and as a teaching resource. It was also requested that a series of simple feed mill fact sheets be prepared for use by feed mill operators and village farmers.
		Draft business models for feed mills completed (PC,A)	Yr1, m12	Draft business models assessed at Yr 1 annual review meeting and at midterm review workshop.
		Feed mill user briefs and business models completed (PC,A)	Yr2, m3	Draft of the feed mill monograph and feed mill fact sheets were completed in Yr 2. The master copy of competed business models has been handed over to NARI economists.

Objective 2. Formulate a range of least cost diets using local feed resources that can be produced by mini mills which meet the nutritional requirements of the most popular farmed fish, pigs and poultry in PNG.

No.	Activity	Outputs/ milestones	Due date of output	Comments
2.1	Develop a range of least cost diets which can be manufactured by mini mills	Meeting held of nutritionists to discuss diet development (PC,A)	Yr2, m1	Meeting held with Tony Carey, Lae Feed Mills consultant and Dr Mark Booth in Yr 1 to discuss development of concentrate diets for pigs, poultry and fish.
		Low cost concentrate diets developed for use in each of the monogastric species (PC,A)	Yr2, m3	Concentrate rations using mainly local ingredients developed by Tony Carey and Mark Booth in Yr 2, These diets will be used for feeding trials. Poultry super concentrate ration was developed.

		Diets manufactured by mini mills at NARI and HAQDEC (PC). Student projects developed	Yr2, m4 Yr2 Yr2 Yr2-Yr4 Yr2-Yr4 Yr4	Diets were manufactured by NARI, Domil mini mill and Lae Feed Mill in Yr 2. Fred Besari completed MPhil thesis on "Comparison of egg production of hens fed sweet potato and cassava based diets blended with a concentrate". The diet was mixed at the Domil mill. Eleo Dowa completed a MPhil thesis on using mini feed mills for chicken feed manufacture in the Domil Community of PNG titled "An assessment of attitude and knowledge of farmers and constraints faced". Janet Pandi is undertaking JAF PhD on role of sweet potato based diets on gut micro structure and digestive enzyme activity. Michael Dom is involved in a JAF Masters study on use of ensiled sweet potato and cassava to supplement locally produced protein concentrates in grower pig rations. Ms Jimaimah Nathaniel is undertaking a Master of Technology in Mechanical Engineering for a project evaluating current small scale feed milling equipment and development of strategies to achieve best practice small scale feed milling in PNG.
2.2	Test a range of diets for fish, pigs and poultry using on-station trials	Aquaculture, pig and poultry feeding trials at NARI and HAQDEC designed (PC,A)	Yr2, m5	Design of aquaculture, pig and poultry feeding trials completed in Yr 2.
		Monogastric feeding trials completed at NARI and HAQDEC (PC)	Yr2, m10	Proof of concept trial using sweet potato as main ingredient completed for broilers at Roseworthy Campus and further trials completed at NARI. Layer feeding trials comparing the egg production performance and egg quality of hens fed sweet potato and cassava based diets completed. Three pig digestibility trials using a concentrate mixed with various forms of sweet potato and cassava completed. Likewise an aquaculture growth trial with tilapia at NARI using a concentrate mixed with sweet potato and cassava was completed
		Results of feeding trials analysed (PC)	Yr2, m12	Results of layer, broiler, pig and aquaculture trials presented at midterm review meeting.
2.3	*Determine best bet feeding option for proof of concept trials*	Nutrition consultants develop concentrates for proof of concept trials (A)	Yr3, m3	Universal Concentrate developed for pig, poultry and aquaculture trials
	Pig, poultry and fish diets manufactured		Yr3, m6	Diets for poultry and fish manufactured at Domil, Labu and Goroka. Delay in construction of Kales piggery mini mill until Yr4.

2.4	Proof of concept trials-production, economic, social and market aspects of mini mills and village, enterprises.	Meeting held of NGO's and project scientists to plan proof of concept feeding trials (PC,A)	Yr3, m6	Yr 2 six monthly review meeting with project participants planned the proof of concept trials.
		Proof of concept trials with crossbred village layers in Madang Province (PC)	Y3, m9 Y4, m3	Trials conducted on village egg farms at Transgogol and Amele in Madang Province.
		Proof of concepts trials with commercial layers in Jiwaka Province (PC)	Yr3, m9 Yr4, m3	Trials conducted on village egg farms near to CLTC Banz campus and on eggs farms associated with the Domil cooperative.
		Proof of concept trials with commercial broilers in Jiwaka province (PC)	Yr3, m7 Yr4, m3	Trials conducted on village broiler farms associated with Domil cooperative
		Proof of concept trials with village pigs in Western Highlands (PC)	Yr4, m5 Yr4, m9	Trail postponed until Kales feed mill constructed Yr4, m4. Trial completed Yr 5, m3.
		Proof of concept aquaculture trials in lowlands and highlands (PC)	Yr3, m9 Yr4, m3	On-farm trial facilities established at Lake Wanum, Yonki, Yalu and Asaro for Tilapia growth trials. Trial completed Yr 5, m1
		Results of feeding trials analysed (PC)	Yr4, m3	Production and cost of production results analysed from on-farm poultry, pig and aquaculture feeding trials and presented at final review meeting Yr 5, m3.

Objective 3. Facilitate the adoption of mini feed mills in the aquaculture, pork and poultry industry in PNG to improve smallholder and semi commercial farm enterprises.

No.	Activity	Outputs/ Milestones	Due date of output	Comments
3.1	Conduct workshops with partners and entrepreneurs to pilot adoption of mini mills	Annual review meetings held (PC,A)	Yr2, m3 Yr3, m3 Yr4, m2 Yr4, m12 Yr5, m3	Yr 1, 2 & 3 six monthly review meetings completed, Yr 1, 2 & 3 annual review meetings completed, Midterm review meetings completed. Final review meeting completed. Representatives from all partner organisations attended each meeting

		Feed mill workshops and business seminars held (PC,A)	Yr3, m3 Yr4, m3	Staff from Domil, Goroka, Tambul and Kiunga mills attended all review meetings and attended workshops on business models, feed mill user brief and value chains. Feed mill business workshop was held in Yr 4, m6 supported by the Crawford Fund. Program included: 1) Examples of proof of concept studies from Yr 3 & Yr 4 activities. 2) Business aspects of establishing a feed mill-where and how to source funds and developing a business plan. 3) Types and source of feed mill equipment 4) Running a business, governance, staff, training and operational issues 5) Marketing of feed and other livestock products
3.2	Update fact sheets and village training materials and college curricula	Meeting held of NGO's and project scientists to review village extension materials (PC, A).	Yr4, m5	Meeting held at final review meeting Yr 5, m3 and fact sheet developed to provide information on how to feed layers, broilers, pigs and tilapia using a protein concentrate. Fact sheets also planned to highlight equipment required for mini mill, layout of mini mill and how to mix diets.
		Extension materials prepared (PC,A)	Yr4, m7	Extension materials prepared Yr5,m4
		Extension materials distributed to village farmers (PC)	Yr4, m7	Extension materials currently being distributed
3.3	Undertake campaign to promote the use of locally made feeds in monogastric enterprises to improve profitability	Project participants develop media campaign to promote the use of locally made feeds and development of monogastric enterprises (PC,A)	Yr4, m5	10 articles have been published in the PNG National Newspaper and NARI website on importance of the use of locally available feed and the role of small scale feed mills since 2013.
		Campaign strategy implemented across PNG through radio, TV, newspapers, road shows and trade fairs (PC)	Yr4, m6	Communication strategy finalised for roll out during final stages of project

Objective 4. Consolidate research outcomes with project partners; involve SARDI junior scientists and interact with a broader range of PNG stakeholders.

Activity 1: Include SARDI junior research scientists in the project

Activity 2: Consolidate research outcomes by having additional meetings with a broader range of stakeholders through the annual review meeting and the final review meeting.

No.	Activity	Outputs/ Milestones	Due date of output	Actions

4.1	SARDI junior scientists	SARDI junior scientists included in project	Yr4, m7	Dr Kelly Drake (poultry production), Dr Cameron Ralph (pig production), Dr Carolyn deKoning (livestock pasture); Dr Kate Plush (pig nutrition and reproduction) and Dr Reza Barekatain (pig and poultry nutrition) included in project
	New project leader	SARDI junior scientist appointed as project leader	Yr4, m7	Dr Kelly Drake was appointed as feed mill project leader on July 1, 2015 given her experience working in Africa and Cambodia. However Dr Kelly Drake was offered a position in NZ and left SARDI in January 2016. As a result Dr Carolyn Dekoning was appointed leader of the feed mill project in January 2016.
	Junior scientists attend project meetings	New project leader and one other junior scientist attend PNG project meetings	Yr4, m11 Yr5, m5	Dr Kelly Drake and Dr Cameron Ralph were scheduled to travel to PNG in Dec 2015 to attend the annual review meeting. Travel was approved by PIRSA CEO. Phil Glatz intended to introduce SARDI scientists to PNG partners in the feed mill project. However security issues in PNG resulted in the Dec 2015 meeting being postponed. Subsequently ACIAR decided that the final review meeting be brought forward and held early in 2016. However the final review meeting was postponed on two occasions and finally held on March 21-22, 2016. SARDI junior scientists were unable to travel given the review meeting dates clashed with their research commitments in Australia.
4.2	Consolidate research outcomes	Review project outputs and update extension program (see 3.2 and 3.3)	Yr4, m7	The annual review meeting was scheduled to be held in Dec 2015 to review project outputs and update the extension program. Security issues in PNG resulted in the Dec 2015 meeting being postponed. Subsequently ACIAR decided that the final review meeting be brought forward and held early in 2016. The ACIAR reviewers were able to offer advice on a communication and extension strategy to use for the final months of the project.
		Interact with broader range of stakeholders at annual review meeting and final review meeting	Yr4, m11 Yr5, m5	There was interaction with project leaders of a new PNG project “Improving opportunities for economic development for women smallholders in rural Papua New Guinea” managed by Professor Barbara Pamphilon and Associate Professor Katja Mikhailovich from the Australian Institute for Sustainable Communities, University of Canberra. Extension information on pig, poultry and aquaculture feeding systems developed in the feed mill project were provided to Barbara and Katja. There were many women smallholders involved in the on-farm trials evaluating the feeding systems developed in the feed mill project who used diets for pigs , poultry and fish mixed by small scale feed mills. In addition contact details of all the feed mill project partners including the NGO partners who had conducted trials with village farmers were provided to Barbara and Katya for use in their project. It was intended they attend the feed mill annual review meeting in Dec 2016 but the meeting was cancelled due to security issues in PNG.

7 Key results and discussion

7.1 Objective 1. Determine the factors affecting the development of mini feed mills for the monogastric industries in PNG

7.1.1 Results of survey

Survey at 4 sites

Farmer characteristics, aspirations and practices

The farmer characteristics studied included farmer age, gender, education, family size, livestock feed used, livestock holdings and factors that motivated farmers to engage in a particular enterprise.

Age and family size

More than half of the farmers were less than 45 years-of-age and felt they were engaged in an enterprise that could improve household income. The family size ranged from 3-15 with 80% of the farmers interviewed being males.

Education

A total of 30% of the farmers interviewed had not received any formal education; 47% had attained an education level between Grades 1-8; 18% had completed Grade 10. Only a few farmers (5%) had been educated up to Grade 11-12.
Education plays a major role in technology adoption, utilization and sustainable practices. Given that 30% of farmers interviewed had no formal education and only 47% of the farmers had Grade 1-8 levels of schooling indicates there is a significant challenge in achieving technology dissemination and adoption of the mini mill concept. Training is considered to be the most important factor that contributes to early adoption of innovations.

Motivation and training

Market opportunity was the main factor that motivated farmers to establish pig, poultry and aquaculture enterprises. Other factors included exposure to training, visiting other farms, achieving a higher return on investment, socio-cultural importance, business opportunity, engaging in a hobby and availability of local feed resources.

Livestock Holding

Farmers at the Keripia and Mt. Hagen sites concentrated on pig farming while at the Domil site most were poultry farmers. Goroka fish farmers also kept pigs, poultry, sheep and goats. At the Kiunga site farmers were mostly engaged in aquaculture (Table 3).

Table 3. Livestock holdings at the 4 survey sites

Enterprise	LIVESTOCK/ASSET HOLDING (farmers by Site)				Total
	Keripia/ Mt. Hagen	Domil	NFA Goroka/Pikosa	Kiunga	
Pig	35	22	13	3	73
Broiler	2	29	3	1	35
Village chicken, layers and ducks	1	6	6	2	15
Sheep and goats	0	0	6	0	6
Fish ponds	3	15	30	25	73
	41	72	58	31	

Feeding Options

The local feed resources available were local ingredients, fish meal, copra meal, mill run, commercial pig and poultry feed, mini mill feed and the NARI concentrate. Thirty six % of the farmers used local feed ingredients which included cooked sweet potato and cassava, sweet potato leaves, kikuyu grass, bamboo grass, broccoli leaves, avocado and cabbage. The other feed used was from mini mills (16.7%), commercial stock feed (14.6%) and fish meal (13.6%). The farmers indicated they had poor access to copra meal, mill run, NARI concentrate and commercial pig feed. The use of traditional feeds will decline as feed production from mini mills is increased.

Needs and constraints

Farmers were asked to discuss the problems they had with feed, its availability, affordability and access. The major problems encountered by farmers included; expensive feeds, shortage of feed, inconsistent supply of feed, farmers too distant from feed suppliers and not sure how to make a nutritionally balanced feed. The most popular feeds used were local ingredients as well as fish meal, commercial stock feed and mini mill feed. Farmers were often not clear on how best to use these feeds. Issues reported by farmers using local ingredients were slow growth of livestock, limited knowledge on feeding options, not sure how to make nutritionally balanced feeds, inconsistent supply and feed shortages. A feed that was not commonly used was sweet potato silage.

Training needs

Table 1. Training needs at the four survey sites

	Keripia/Mt Hagen	Domil	Goroka	Western Province	
Proper feeding of animals	11.4%	7.7%	9.9%	7.0%	35.9% (98)
Animal health care	8.4%	7.3%	4.1%	2.9%	22.7% (62)
Proper breeding	3.7%	1.8%	6.9%	6.6%	19.0% (52)

Others	5.9%	4.8%	4.7%	7.0%	22.3% (61)
Total	29.3% (80)	21.6% (59)	25.7% (70)	23.4% (64)	100.0% (273)

Table 4 presents the results on the training needs reported by farmers. The training required included proper feeding of animals, animal health care, management, cost benefit analysis and book keeping while the least important issue was appropriate breeding of livestock. Nevertheless proper breeding was important in the Goroka and Western Province sites. At the Domil and Keripia sites where there were mainly fish farmers their main issue was sourcing fingerlings to restock fish ponds. On the other hand Domil poultry farmers were able to obtain day-old chicks from a commercial hatchery and their Keripia/Western Highlands counterparts were able to breed piglets from their own stock.

Purchasing feed from mini mills

Farmers at the Domil site expressed satisfaction in purchasing feeds made by their cooperative mini mill. Similar sentiments were expressed at other sites with 96% of farmers willing to purchase feed from the mini mill. Farmers also indicated how much they were willing to spend on mini mill feed. Most farmers indicated they were willing to buy mini mill feed. However the farmer's ability to purchase feed is generally low due to poor farm income.

Market constraints/issues

The market segments that farmers use to sell livestock and fish are mainly village and roadside markets and the market established by the cooperative. Some farmers sell their animals and products at the informal town markets. Very few farmers had contracts to supply their products to hotels, educational institutions, mining camps and LNG mining sites. Whilst in the process of carrying out the day-to-day business using village, roadside and cooperative markets, farmers indicated they are constrained developing the market in the following order of priority;

- Poor access to transport to and from the market
- Stock not sold out quickly
- Poor infrastructure for marketing and storage
- Lack of knowledge and skills to negotiate market and link up with buyers
- Low returns
- Inconsistent supply to the market
- Poor post-harvest and handling

General macro constraints/issues

There were some other important issues raised by farmers. They are confronted with technical, geographical, infrastructure, financial and information challenges. The most pressing external issues affecting the farmers included limited infrastructure, lack of extension, training and technical assistance, inconsistent supply of feed, day-old chicks and fingerlings, expensive feed and high input costs, inefficient and poor market supply chain, lack of funding and the need for cheaper, flexible micro financing.
When classified by site, farmers at the Keripia/Mt Hagen, Domil and Goroka sites indicated an almost equally higher percentage of problems compared to their Kiunga counterparts. This is very evident because Ok Tedi Development Fund staff has a heavy involvement at Kiunga and have made it possible for farmers to access funds for infrastructure development while the other sites do not have any form of financial assistance from the government, NGOs or mining projects.

Conclusion (Survey 1)

To make the industry sustainable, farmers should have strong income earning opportunities. Findings indicated that farmers are willing to spend their money to buy formulated feed. However, their income is low and it is difficult for farmers to buy expensive feed. The issues in piggery, poultry and inland fish farming sectors are similar. However the stages of development and support for each sector are different. This therefore means having a specific enterprise strategy. The results showed that the needs of poultry farmers are different from communities involved with aquaculture and pig farming.

Results of Survey 2 conducted at the Domil Cooperative

Attitude, knowledge and constraints are important factors that determine the adoption of improved technologies (Cavane, 2011; Parminter, 1997; Rahman, 2003; Syamsu et al., 2009 and Sadati et al., 2010). The discussion below provides information on attitude, knowledge and constraints of Domil farmers, while socio-economic attributes that had relationships with these three main factors are also discussed.

Attitude

Table 5 presents the results of the attitude of farmers toward utilisation of the mini mills in three categories with scores ranging from 0-90. The results show the attitude score of farmers ranged from 46-81 and 82-90 under the category of favourable and highly favourable, respectively.

Table 5. Classification of Domil farmers according to their attitude.

ATTITUDE SCORE (90)				
Categories	**Frequency**	**Percent**	**Mean**	**Standard Deviation**
Unfavourable Attitude (0 - 45)	0	0	73.7	6.9
Favourable Attitude (46 – 81)	44	88		
Highly Favourable Attitude (82 - 90)	6	12		
Total	50	100		

It was shown that 88% of farmers had a favourable attitude towards using feed from the mini feed mills, while 12% had a highly favourable attitude. Therefore farmers favour the use of mini mills to mix feed, compared to using feed from commercial feed manufacturers.

On occasions, Domil poultry farmers weren't able to obtain feed from the mini mill and they had to source feed from suppliers in Mt Hagen. However if farmers are given a choice between buying feed from a mini mill or from a commercial manufacturer, they would choose to buy feed from the mini feed mill. Farmers have a strong belief that they expect good financial returns from the mini feed mill which will result in positive outcomes for their livelihood (Parminter, 1997). This was shown very clearly with the spin-off benefits to the Domil community which include:

- Secured a bank loan using the mini mill as collateral

- Employment and community policing and security
- Unity and co-operation amongst villagers
- Positive attitude, purpose and direction
- Alternative cash crop introduced (cassava)
- Community a model for other groups
- Farmers maximise the use of their time and therefore little time for other activities (e.g. tribal fights)
- Women empowerment. Women are able to sell cassava as an alternate cash crop, as men dominate the coffee crops
- Poultry manure can be used to improve soil fertility and increase the quantity of green and leafy vegetables
- Improve nutrition for the family using chicken offal as protein supplement
- Change in farming system to a mixed sweet potato-cassava system compared to mono-cropping
- Increased in income earning opportunities.

Due to the favourable and highly favourable attitude towards the utilisation of the mini feed mill by Domil farmers, the demand for feed had reached 570 kg/day (4 tons per week). However the Domil Society mini mill at the time of the survey produced 120 kg/day. There was over-use of the mini mill due to the high demand for feed, leading to breakdown of the mill equipment.

Knowledge

The second variable measured was knowledge of farmers, where the scores ranged from 0-30. Table 6 shows the knowledge of farmers ranged from low to very high.

Table 6. Farmer knowledge scores

KNOWLEDGE (30)				
Categories	**Frequency**	**Percent**	**Mean**	**Standard Deviation**
Low knowledge (<= 15)	25	50		
High knowledge (16 – 24)	15	30	18.02	6.002
Very high knowledge (25 - 30)	10	20		
Total	**50**	**100**		

The farmers who had a very high knowledge score (50% of farmers) had an advantage in that they had received training in the operation of the mill. The training on the operation of the mini feed mill equipment may not be seen as necessary by some farmers. However, farmer involvement and participation is important for technology adoption and for expansion; therefore more farmers require a baseline understanding to appreciate how the mini mill operates and the processes involved. The training promotes the positive impact of the mini feed mill to their colleagues, increasing peer awareness. Social learning and networking by individual farmers as indicated by Baumüller (2012) can lead to increased awareness on issues affecting individual farmers including creation of knowledge and better decision making on innovation and technology adoption.

Constraints

Table 7 presents the result on the constraints faced by farmers. The possible scores for constraints ranged from 0-27, where a total score of 0 indicated no constraints in using support activities associated with the mini feed mill, while a score of 27 indicated the highest extent of constraints faced.

Table 5. Level of constraints faced by farmers

CONSTRAINTS				
Constraints Categories	**Frequency**	**Percent**	**Mean**	**Standard Deviation**
Low constraints (<= 14)	32	64		
High constraints (15 - 19)	12	24	0.70	1.48
Very high constraints (20+)	6	12		
Total	**50**	**100.0**		

During the implementation of the survey, most farmers who ranked low on constraints (64% of farmers) was due to low market value, lack of feed ingredients and lack of marketing. However these constraints were being addressed by the society and therefore farmers had an advantage because they supplied their chickens for processing and sale by the society. However, lack of training and poor extension, which required external assistance, was a major area for intervention. It was noted that most farmers in Domil Community have low constraints due to the society's intervention to address issues relating to lack of feed ingredients, lack of markets and marketing and low market value. These issues however are major constraints in many other sites of PNG. Three main constraints that needed immediate attention at other PNG sites include poor extension services, lack of training and poor access to day-old chicks. Other constraints include high chick mortality, lack of knowledge and skills in feed formulation and inconsistent supply of raw ingredients.

Conclusion (Domil site survey)

All farmers had high to very high positive attitudes towards the use of the mini feed mill and had a firm belief that there is a strong financial return for them if they use the mini mill technology. It can be concluded that the mini feed mill technology has been well adopted in the Domil village. Additional reasons why the technology was successful in Domil were as follows;

- Leadership of the association (e.g. transparency, honesty, dedication, education level, and good direction)
- Location of the project site (e.g. close to main roads, which created more opportunities)
- High utilization of the mill
- Positive attitude of people towards the mini feed mill
- High population of poultry farmers who can use the feed produced by the mini mill

Syamsu et al., (2009) supported the view that good human resources (e.g. leaders) and high poultry populations are key issues which may influence the success of mini feed mill operations. It can be concluded that poor extension and training is the main external challenge for the adoption of the mini feed mill across PNG. Additional internal challenges for other sites in PNG include sustainable supply of raw ingredients to make feed, sourcing of chicks and post-harvest or food safety issues during processing. Other internal challenges of adoption constitute the community's resource endowment, as well socio-cultural practices of the communities.

Generally, farmers in other sites of PNG may have a positive attitude towards using improved technologies. However, there may be a need to invest in a new plant and equipment, as well as improve the management and exposure of farmers to practices outside their community to allow them to obtain relevant skills to prepare them to utilise the mini feed mill technology. The positive attitude may only be the farmers' intention; therefore this has to be supported by farmers having an organization to guide them with planning, internal resources (e.g. human, land and labour) as well as support from

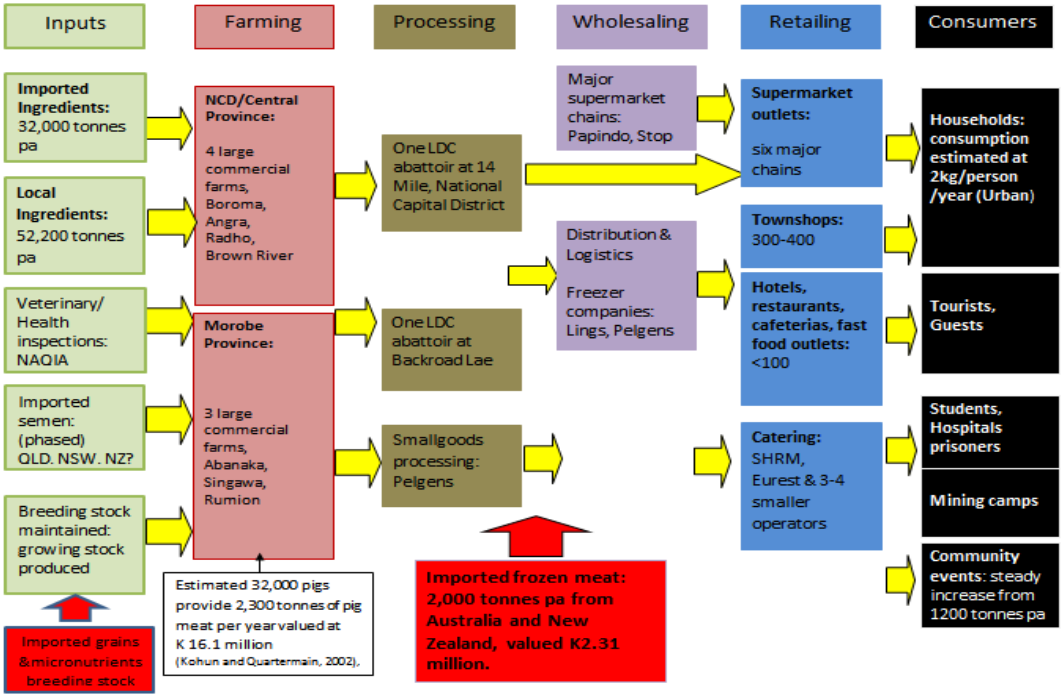
extension and development institutions, before the intent of the farmers can be implemented (Parminter,1997).

7.1.2 Mapping of the pig, poultry and aquaculture value chains

Mapping of the commercial and smallholder sectors

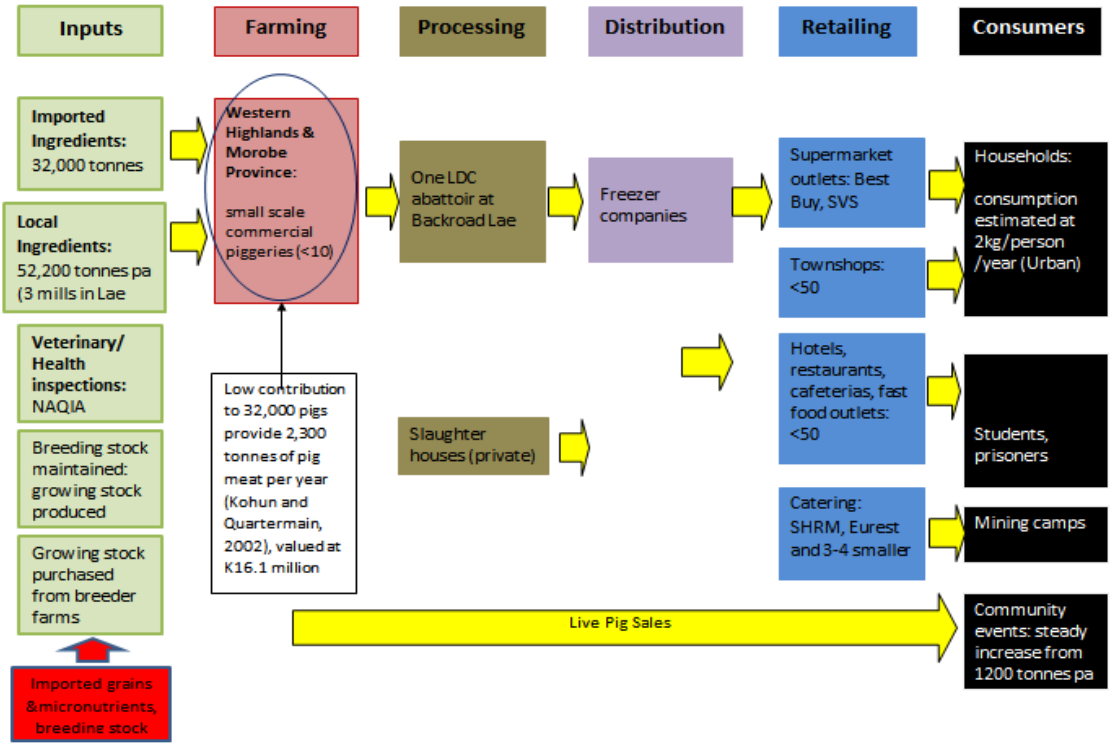
The value chain maps for the overall commercial and small holder sector in the pork, egg and aquaculture industries and the structure of the industry and where the mini mills fit in are shown in the value chain maps below (see Figures 1-5). For the table egg value chain map the only data available was for layers sold by CLTC in the highlands. According to the 2000 PNG national agricultural census, about half of rural households raise pigs for a living and an average of one pig is kept for every three people (NSO 2002). In parts of Southern Highlands, Enga, Western Highlands and Simbu Provinces, pig keeping is more widespread and significant, with up to three quarters of households engaged in the enterprise. Pigs are therefore the most important smallholder livestock in the country (Ayalew 2011) and a conservative estimate of the potential economic value of the small-scale pork industry is PGK 162 million. On the other hand the PNG livestock commercial sector is dominated by broiler chickens production due to a high demand for poultry meat. Expansion and sustainability of this sub-sector is dependent on encouraging more people to farm broilers by support with critical inputs such as lower feed costs, animal health services and regular extension services, thereby making it attractive and profitable. There are more than 20,000 fish farmers in PNG. The major constraints faced by these farmers are a lack of fish feed, limited availability of fingerlings, lack of training and access to information and extension services. Most PNG fish farmers are subsistence based, producing carp (Cyprinus carpio) and Genetically Improved Farm Tilapia (GIFT). GIFT have many desirable traits including high growth rate, ability to feed on natural aquatic food and supplemental feeds, tolerance to diseases and adverse environmental conditions (Rakocy 1989). More recently farmers have been farming trout (Oncorhynchus mykiss). Despite the lack of feed and technical knowledge required to formulate simple farm based feeds, interest in inland aquaculture farming in PNG has increased due to household protein demand and prospects for income generation.

Figure 1. Large scale commercial pig production value chain map for PNG



NCD is in the Central Province and includes the capital city Port Moresby and the Morobe Province includes the city of Lae.

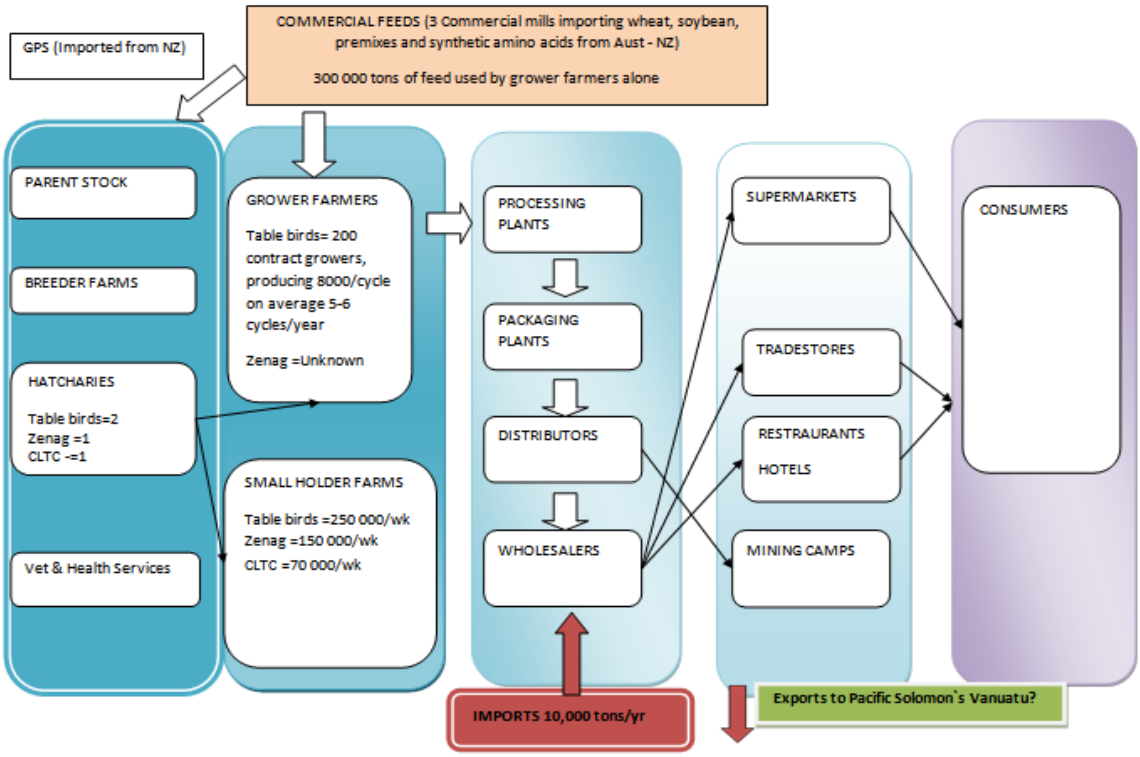
Figure 2. Small scale pig production Value Chain Map for PNG



14 Mini-mills in PNG: Domil (Jiwaka, 2010), Avi (WHP, 2011), Labu (Morobe, 2010), Tambul (WHP, 2011), Moses – HFPA (WHP, 2012).Kerevat (East new Britain), CLTC, (Banz),Pikosa (Goroka), Kiunga (OkTedi DF), Kondiu (Simbu Province), Kafetina Kianantu, Ioura (Highlands Aq Dev centre), Yonki (Goroka)

The Morobe province includes the city of Lae and the Western Highlands province includes the city of Mt Hagen.

Figure 3. Frozen and live meat chicken value chain map for PNG



Smallholder farms listed above sell birds live to village markets

Figure 4. Commercial table egg value chain map for CLTC in PNG

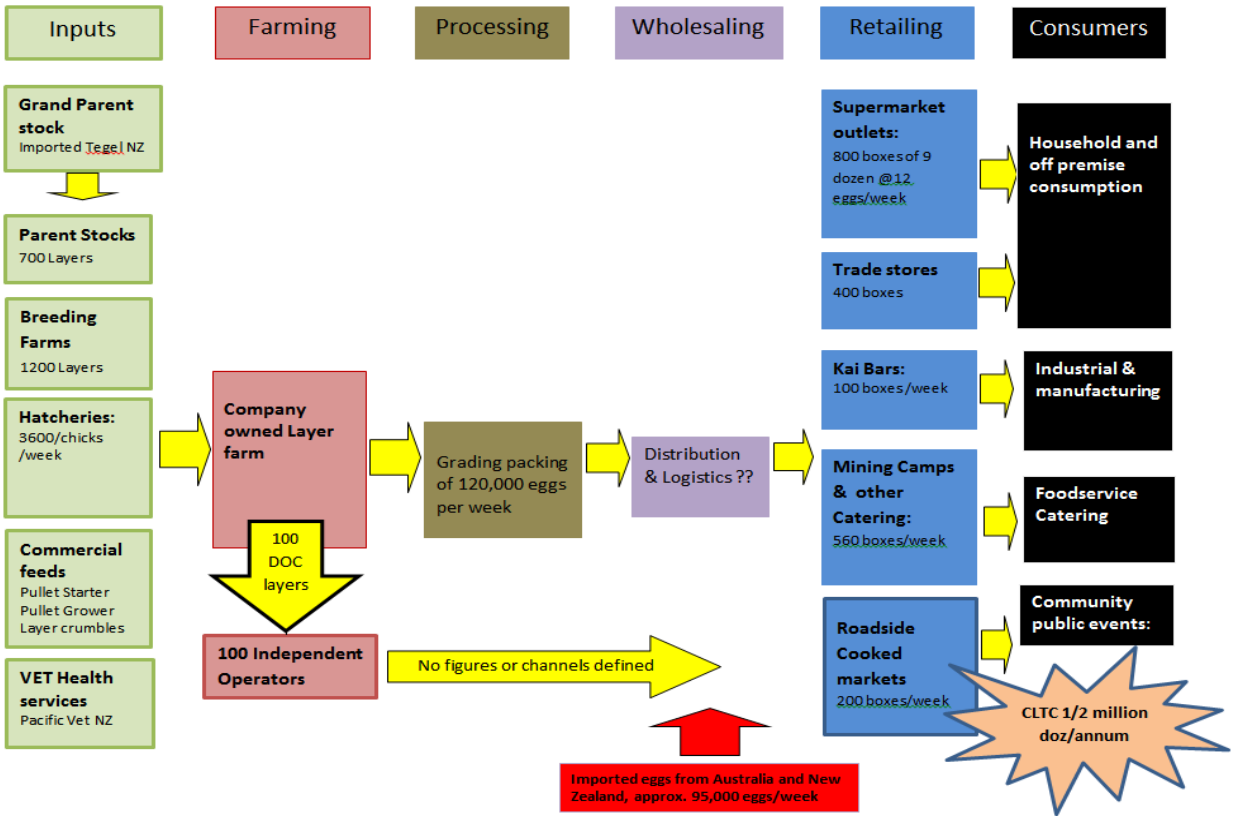
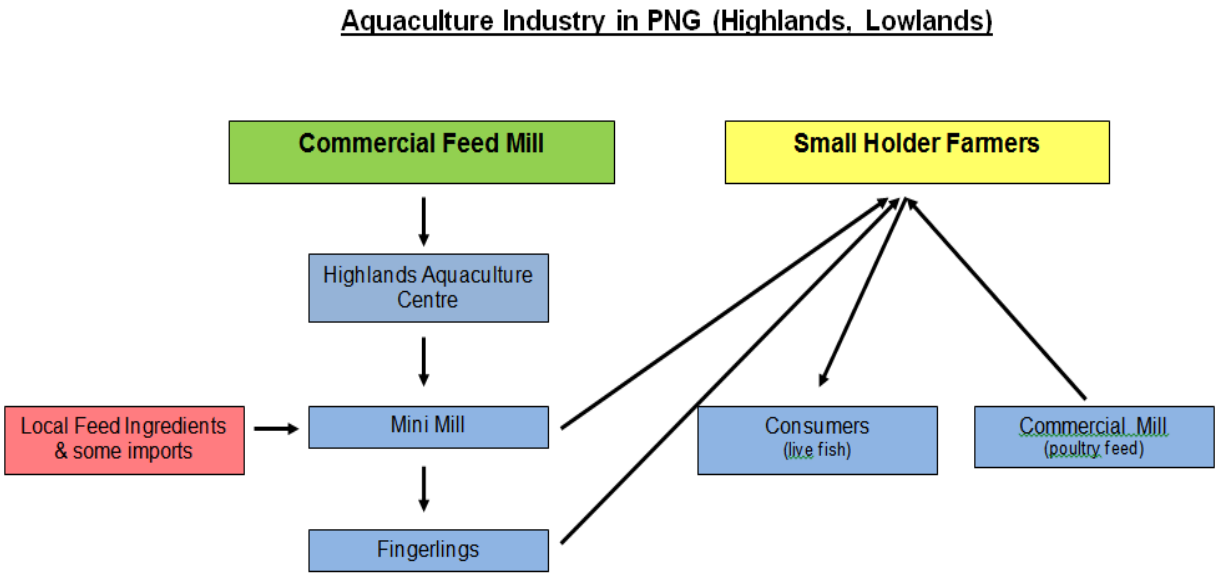


Figure 5. Aquaculture value chain map in PNG



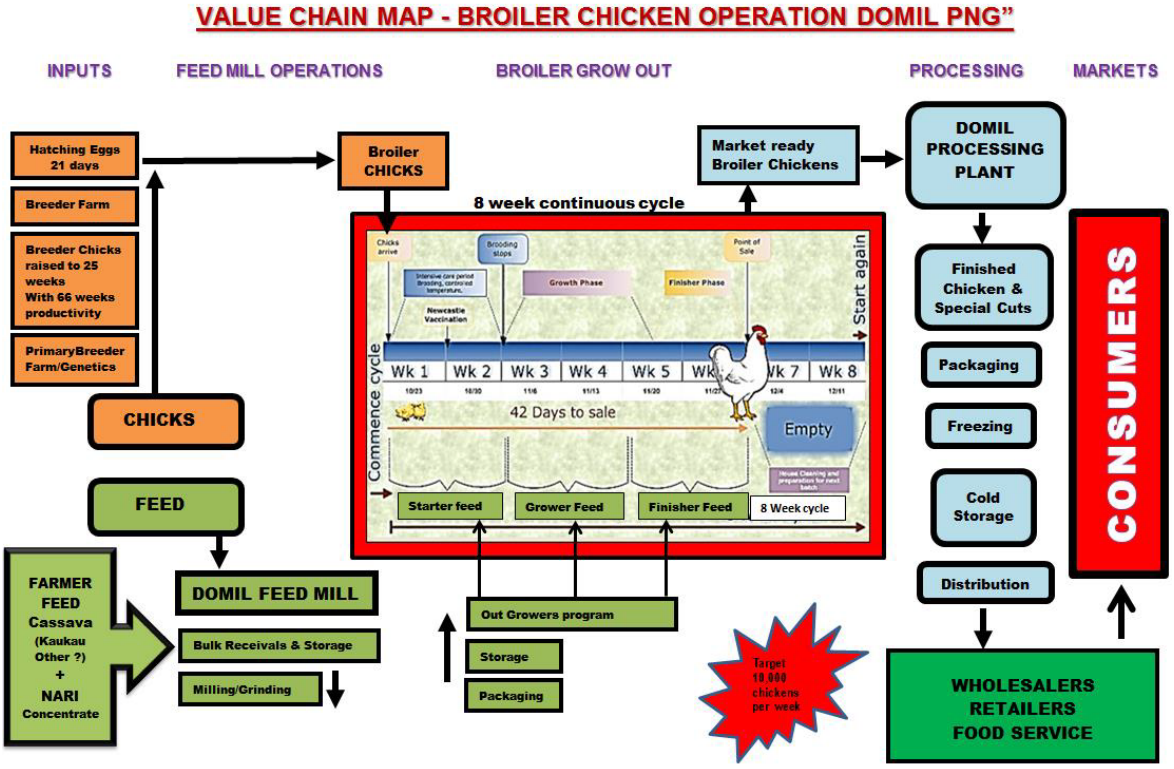
Mapping of Domil, Goroka, Pikosa and Tambul mini mills

The value chain analysis for individual mini mills was undertaken at the Domil mill with a focus on broilers, while the NFA Goroka mill and Pikosa Community Mill had a focus on inland fish and the Tambul private mill was focused on pork.

Domil mill

At the Domil mill the analysis highlighted the need to encourage the community to include egg production. The constraints include the lack of a backup generator, hammer mill and capital to further develop the business. It is recommended that the Domil Cooperative be used as a model in PNG and expand their operations as demonstrated in Figure 6. The value chain assessment highlighted some of the key opportunities to improve their operations.

Figure 6. Value chain map for the Domil Cooperative



Pikosa site

At the Pikosa site informal fish farming operations are in place but little use is being made of commercial or home grown feed to support fish farming except for integrated pig and tilapia farming. The Pikosa village has 5,000 brood stock maintained in various ponds. There has been limited use of commercial feed by the group with tilapia farming relying on the natural pond ecosystem and occasional supplementary feeding of food scraps. At the Pikosa site there are 100 fish ponds with a group of 20 farmers looking after the breeder farms for fingerlings while farmers who have fish ponds are encouraged to look after fish for their own nutritional security.

The co-operative has a large hammer mill powered with a generator and three hand-operated mincers. This equipment is used to prepare a tilapia diet comprising Fish meal (40%), banana (15%); avocado (15%), sweet potato (15%) and cassava (15%). The review identified that fish farming in this community is significantly constrained and limited to subsistence living only. Significant interventions and resources are required to move the facilities and practises to a level where consistent farming can be undertaken. There is some merit in the development of a demonstration pond facility in the area that can be used to catalyse learning, training and practical instruction. The village has good leadership and a management structure and considerable effort has gone into planning for the future.

Goroka site

The Goroka mill has operated for 10 years by NFA staff and can produce 200 kg of feed daily. The mill is located in central Goroka and formulates and supplies government subsidized feed to trout, tilapia and carp farmers in the highland areas. The operation and supply of feed is critical to support subsistence livelihoods and plays an important role in food security. The facility is also important as a centre of knowledge with staff also

provided advice and some extension services to farmers and others interested in the industry. Many interested farmers and organizations, NGO`s, schools, visit the facility to view the operations and learn about feeding practises and aspects about the industry. Storage space is a current constraint and there is need for larger storage area and possibly a container/chiller to store fish meal and finished feed. The cool climate of Goroka helps with shelf life but there have been some instances of stock packed in bags going rancid.

The lack of commercial feed for aquaculture farming in PNG, particularly in highland areas is considered a significant impediment to industry development. Most of the farmers operate at a subsistence level and feed cost is an issue with farmers relying on natural feed resources in the pond. This results in very low stocking rates and growth rates limited to 200-250 gram fish. Whilst feed production capacity is limited to subsistence farming there are signs that some farmers are keen to move to semi-intensive levels.

It is likely that the demand of feed will grow and a review of operations will be required to enable expansion with adequate infrastructure, plant layout and new equipment. Privatization may also be an option once demand levels are significant enough to enable an investor to operate profitably. In the meantime whilst there appears to be an untapped market for fresh fish in the highlands the fish farming industry is constrained by many factors. Some of these factors were highlighted during a short workshop carried out with local farmers and potential investors.

Tambul mill

The Tambul mini mill aims to supply pig feed, aquaculture feed and poultry feed (meat birds and layers) to farmers in the Western Highlands Province of PNG. The Tambul mini feed mill currently produces a small amount of pig grower and broiler finisher feed but has limited funds, lacks a pellet machine and has no storage facilities.

In the Mt Hagen area, the Kale family are operating at a sufficient scale (500 grower pigs/annum) to justify the establishment of a mini mill facility. They have a significant issue with feed shortage and quality. There exists a significant opportunity to use the 30 acres of state land around their current pig and vegetable growing establishment to promote the growing and processing of feed. During the project, NARI staff led by Michael Dom and Stanley Amben established a mini mill at the Kales piggery that is being used as an example to demonstrate benefits to other village farmers. However the provision of simple mill equipment to communities (or private investors) as has been shown from the experiences around other locations is insufficient without a properly resourced, holistic and multi-disciplinary industry development strategy and plan.

7.1.3 Strategic Plan for PNG mini mills

As a result of the survey work, value chain analysis and results from feeding trials a strategic plan to develop the PNG mini mill industry was developed.

Vision and Mission

Promote development of mini feed mill enterprises in PNG by implementing improved operation, business and marketing skills and greater use of local feed.

Vision

A viable mini feed mill enterprise sector supporting the expansion of the monogastric sector in PNG.

Mission

To ensure training in operational, business and marketing skills and greater use of local feeds in mini mill enterprises leads to an expansion and improvement of profitability in the smallholder monogastric sector in PNG

The five year strategic plan 2016-2021

Overall Objective:

NARI, UNITECH and SARDI and their PNG Industry and NGO collaborators are committed to ensuring that there is continued development of profitable and well operated feed mill enterprises in PNG with a focus on developing the market to supply cheap feed to support the expansion of the monogastric sector in PNG.

Objective One: Improve operation of mini feed mills in PNG

Activities

- Improve maintenance and equipment repairs in mini feed mills.
- Improve operational protocols for mills.
- Develop training packages for mill staff.

Targets

- Maintenance, equipment repair and operational plans developed.
- Mini feed mill engineer and maintenance officer appointed to service mini feed mills.

Performance indicators

- Mini feed mills report fewer breakdowns.
- Expansion of the monogastric sector through availability of cheaper feed produced by mini feed mills

Objective Two: Improve business skills of current PNG mini mill managers and provide advisory service to new mill investors.

Activities

- Improve record keeping and business operation skills for mini mill managers.
- Provide advisory service to new mini mill investors on capital, equipment and business planning.

Targets

- Record keeping and business operating protocols developed for mini mills.
- Advisory service to new mini mill investors established.

Performance indicators

- Improvement in profitability of mini mill enterprises.
- Increase in number of mini mills established in PNG.

Objective Three: Improve the livestock and fish value chain (associated with mini mills) and collaboration amongst stakeholders by improving production, processing, delivery and sale of products to consumers.

Activities

- Encourage improvement of the livestock and fish value chains in PNG.
- Develop new value added products from the livestock and fish sectors.
- Provide greater incentives for market participation.

Targets

- More effective, market-oriented value chains developed.

- Increase in output, quantity, quality, prices and distribution of pigs, poultry and fish products in enterprises associated with feed mills.
- More efficient production and distribution of products.

Performance indicators

- Increase in profitability of all sectors associated with the pig, poultry and fish value chains.
- Improvement in smallholder farmer livelihoods.

Objective Four: Expand the use of local feed ingredients in the small holder sector through evaluation of the digestibility and production efficiency of pigs, poultry and fish fed a greater range of novel concentrates blended with local feed ingredients.

Activities

- Evaluate digestibility and production efficiency of pigs, poultry and fish fed Universal Concentrate and super concentrates blended with local feed ingredients.
- Establish the role of PNG feed ingredients on gut health, nutrient retention and partitioning in pigs, poultry and fish.
- Formulate diets that more effectively meet the nutrient requirements of pigs, poultry and fish based on digestibility, efficiency and gut health studies.

Targets

- Universal Concentrate and super concentrates blended by mini mills for sale to village sector.
- Improvement in feed conversion efficiency of livestock and fish fed concentrates blended with local feeds.

Performance indicators

- Increase in production of fish, pigs and poultry in PNG.
- Improvement in smallholder farmer livelihoods.

7.1.4 Business Models

Models developed

Twenty four models (Table 8) were derived including a number of sub-models for layers which included the commercial hybrid layer, well-bred Australorp and inbred Australorps.

Table 8. Mini mill, pig, poultry and aquaculture business models

Mill type	**Kaliber mini-mill (purchased from Indonesia)**		**(PSS mini-mill (purchased from Lae, PNG)**	
Region	Highlands	Lowlands	Highlands	Lowlands
Enterprise feed concentrate produced				
Broilers	Model 1	Model 2	Model 3	Model 4
Eggs	Model 5	Model 6	Model 7	Model 8
Hybrid pigs	Model 9	Model 10	Model 11	Model 12
Tilapia	Model 13	Model 14	Model 15	Model 16

Village enterprise type		
	Highlands	Lowlands
Village Enterprise Feed	Sweet potato + concentrate	Cassava + concentrate
Broilers	Model 17	Model 18
Eggs	Model 19	Model 20
Hybrid pigs	Model 21	Model 22
Village Enterprise Feed	Concentrate	Concentrate
Tilapia	Model 23	Model 24

Mini mill models

The mini mill model spreadsheets cover the cost of feed ingredients as well as fixed and annual costs. Some of the costs are common to each of the models but different feed ingredients are needed for specific pig, poultry and aquaculture concentrates. Table 9 shows the results from the mini-mill modelling. An arbitrary 30% has been included as a mini mill margin at the mill gate. An arbitrary 30% has been added to the mill gate price as an allowance for transport to the reseller as well as reseller margin.

Table 9. Mini-mill models: prices of concentrate (K/kg)

Type	**Price at mill gate**		**Price at reseller**	
	Highlands	Lowlands	Highlands	Lowlands
Broilers	2.4	2.2	3.1	2.8
Broilers UC	2.4	2.2	3.1	2.8
Layers	2.0	1.7	2.6	2.2
Layers, UC	2.0	1.8	2.6	2.4
Hybrid pigs	1.4	1.1	1.8	1.4
Tilapia	3.2	2.8	4.1	3.7

UC = Universal Concentrate

Table 10 shows an example of the final spreadsheet of a mini-mill model in the PNG highlands producing broiler concentrate.

Table 10. Costs and revenue for producing mini-mill concentrate for broilers in the PNG highlands

Ingredient prices and example cost/tonne			
	Kina/tonne	kg used in a 1 tonne mix	Cost/revenue (kina)
High Protein			
Fishmeal	2557	200	511
Copra meal	950	200	190
Soybean meal	2493	250	623
High Energy			
Palm oil	2746	70	192
Low cost by-product			
Mill run	350	270	95
Premix	15668	10	156.7
Total		1000	1768
800 tonne/year (20 tonne/wk for 40 weeks/year for running mill)			1414397
Annualised capital cost			27642
Operating			44500
Total			**1486539**
Inclusive of profit margin(30%)			1932500
Price per tonne at the			2416
mini-mill gate			
Price per tonne at the			
retailer (+30%)			3140

Tables 11 and 12 show the annualised capital costs and operating costs for a mini mill. The price estimates were obtained from project participants during project review meetings. The Universal Concentrate price is estimated for margins and running costs and produces a result that is no different to using normal mini-mill feed ingredient in the highlands and is only marginally different in the lowlands.

It is thought that the prices of mini-mill concentrates, shown in Table 9 are highly competitive with concentrates offered by the large feed mills, for the village broiler and layer industries. When these concentrates are mixed with sweet potato or cassava to create a village enterprise feed, the combination is also thought to be highly competitive with the full-feed equivalent offered by the large feed mills and by companies that import feed directly from overseas.

Table 11. Annualised fixed costs for a mini-mill in the lowlands

	Cost kina	Amortisation years	Annual Cost
Capital			
Land	**6000**	20	300
Fence	**2500**	10	250
Sheds	**5000**	20	250
Roads, compaction, etc	**4000**	2	2000
Mini Mill[1]			
Hammer Mill (including electric motor)	**4774.7**	10	477
Discharge screw & electric motor	**2835.56**	10	284
Elevator (including electric motor)	**4314.52**	10	431
Mixer with gear motor and slide below mixer	**5439.7**	10	544
Hopper with frame	**3710.7**	10	371
Discharge screw & electric motor	**2835.56**	10	284
Pellet mill (including electric motor)	**9738.26**	10	974
Panels and cabling	**5846.68**	10	585
Shipment to Lae, installation and testing	**17290**	10	1729
Total	56785.68		
Scales	**1200**	5	240
Power supply and connection to machinery	**9600**	5	1920
Hand cutting and handling tools	**120**	5	24
storage & materials movement equipment	**360**	5	72
Office equipment	12000	5	2400
Bags, bins etc	15000	5	3000
Vehicle (second hand)	27000	5	5400
Less average annual interest on savings banked for replacement of capital			4134
	139565.7	1	17400

Table 12. Annual costs for running a mini-mill

	Lowlands	Highlands
	Kina	Kina
Fuel	16000	20000
Municipal rates	0	0
Power	0	0
Phone	500	500
Night Security	4000	4000
Office supplies	1000	1000
Pest control	1000	1000
Labour:		
Manager/Skilled Manual labourer	6000	6000
Labourers (2)	6000	6000
Repairs & maintenance	6000	6000
& replacement		
TOTAL	40500	44500

The farm enterprise models

Table 13 shows the results from the farm enterprise modelling with poor profitability for the tilapia growing enterprise. The relatively expensive high protein concentrate (see Table 1), fed without dilution, together with a lack of premium for fish protein is responsible for this poor profitability. Table 13 also shows that broiler farming has lower profitability than egg or pig farming. However, in its favour is the fact that the enterprise is a very simple operation to run.

Table 13. Profitability (%) of village enterprises by type and region

Type			**Highlands**	**Lowlands**
			Village feed mixed with	
	Batch	*Batches*	*mini mill concentrate*	
	size	*per year*	Sweet potato	Cassava
Broilers	50	4	**40**	**43**
Eggs	100 layers	1	**57**	**59**
Hybrid pigs, SP tubers	75 growers	2	**57**	**66**
Hybrid pigs, SP silage	75 growers	2	**59**	
Tilapia (concentrate only used)	1000	2	**18**	**20**

The village enterprises for broilers, eggs and hybrid pigs are highly profitable, and represent good business opportunities. However, once family and social obligations are met, whereby produce is given away, bartered or sold at cost, profitability will fall significantly.

The farm enterprise models consist of one spreadsheet only. Table 14 shows an example, in this case, a farm enterprise broiler growing industry in the highlands.

Table 14. Highlands broiler farming using mini mill feed mixed with sweet potato

Table 4: Highlands broiler farming - mini mill concentrate + sweet potato

				Total cost
	Quantity	Unit	Price	or revenue
			(Kina)	
COSTS PER BATCH OF BIRDS				
Mini Mill concentrate	60	kg	3.15	189
(retail outlet price inclusive of transport)				
Sweet potato fresh	120	kg	0.63	75.6
(energy source added to concentrate)				
Shed & equipment (5 yr shed life, 4 batches a year)			1000	50
Labour	50	hours	1.8	90
Day old chicks	52	chicks		200
Mortality	2	birds		
Age to market	50	days		
TOTAL COST PER BATCH				604.6
REVENUE PER BATCH				
live bird sales	50	birds	20	1000
BATCH OPERATION SURPLUS				395.4
Annual turn out (batches/year)	4	batches		
OPERATION SURPLUS PER YEAR				1581.6
Profit (%)				**40**

7.1.5 Feed Mill user brief

The feed mill user brief has been titled “Mini feed milling in Papua New Guinea” comprising two parts; 1) Mill management and 2) Feed ingredients and species formulations. The document could be released as an ACIAR monograph but in the first instance in included as an appendix in this report.

PART 1. MILL MANAGEMENT

Chapter 1. Introduction to mini feed milling

Chapter 2. Business and financial plans

Chapter 3. The milling process

Chapter 4. Mill layout and equipment

Chapter 5. Mill management

Further reading

Appendixes

Appendix 1. Business Plan template

Appendix 2. Audit Checklist

Appendix 3. Feed Mill Audit Scoresheet

Appendix 4. Code of Good Manufacturing Practice for Mini Mills in PNG

Appendix 5. Standard Operating Procedures

PART 2. FEED INGREDIENTS AND SPECIES FORMULATIONS

Chapter 6. Nutrient requirements of pigs

Chapter 7. Nutrient requirements of poultry

Chapter 8. Nutrient requirements of fish

Chapter 9. Feed ingredients

Chapter 10. Feed formulation

7.2 Objective 2. Formulate a range of least cost diets using local feed resources that can be produced by mini mills which meet the nutritional requirements of the most popular farmed fish, pigs and poultry in PNG.

Pig grower trials with protein concentrate blended with sweet potato roots either boiled or ensiled with or without vines

The experiment was conducted on-station at the Livestock Research Station at NARI. Four Large White–Landrace×Duroc grower pigs (25.5 kg) nine weeks-of-age were used with four diets (control vs. sweet potato diets).

The diets were as follows;

- Commercial pig grower diet;
- Pig concentrate (57%) mixed with boiled sweet potato roots (43%); i.e. SPBR
- Pig concentrate (57%) mixed with ensiled sweet potato roots (43%); i.e. SPER
- Pig concentrate (60%) mixed with ensiled sweet potato roots and vine (40%); i.e. SPERV

Nutrient utilization in grower pigs fed SP roots either boiled (SPBR43) or ensiled (SPER43), was higher ($p<0.05$) compared to the wheat based commercial feed (STDPG). Ensiled mixed root and vine diet (SPERV40) resulted in reduced nutrient utilization in grower pigs, particularly CP and N digestibility ($p<0.05$). The higher nutrient utilization for SP roots in either boiled or ensiled form when combined with the complementary protein concentrate was an important finding for advancing the nutrition offered for small-scale pig production. These two blended SP diets should be recommended to small-scale pig farmers. The higher N digestion found for pigs fed the boiled SP diet could have implications with respect to the amount of supplementary protein required to meet the animal's N requirement and warrants follow up.

Pig grower trials with protein concentrate blended with cassava roots either boiled or ensiled with or without vines

The experiment was conducted at the PNG National Agricultural Research Institute (NARI) Livestock Station, Morobe Province. The experiment design was 4x4 Latin Square with four diets (control vs cassava based diets) as interchanged treatments fed to four grower pigs on four consecutive eight-day feeding periods.

The diets were as follows;

- Commercial pig grower diet;
- Pig concentrate (55%) mixed with boiled cassava roots (45%); i.e. CABR
- Pig concentrate (55%) mixed with ensiled cassava roots (45%); i.e. CAER
- Pig concentrate (55%) mixed with cassava milled roots (45%); i.e. CAMR

Dry matter, fibre, nitrogen-free extract (NFE), calcium and percentage energy digestibility were significantly different to the standard but ash, fat, protein and phosphorous were similar for all diets ($p>0.1$). The three cassava diets were superior to STDPG in DM, NFE and calcium and percentage energy digestibility ($p<0.05$). Fibre digestibility was significantly better for the high DM diets (STDPG and CAMR) than the low DM diets CABR and CAER ($p<0.05$), but STDPG showed a significant net loss of calcium ($p<0.05$). However, growth rate and feed conversion were superior for pigs fed the blended roots than the commercial feed. These results may be related to different root processing and the type or amount of protein ingredients. The significant improvement for DM digestibility of nutrients and energy and equal N-retention of the blended cassava root diets demonstrated their suitability for high performing genotypes.

Cassava roots blended at 55% of the diet improved the nutrient and energy utilization to grower pigs regardless of the mode of preparation. These blended cassava root diets are recommended but further performance and economic assessment is needed for small-scale farms producing local mixed genotype pigs.

On-farm proof of concept pig feeding trial using ensiled sweet potato roots fed to local mixed genotype pigs in the Western Highlands Province

The trial was conducted at Robinson Kale's pig farm at Kindeng in the Western Highlands Province farm. The aim was to test the performance (feed intake, growth rate and feed efficiency) of local mixed genotype grower pigs fed ensiled sweet potato roots blended with a Pig Concentrate (SPER) compared to pigs fed a commercial pig grower standard feed (STDPG) under restricted feeding. Due to the severe drought and shortage of sweet potato the diet feed could only be provided to pigs on a restricted basis.

The trial was conducted for 80 days over the period November 2015 to January 2016. An equal number of barrows and gilts about 7-10 weeks age were used in the trial with body

weight ranging from 10-40 kg. The diets tested were the Pig Concentrate (57%) mixed with 43% sweet potato ensiled roots (SPER) compared to commercial grower pellets (ie. STDPG)

Feed offered was restricted to 1.0 kg DM/day/pig for the SPER diet and 1.5 kg DM/day/pig for the STDPG diet due to sweet potato shortage as a result of the drought.

Pigs fed the STDPG diet had a higher finishing weight (61.1 kg vs. 58.5 kg) after 80 days with a 10% higher growth rate. As mentioned previously the trial was undertaken during a drought period and was constrained by a shortage of sweet potato. The total body weight gain of pigs was was 36.9 kg and 42.5 kg for pigs fed the SPER and STDPG respectively (13% difference).

However pigs fed the SPER diet had a superior FCR (2.75) compared to a FCR of 3.65 for pigs fed the STDPG diet (32% difference). This finding is important as it indicates that the SPER diet was cheaper to feed than the STDPG diet.

Poultry diets

Production performance of a Hyline Brown, a Hyline Brown x Australorp crossbred and Indigenous layers fed on a sweet potato or cassava based layer concentrate diet.

The experimental work was conducted at the PNG National Agricultural Research Institute (NARI), Livestock Research Station at Labu located near to the Lae Township.

Experimental diets

Birds were fed 3 diets as follows;

- High Energy Layer concentrate mixed with boiled mashed sweet potato (HELC+BMSP),
- Low Energy Layer concentrate blended with boiled mashed cassava (LELC+BMC), the
- Commercial layer pellet (Con) as the control diet.

Feed intake, egg production and egg weight were recorded. Body weight of pullets was recorded at the start of the trial and at monthly intervals thereafter until the trial was terminated.

The unit costs of diets/kg on DM basis were K1.75 for the HELC+BMSP diet, K1.55 for LELC+BMC diet and K2.64 for the commercial diet (Table 15).

Table 15. Costs of feeding layers on a sweet potato or cassava based Layer concentrate diet.

Ingredients	Boiled mashed ratio	Qty/kg feed concentrate	Qty/kg feed SP or Cass	Cost/kg (PGK) as fed basis	Cost/kg (PGK) DM basis
HELC+BMSP	2.7 : 5.9	0.30	0.70	1.25	1.75
LELC+BMC	2 : 4.5	0.31	0.69	1.19	1.55
Commercial	-	-		2.32	2.64

Overall mortality of 4.8% was noted for the Hyline Brown x Australorp crossbred and Indigenous layers which was significantly lower (P<0.05) than the 25.8% mortality for the Hyline brown strain. Similarly, layers fed on HELC+SP and LELC+Cass diets had significantly (*P*<0.001) lower mortality rate of 2.04% and 7.14%, respectively, than birds fed on the commercial diet with a mortality of 26.2%.

The high mortality in Hyline Brown and the Hyline Brown x Australorp crossbred fed the commercial diet was almost exclusively caused by injurious pecking. The Hyline Brown x

Australorp crossbred achieved consistently higher egg production throughout the trial compared to the Hyline Brown. It was expected that the Hyline Brown would achieve peak egg production of 94-96% (Hyline Brown International, 2009). The observed cannibalism and feather pecking clearly had a substantial impact on egg production; birds only achieved a peak egg production of 70-75%.

Table 16. Feed intake, egg weight, egg production %, FCR and body weights of 3 genotypes of birds fed on sweet potato or cassava based layer concentrate diet versus a commercial diet over 25-35 weeks-of-age.

Treatment	DM Feed Intake (g/b/d)	Egg weight (g)	Egg production (%)	FCR (g feed/kg egg)	Body Weight (kg)	Weight Gain (g)
Village	92.6a	50.2c	38.1c	1.9c	1.497a	10
Hyline Brown x Australorp	128.9b	55.9b	70.3a	2.3b	1.790b	45
Hyline Brown	122.5c	57.9a	52.6b	2.1a	1.620c	40
P-value	<0.001	<0.001	<0.001	<0.001	<0.001	0.356
HELC+BMSP	111.4a	54.3a	52.7b	2.1a	1.672	56
LELC+BMC	129.9b	53.5a	61.8a	2.4b	1.625	3
Commercial	96.7a	56.1b	46.5c	1.7c	1.612	36
P-Value	<0.001	<0.001	<0.001	<0.001	0.066	0.141
Grand mean	114.7	54.65	53.7	2.1	1.636	31
LSD 5%	4.712	0.539	2.70	0.0825	0.0523	52.9

HELC + BMSP = high energy layer concentrate mixed with boiled mashed sweet potato; LELC + BMC = low energy layer concentrate mixed with boiled mashed cassava. Means followed by a common letter are not significantly different (P>0.05).

As expected the village hens had the lowest egg production percentage (Table 16). Hens fed the low energy layer concentrate mixed with boiled mashed cassava performed best while the birds fed the commercial diet had the lowest egg production.

The feed intake was highest (P < 0.05) for the Hyline Brown x Australorp crossbred followed by Hyline Brown hens and village hens (Table 16). The Hyline Brown hens produced the highest egg weight as expected followed by the Hyline Brown x Australorp crossbred and then the village hens (Table 16). In addition, chickens fed the standard commercial layer pellet achieved the highest egg weight compared to hens fed on the sweet potato or cassava based layer concentrate.

The FCR results showed there was a significant (P <0.05) difference between genotypes and diets. The most efficient converter of feed was the village hen followed by the Hyline Brown and the Hyline Brown x Australorp crossbred (Table 16).

Table 17. Egg weight equivalent of feed intake and feed cost of eggs produced by diet

Diets	DM feed intake per day(g)	Cost/kg DM feed (PGK)	Cost of daily DM feed consumed (PGK)	FCR	Egg weight equiv. of feed intake (g)	Daily feed cost of egg (PGK)	Feed cost of 53g egg (PGK)
Commercial	96.7	2.64	0.255	1.7	56.9	0.150	0.140
HELC+BMSP	111.4	1.75	0.195	2.1	53.0	0.093	0.093
LELC+BMC	129.9	1.55	0.201	2.4	54.1	0.084	0.082

HELC + BMSP = high energy Layer concentrate mixed with boiled mashed sweet potato; LELC + BMC = low energy Layer concentrate mixed with boiled mashed cassava.

Average feed cost of egg production was derived from calculated values of daily feed intake, cost of rations and the FCR (Table 17). Combining DM feed intake with FCR gives egg weight equivalent of feed intake of 56.9 g per day for the commercial diet, 53.0g for the high energy layer concentrate mixed with boiled mashed sweet potato and and 54.1g for the low energy layer concentrate mixed with boiled mashed cassava. Relating these to the average cost of diets gives an estimate of daily feed cost of egg production for each diet; ie. PGK0.15 for the commercial ration, PGK0.093 for high energy layer concentrate mixed with boiled mashed sweet potato and PGK0.084 for the low energy layer concentrate mixed with boiled mashed cassava. It can be inferred that the overall feed cost of egg production using the high energy layer concentrate mixed with boiled mashed sweet potato and the low energy Layer concentrate mixed with boiled mashed cassava was reduced by 66.4% and 58.6% respectively compared to the control commercial layer pellet.

It was observed that high mortality in Hyline Brown hens was related to injurious pecking which can be controlled by beak trimming (Bourke *et al., 2002*), which also concurs with an earlier study of the high incidence of brown egg layers to pecking related high mortality rates (Häne et al., 2000).

The two test diets were presented as wet feeds (mashed boiled sweet potato or cassava tuber with the concentrates) which may have contributed to their significantly higher average daily DM feed intake relative to that of the commercial layer pellet. Similarly, Tadtyanant *et al*. (1991) observed that wet feeding increased the dry matter (DM) intake and thereby alleviated partially the effect of heat stress on feed intake and laying performance.

Given the dietary effects noted for genotype on egg production performance and mortality, the best bet option to recommend to village poultry producers is to use F1 hens and feed them with sweet potato and cassava based concentrate diet for layers. The results indicate that Hyline Brown cross and village hens can be effectively used for egg production when fed on cassava and sweet potato based concentrate diets in PNG and other Pacific Island countries with similar agro-ecological zones where sweet potato and cassava serve as the main staple food.

Egg production performance of Hyline Brown hens fed on poultry concentrates blended with sweet potato or cassava in the highlands of PNG.

This trial was conducted at the CLTC farm in Banz, Jiwaka Province.

There were three dietary treatments in this trial.

- High energy layer concentrate (HELC) mixed with boiled and mashed sweet potato (BMSP) tubers.
- Low energy layer concentrate (LELC) mixed with boiled mashed cassava (BMC) tubers.
- Standard commercial layer diet prepared by a commercial feed mill.

The treatment diets had highly significant effects on all variables measured except egg weight, body weight changes and egg shell thickness (Table 18).

Table 18. Egg production variables, shell thickness and feed costs of Hyline Brown layer hens fed on 3 different diets from 21-33 weeks-of-age.

	Treatments				
Parameter	**HELC+BMSP**	**LELC+BMC**	**Commercial**	**SE**	**P value**
Egg production (%)	66.3a	74.3a	86.2b	2.49	0.002
Egg weight (g)	55.5	52.8	56.5	1.07	0.091
Feed Intake (g) dm basis	94.8a	101.8a	123.5b	3.2	0.001
FCR (kg feed/kg egg)	1.69a	1.95b	2.17c	0.063	0.002
Body weight changes (g)	0.19	0.18	0.153	0.015	0.076
Feed cost per kg egg (Kina)	4.25a	4.92a	5.76b	0.152	0.001
Egg shell thickness (mm)	0.46	0.45	0.45	0.011	0.507

K = Kina; means within rows with different superscripts are significantly different at P<*0.01*.

Hens fed on the commercial diet had significantly (P<0.05) higher egg production, feed intake, FCR and feed cost than hens fed on the cassava and sweet potato-based diets (Table 18). The egg yolk colour was better for hens fed on the commercial diet. The results of this trial are similar to other workers who fed diets containing cassava and sweet potato to layer hens. Aina and Fanimo, (1997) found that diets containing cassava and sweet potato did not affect egg weight but significantly reduced egg production of Isa Brown layer hens. Lodakun, *et al*. (2007) also reported significantly lower hen-day egg production for Isa Brown hens fed on diets which contained different combinations of sweet potato meal and sweet potato tops as compared to diets which contained maize but no sweet potato products. Similarly, Afolayan *et al*. (2013) reported a significant reduction in hen-day egg production for hens which were fed diets containing 30% and 40% sweet potato meal as compared to hens fed on a diet containing 41.2% maize and no sweet potato. The feed cost of the commercial diet was significantly higher than the cassava and sweet potato diets while feed cost of the cassava and sweet potato diets were similar. The lower cost of the sweet potato and cassava layer diets suggests that these diets could be a viable alternative to the commercial layer diets especially in parts of PNG which are located at some distance away from commercial feed mills.

Egg production performance of village hens fed on poultry concentrates blended with sweet potato or cassava in lowlands of PNG.

The experiment was conducted at the village chicken breeding and distribution facility at LDS Centre in Malahang, Lae. The trial was conducted for 7 weeks.

There were three dietary treatments in this trial.

- 60% of a high energy layer concentrate (HELC) mixed with 40% of boiled and mashed sweet potato (BMSP) tubers.
- 60% of a low energy Layer concentrate (LELC) mixed with 40% of boiled mashed cassava (BMC) tubers.
- Standard commercial layer diet.

Table 19. Egg production, egg weight, feed intake, FCR, weight change, feed cost per kg egg and egg shell thickness of village hens fed three different treatment diets at LDS.

		Treatments						
Parameter	**N**	**HELC+BMSP**	**N**	**LELC+BMC**	**N**	**Commercial.**	**SE**	**P-value**
Egg Production (%)	3	41.3	3	46.6	2	37.0	3.07	0.59
Egg Weight (g)	3	51.3	3	46.8	2	51.0	0.86	0.004
Feed Intake (g/b/day))	3	117	3	123	2	73	10.64	0.15
FCR (kg feed/kg egg)	3	2.28	3	2.64	2	1.44	0.24	0.13
Weight Change (g)	3	66.7	3	66.7	2	70.7	21.13	0.46
Feed cost per kg egg (K)	3	9.95	3	9.26	2	6.57	0.79	0.26
Egg shell thickness (mm)	3	41.4	3	46.0	2	43.80	1.5	0.50

The egg production percentage was highest for hens fed on the cassava based diet followed by hens fed on the sweet potato based diet and lowest for hens fed on the commercial diet (Table 19). However the numerical differences in egg production were not significantly different. The lack of significance between the treatments is probably due to the low number of replicates in the trial. Nevertheless the experiment demonstrated that use of local feeds resulted in satisfactory egg production relative to the commercial feed. The highest average egg weight was obtained from village hens fed on the sweet potato diet which was equivalent to the egg weight of hens fed on the commercial diet but significantly ($P<0.05$) higher than the mean egg weight of hens fed on the cassava based diet. While it is difficult to draw a sound conclusion without significant differences being observed in egg production for treatment diets, hens fed on the cassava diet tended to lay more eggs and their egg weight was significantly lower than that of hens fed on the other diets. On the other hand hens fed on the sweet potato diet tended to have similar egg production percent and egg weight compared to hens fed on the commercial diet (Table 19). Generally therefore, it appears the sweet potato diet produced the same results as the commercial diet in terms of egg production % and egg weight.

Village chickens dominate the family poultry production systems in the village environment despite their lower genetic potential in terms of meat and egg production (FAO 2014). The egg production percent of hens fed on the cassava, sweet potato and commercial feeds were better than egg laying rates reported for scavenging village chickens under field conditions. Egg shell thickness is an important factor in egg shell strength and is dependent on the calcium and phosphorus content of the diet and bird feed consumption. No significant differences in egg shell thickness were found between eggs from hens fed on the three treatment diets in this trial. This result suggests that, even though the cassava and sweet potato diets contained slightly lower calcium and phosphorus, they did not significantly affect egg shell thickness relative to the standard commercial diet. This suggests that the diets provided similar amounts of the major nutrients involved in egg shell formation.

The results also indicated that the treatments had no significant effects on the feed cost per kilogram egg weight even though the commercial diet tended to be cheaper than the cassava and sweet potato diets. This tendency may be due to the lower feed intake of hens fed the commercial feed.

The village chicken genotypes are well adapted to the local ingredients used in this study and this adaptation could be exploited to reduce costs of feeding local chickens. The tubers are available for use by smallholder farmers and can be blended with layer concentrates. It is also noted that yellow tubers can be used extensively to improve yolk colour and further processing, proper storage and handling of sweet potato, cassava and concentrates can improve the performance of hens.

Use of a Universal Concentrate in poultry proof of concept feeding trials

Performance of broiler chickens fed cassava blended with a Universal Concentrate in an on-farm study

Six farms from the Domil Cooperative in the highlands region of the Nondugl Rural Local Level Government District were used in this study.

The dietary treatments as outlined previously tested a Universal Concentrate, palm oil and broiler premix blended with cassava flour and compared with the standard finisher ration.

Data on feed intake, body weight gain and cost of feeding each diet were recorded over 20 days commencing on day 22.

The birds fed the UC+Cas diet consumed less feed and had a slightly better FCR than birds fed the commercial finisher but the differences were not significant (*P>0.05*). All other measured parameters did not differ significantly except feed costs. The costs (K/kg) of feeding finishing broilers differed significantly (6.15 vs. 4.89; *P<0.05*) with the least cost observed for the UC+Cas diet (Table 20). These results were similar to those reported by Maxwell *et al*. (2014) and Ngiki *et al*. (2014) when broilers were fed with cassava-based diets. Maxwell *et al*. (2014) observed broiler chickens fed with cassava diets were heavier than birds fed a control diet.

Table 20. Comparison of mean DMI, FCR, ADG, FBW and cost of birds fed UC+Cas and a commercial finisher ration.

Parameters	DMI (g/day)	FCR (kg/kg)	ADG (g/day)	FBW (kg)	Costs (K)†
Standard	99.1[a]	1.84[a]	20.4[a]	2.50[a]	6.15[a]
UC+Cas	97.7[a]	1.75[a]	21.0[a]	2.49[a]	4.89[b]
S.E.M	2.31	0.12	1.09	0.09	0.13
Significance					
F pr.	0.667	0.609	0.707	0.941	0.001
CV (%)	5.8	16.8	13.0	9.1	6.2

[a] Means within columns with similar superscripts are not significantly different at *P<0.05*. S.E.M = Standard Error of Mean. BR_STD = standard broiler finisher (LFM). UC+Cas = Universal Concentrate (56.8%) blended with cassava flour (39.8%) including broiler pre-mix (0.4%) and palm oil (3.0%). [†]Cost of feeding based on feed intake of broilers during the finishing phase (day 22-42).

Substituting commercial feed with local carbohydrate sources has cost reduction advantages for village broiler enterprises (Black and Yalu, 2010). The inclusion of cassava flour at 40% proved to be economical with costs savings of up to 12.9% observed for chickens fed the UC+Cas diet during the finishing off period (Table 6). Similar cost savings of 13.25% were reported by Maxwell *et al*. (2014) when maize was substituted with cassava in chicken diets.

Table 21. Cost per diet according to feed intake of Ross 308 broiler chickens during the finisher phase.

Feed Type	Cost/b (K) Starter	Cost/b (K) Finisher	Total Cost/b (K)	Selling Price/b (K)	Profit Margin/b (K)
BR_STD	4.15	6.15	10.30	30.00	19.70
UC+Cas	4.15	4.89	9.05	30.00	20.95

This study showed that the UC+Cas ration supported feed efficiency and growth of broiler chickens with distinctive cost advantages. Cassava flour could therefore be an alternate source of energy to use as a substitute for wheat and sorghum in broiler diets. These findings need to be supported by further studies that use cassava flour in starter rations and the associated costs of the diet. Attention also needs to be given to measuring the cyanogen content of cassava flour after drying and milling and to reduce its dusty characteristics in the diet.

Performance of a local chicken crossed with Shaver Brown layer fed on universal poultry concentrate blended with cassava

The study took place in two villages, Amela and Amarub in the Trans-Gogol area of Madang Province situated in the Central North of the PNG mainland. Nine farmers were selected given their interest in the project. Two trials were undertaken; the first involved 5 farmers; and in the second trial 4 farmers participated.

The Universal Concentrate was mixed with 50% cassava flour and complemented with 10.35% of palm oil, sunflower oil, limestone, salt and layer premixes to produce a complete layer diet. The variables measured were feed intake (g/bird/day), egg weight (g), hen-housed-egg production (%), feed conversion ratio (FCR), cost of feed per hen per day, feed cost to produce a dozen eggs and the total feed cost over the experimental period.

There was no significant difference in egg weight and rate of lay (Table 22) with better performance observed in birds fed the standard ration. No significant differences were observed for feed intake and FCR with superior performance noted for birds fed the UC+ Cas diet.

Table 22. The rate of lay (%), feed intake (g/bird), egg weight (g) and FCR of a cross breed strain of Shaver Brown hens fed UC + Cas vs. a standard diet.

Parameters	Feed intake	Egg weight	Rate of lay	FCR

UC+Cas	112.7	49.41	0.38	2.27
Standard	119.5	51.35	0.48	2.33
S.E.M	6.92	0.935	0.039	0.1208
CV (%)	17.9	5.6	27.5	15.8
P-Value	0.497	0.161	0.093	0.737

The feed cost for the standard diet was higher than the UC+Cas diet at PGK 2.75/kg and PGK 2.00/kg respectively (Table 23). Furthermore it cost PGK 0.91 and PGK 0.77 to produce one egg using the UC+Cas and the standard diet respectively.

Table 23. Cost of production and projected profit margin based on selling price of PGK1.00 per egg in local markets by farmers.

Diet	Total Feed Intake (kg)	Total Feed Cost (PGK)	Cost/kg (PGK)	Eggs Produced	Cost/egg (PGK)
UC+ Cas	357.12	*714.24	2.00	785	0.91
Standard	405.85	*1116.09	2.75	1445	0.77
Diet	Eggs Laid	Selling Price/Egg (PGK)		Gross Revenue (PGK)	Profit Margin (PGK)
UC + Cas	785	1.00		785	70.76
Standard	1445	1.00		1445	328.91

*These calculations were based solely on the costs of feeding and exclude other related costs.

The feed intake of the laying hens were comparable to intake (110 g/hen/day) recommended for laying hens by NRC (1994) and DM based feed intake recorded by Ahizo *et al.* (unpublished) when Shaver Brown and Australorp crosses were fed with a low energy layer concentrate blended with boiled and mashed cassava. The egg weight in this study was lower than the egg weight recorded by Ahizo *et al.* (unpublished), but were higher than those reported by Glatz *et al*. (2013) when high and low energy layer concentrates blended with boiled and mashed sweet potato and cassava were fed to laying hens. The cost of feeding the UC+Cas diet was 36% lower than the standard diet. As expected, birds fed the standard diet performed better than hens fed UC+Cas ration. The UC+Cass diet was cheaper with both diets generating reasonable profits.

Aquaculture Diets

Comparative performance of juvenile gift tilapia fed on broiler concentrate mixed with sweet potato or cassava meal

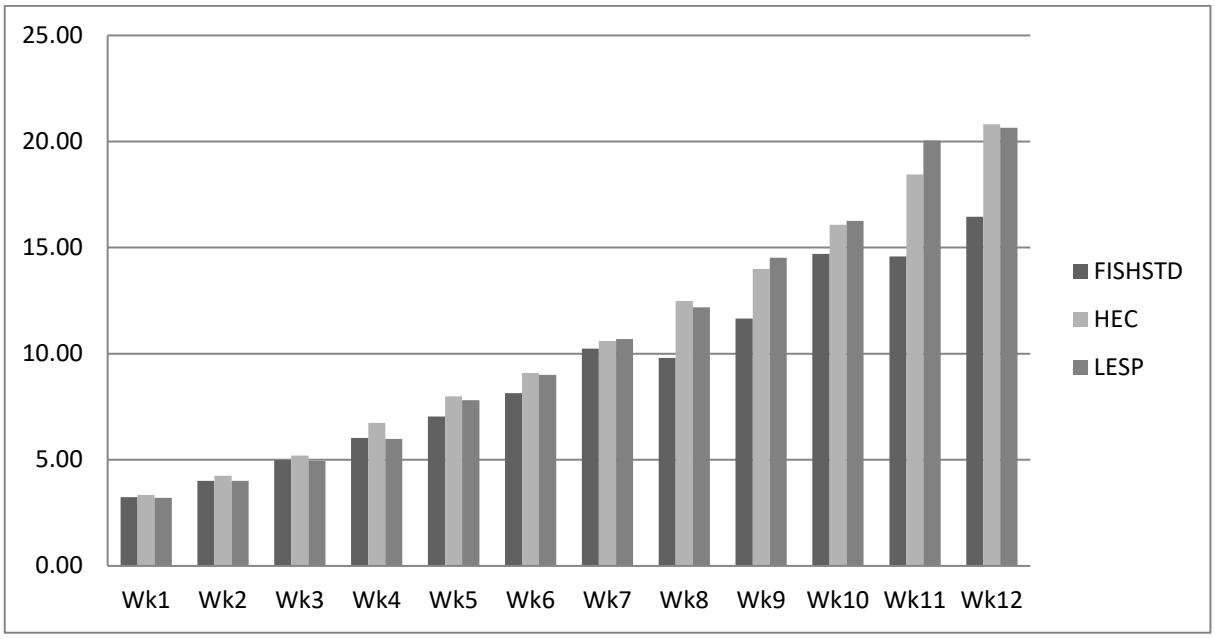
The experiment was conducted at the Inland Aquaculture Research Facility at NARI's Labu Livestock Research Station in Lae, PNG.

A total of forty-eight (48) mixed-sex juvenile GIFT tilapia fingerlings were used in the experiment. Groups of four fish (35g) were randomly selected and allocated to each of the twelve (12) experimental tanks. The benchmark feed used in the experiment was supplied by the National Fisheries Authority (NFA) mill in Goroka, PNG. Sweet potato dry milled

tuber was mixed with LE broiler concentrate (LESP) and cassava was mixed with the HE broiler concentrate (HEC).

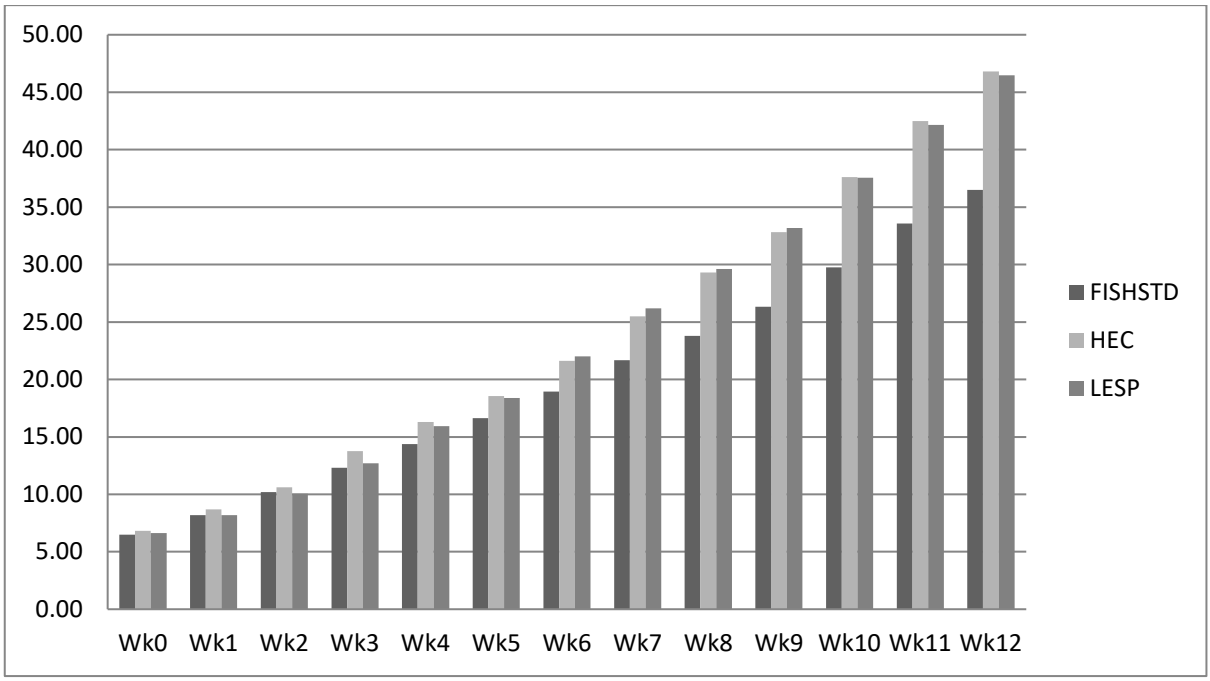
There was no significant difference between weekly feed intake, mean body weight or feed conversion ratio of juvenile GIFT Tilapia fed the HEC, LESP or FishSTD diets. Juvenile GIFT Tilapia fed the HEC treatment recorded the highest feed intake from week 1 to week 6 (Figure 7). From week 7 through to harvest, feed intake tended to be higher in GIFT juveniles fed the HEC and LESP diets compared to fish fed the FishSTD diet. At the conclusion of the trial weekly feed intake of fish fed the HEC and LESP diets was about 25% higher than those fed the FishSTD diet (Figure 7).

Figure 7. Mean weekly feed intake (g) of GIFT juveniles fed with 3 test diets over 12 weeks



The experiment was conducted under optimum environmental conditions to minimize factors that may influence fish growth such as dissolved oxygen (DO), temperature and light intensity. GIFT tilapia species has a monogastric digestive system whereby poultry feed can be effectively utilized. According to Chiayvareesajja et al. (1988) chicken pellets (19.9% crude protein) were determined to be a suitable supplemental feed for cage culture in Thailand.

Figure 8. Mean weekly body weights (g) of GIFT juveniles fed with 3 test diets over 12 weeks



In the present study the diets containing a mixture of 75% broiler concentrates (HE and LE) and 20% cassava meal (HEC) or sweet potato meal (LESP) were found to support a higher growth of GIFT Tilapia juveniles than fish fed the FishSTD diet. At the end of the experimental period the mean values of feed intake, bodyweight (Figure 8) and feed conversion ratio of juvenile GIFT tilapia fed HEC and LESP was not significantly (P>0.05) different from those of the commercial control diet (FishSTD). Although not significant, our results support the findings of Cao Thang Binh et al. (1996) who reported that a diet containing 20% crude protein formulated from concentrated poultry feed (40% crude protein) and cassava meal gave best growth of Nile Tilapia.

The higher intake and bodyweight gain of fish fed on HEC and LESP compared to the FishSTD diet may have been due to the processing (i.e. boiling, oven drying, sun drying, grinding and pelletizing) of the cassava and sweet potato prior to pelleting. These processing steps may have reduced the anti-nutrients in cassava and sweet potato thus increasing the palatability of these two diets.

In conclusion, the results of this study show that a diet using a 75% low energy broiler concentrate combined with 20% of cooked sweet potato and a diet of 75% high energy broiler concentrate combined with 20% cooked cassava will support acceptable growth rate of juvenile GIFT tilapia when reared in tanks. There was evidence that GIFT tilapia reared on the blended diets had eaten more feed and were heavier at harvest than fish reared on the FishSTD diet; this shows that GIFT Tilapia can utilize sweet potato and cassava in a formulated diet. The blended diets appear promising and new trials should be conducted to determine if this technology can be used in farm-based ponds and cages. If this technology is successful it will go a long way to meeting the growing demand for low protein fish feeds amongst village farmers.

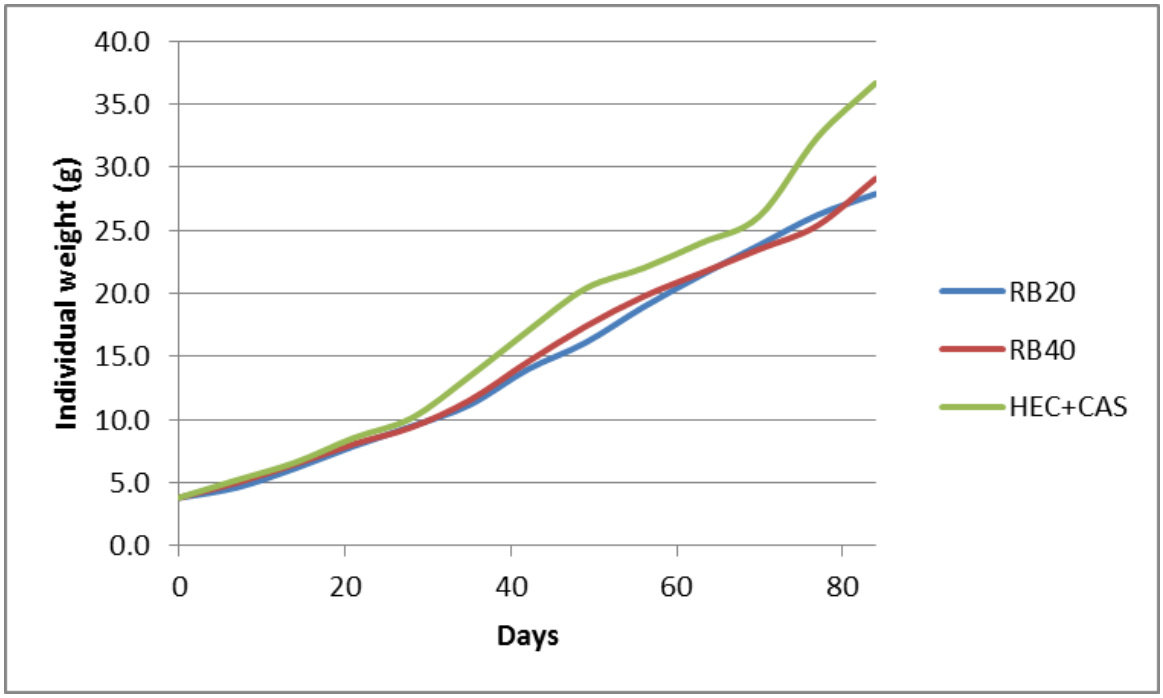
Growth Performance of Juvenile GIFT Tilapia (Oreochromis niloticus) fed two levels of Rice Bran and a High Energy Universal Concentrate mixed with Cassava Meal

The experiment was conducted at the Inland Aquaculture Research Facility at NARI's Labu Livestock Research Station in Lae, PNG. Ambient air temperature within the facility ranged from 20-32^{0}C.

Three experimental feeds were prepared. Two isoproteic (28% crude protein) and isoenergetic (17 MJ/kg) feeds were formulated using fishmeal, cassava meal and mill run to contain either 20% or 40% rice bran (known as RB20 and RB40). These diets were compared to a high-energy Universal Concentrate blended with 31% cassava meal (known as HEC+CAS; 24% crude protein, 17 MJ/kg) as presented in previous section on aquaculture diets.

Weight gain was consistent throughout the trial with the specific growth rate (SGR) of fish fed HEC+CAS, RB40 and RB20 being 2.68, 2.40 and 2.36%/day, respectively (Figure 9). One-way ANOVA found no difference between the final body weights of fish fed RB20, RB40 or HEC+CAS. However, fish fed HEC+CAS were approximately 25-30% heavier than fish fed RB20 and RB40.

Figure 9. Average weight gain of juvenile GIFT Tilapia on 3 experimental feeds (n=4).



FCR of test diets was not significantly different after 84 days feeding. However FCR was best for fish fed HEC+CAS than for fish fed the RB40 and RB20 diets. When feed input is calculated using weekly biomass of experimental tanks, fish fed HEC+CAS tended to receive less feed on a per biomass basis than the other two treatments. The lower relative feed intake coupled with a higher weight gain indicates the HEC+CAS diet was superior to diet RB20 and RB40 under the feeding strategy employed. There was a significant

improvement in the protein efficiency ratio (PER) of fish fed the HEC+CAS diet; however, there was no difference between the PER of fish fed RB20 and RB40diets.

This experiment was designed to evaluate the performance of GIFT Tilapia reared on diets formulated to contain 20% (RB20) and 40% rice bran (RB40). Both diets had similar levels of crude protein, gross energy content and both had similar levels of fishmeal, tallow and mill run. The performance of tilapia on these diets was compared against fish fed a high energy Universal Concentrate suitable for broilers, pigs and layers that was mixed with a high level of cassava meal (31%) and cooking oil. Diets formulated for this trial were based on crude nutrient and energy values of ingredients, thus the digestible protein and digestible energy density of each diet may be quite different and may have influenced the results. Maximum daily weight gain of Tilapia in our trial was about 0.4g per day with an SGR of 2.68%/day which was similar to that reported by Ng and Wee (1989) for juvenile Tilapia fed fishmeal control and cassava leaf meal based diets (i.e. 13 to 86 g in 70 days).

Chitmanat et al. (2009) reported that rice bran included at 33.19, 39.47 and 43.73% did not affect average weight gain, body weight and FCR in juvenile tilapia, but the performance was improved at the highest inclusion of 49.15%. We observed similar growth, FCR and PER of tilapia fed a diet containing 20% or 40% rice bran. RB20 and RB40 also had similar levels of fishmeal and wheat millrun. Under the feeding regime we used the level of rice bran could be increased to 40% and the level of cassava meal reduced to 5% without greatly affecting performance. This indicates that rice bran and cassava meal are almost exchangeable on a gram for gram basis in terms of the nutrients and energy they can provide to this species, at least in similar formulas to those tested here.

At present it is difficult or impossible to obtain commercial fish feeds in PNG and if they could be obtained the cost would be prohibitive. Alternatively, fish farmers can use manufactured feeds formulated for poultry and pigs. These too can be expensive and hard to obtain. Options to reduce costs and improve flexibility include blending commercial pig and poultry feeds with locally available ingredients. Alternatively, farmers with knowledge of nutrition can make their own farm-based feeds using a suitable source of protein mixed with local ingredients such as rice bran, copra meal, mill run, sweet potato or cassava.

Comparative evaluation of locally formulated fish concentrate combined with sweet potato and cassava as feed source of juvenile GIFT Tilapia

The experiment was conducted at the Inland Aquaculture Research Facility at NARI's Labu Livestock Research Station in Lae, PNG.

Diets tested were a fish concentrate + sweet potato; fish concentrate + cassava; fish concentrate + cassava leaf + sweet potato compared with a standard control diet. Fish fed the alternative diets performed better than the standard diet when assessed on the basis of body weight and weight gain (Figure 10). Weight gains were greater than 500g for all test diets. The fish fed the concentrate + cassava consumed more feed than other diets over the 12 week trial period. The FCR was comparable with the standard diet despite intake being higher for the treatment diets (Figure 11). Investigation is now required to test the alternative diets on-farm. If the technology is successful it will go a long way to meeting the growing demand for low protein fish feeds for village farmers.

Figure 10. Average bodyweight per fish

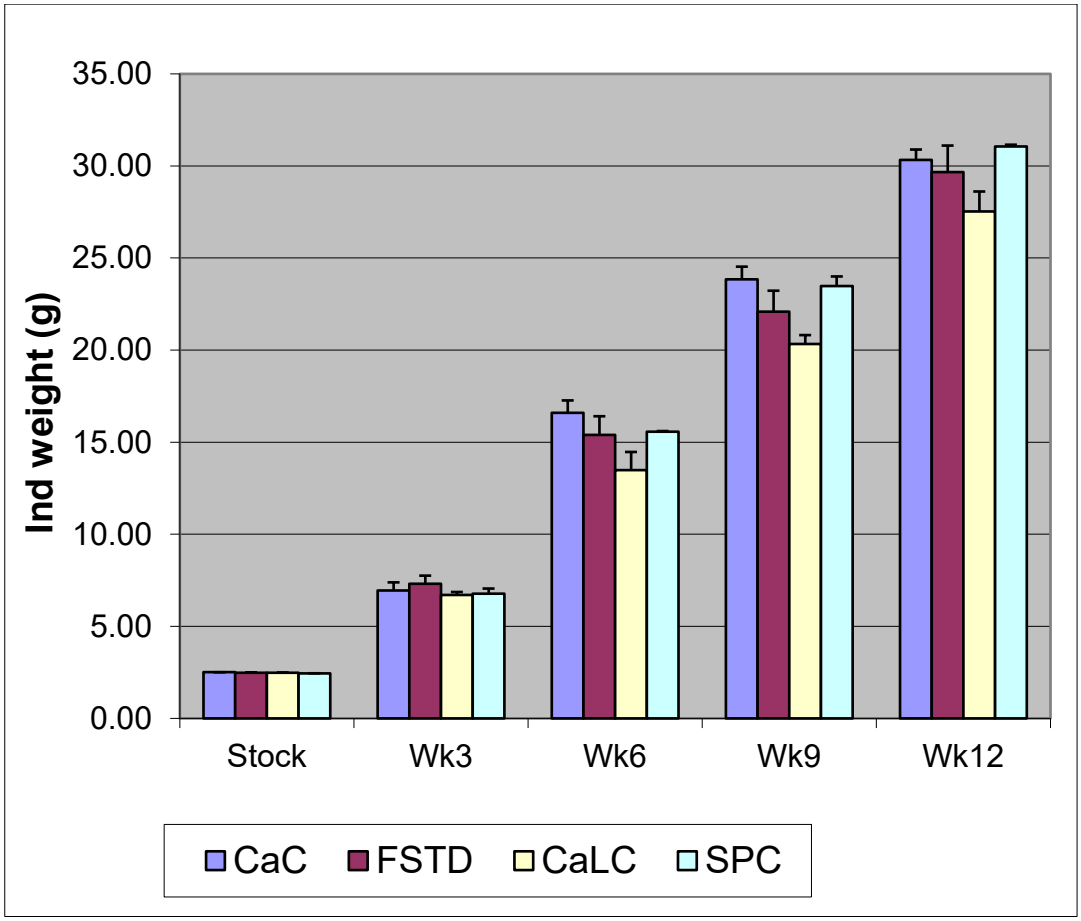
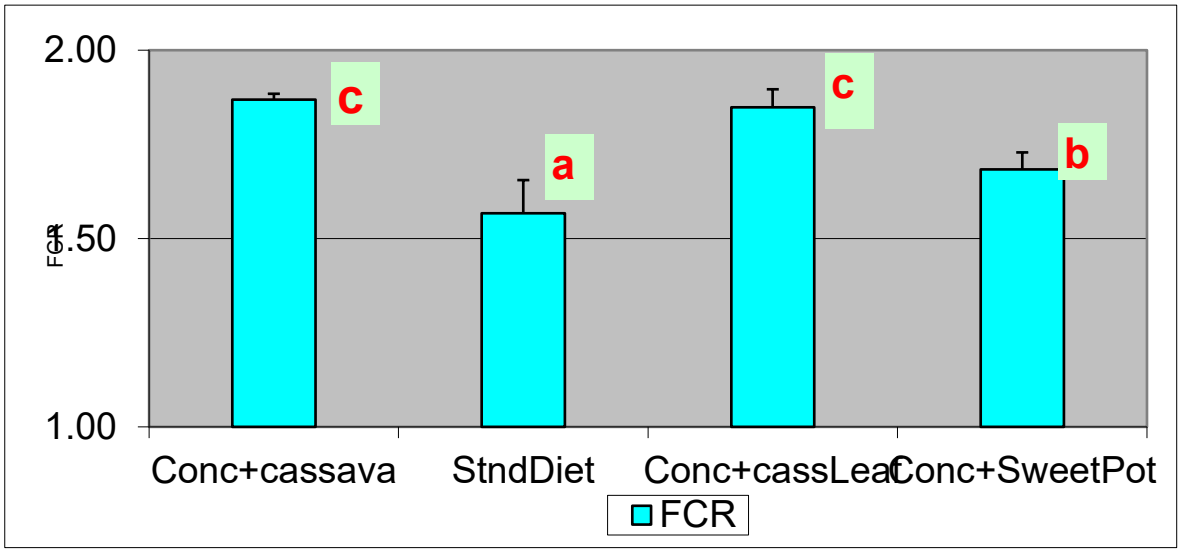


Figure 11. Average FCR of per fish



On-farm proof of concept grower tilapia fish experiment

As described previously the aim was to conduct an on-farm proof of concept trial to assess the growth performance of GIFT Tilapia grower fed with diets of sweet potato or cassava combined with a fish feed concentrate compared to a control diet.

The three diets tested comprised;

1) 50% cassava mixed with fish concentrate (CAFC)

2) 50% sweet potato mixed with fish concentrate (SPFC)

3) Fish standard diet (FSTD)

The three diets were tested in 12 week on-farm feeding trials at Yalu and Kefamo using earthen ponds and at Yonki using cage culture.

The main findings from the on-farm trials were as follows:

- The was no difference in the dry matter intake of fish fed the FSTD and CaFC
- The body weight gain of fish fed the SPFC and CaFC diet was significantly different ($P < 0.05$) from standard diet. In the trial conducted at Yalu fish fed CaFC had poorer growth and FCR than the control diet but at Yonki and Kefamo fish fed the with SPFC had better growth and FCR than the standard diet.
- The use of the feed concentrate technology with inclusion level of sweet potato and cassava has resulted in promising growth of tilapia.
- The cost of the feed concentrate and manufacturing of the diet at the Labu Mill is cheaper than cost of producing a standard fish diet.
- Additional trials are required using refined formulations for the fish concentrate, cassava and sweet potato (CaFC and SPFC) based diet and conduct digestibility tests.
- A full economic assessment of the lake cage culture system and earthen pond culture system is required as farmers are keen to continue use of cheaper diets in these production systems.

7.3 Objective 3. Facilitate the adoption of mini feed mills in the aquaculture, pork and poultry industries in PNG to improve smallholder and semi commercial enterprise profitability.

7.3.1 Business Planning

The business planning workshop was held over three days at the NARI conference centre in Lae, PNG. The structure of the workshop was a combination of presentations followed by group work on each section of a real business plan. The business plan, framework and associated worksheets were given to each participant in hard copy and also an electronic copy. Participants worked in groups representing actual feed mill operations or those intending to start a feed mill. PNG researchers and extension officers supported the farmer groups. There were seven teams who worked on developing the draft of their feed mill business plan. These teams included:

- PNG Unitech staff
- Kales family pig farm
- Domil Community Mill group
- Lutheran Development Service team
- Christian Leaders Training College group
- Labu Feed Mill team
- National Fisheries Authority group

Each team created a basic draft of a business plan for their own circumstance, using actual figures or estimates as appropriate. At the end of the workshop, each group reported on the business plan they had developed from the training they had received during the workshop. Feed mill owners and managers at the end of the training session were able to:

- Undertake market research and environment and industry analysis of the PNG feed and monogastric sector.
- Undertake SWOT and competitor analysis.
- Quantify the customer base, market target, key personnel and consultants required and market demand.
- Implement appropriate business governance.
- Consider capital purchase requirements of equipment and physical set up of mill and have knowledge of operational protocols.
- Assess growth potential of a feed mill business including knowledge of fixed and variable costs, profit and loss forecasting and budget and cash flow statements, costing and pricing strategy.
- Undertake assessment of finance required and financial projections.
- Assess risk and how to run the business.
- Write a business plan.

PNG Unitech staff

The staff reported that the workshop was conducted in a great teaching environment and facilities for the workshop were ideal and the presentations were of high quality. Unitech indicated they need to obtain some data on their market potential so that they can further develop their business plan.

Kales family pig farm

The Kales team indicated the business workshop has increased their understanding of the business tools that are available and how it can be applied in their business. Instruction received during the workshop on cash flows and basic book keeping will result in the farm business tightening up on their payments.

Domil Community Mill

The manager of the Domil enterprise said their team enjoyed the workshop. The training activity had opened up their mind on all the issues that must be considered in developing a feed mill enterprise. In particular they learnt how important it is to link the market potential with the capital investment required and how cash flow estimates can be used to plan payments. They plan to have a strong focus on sale of organic chicken in their vertically integrated feed mill poultry processing enterprise. The Domil manager's final comments were; "The feed mill business workshop had changed their teams mindset, given them a business perspective and they felt blessed that they had attended the training".

Lutheran Development Service (LDS)

The large network of farmers associated with Lutheran Development Service (LDS) has requested that a feed mill is established so farmers can purchase cheap feed. The business workshop has provided LDS with the planning skills that will enable them to establish a viable business. The team particularly enjoyed the financial planning aspects of the business workshop.

Christian Leaders Training College (CLTC)

The team said the workshop had helped them understand how to develop a feed mill business plan. They believed the principals learnt in the workshop will be applicable to other business enterprises at CLTC. It is critical for poultry unit at CLTC to submit a business proposal to CLTC management to establish a mini mill so that feed costs can be reduced.

Labu Feed Mill

The Labu team indicated the business planning activity was more complex than they had expected and they learnt the need to consider all the factors that can impact on a feed mill enterprise. It is the first occasion where business and marketing was the focus of the activity rather than just producing feed.

National Fisheries Authority (NFA)

The NFA team indicated that they wished they had prepared a business plan before they had purchased feed mill equipment. Currently NFA are subsidising the cost of feed to customers. The business planning activity has identified the pricing problem. NFA team will develop plans to overcome the cost of feed issue.

Other comments

- All groups identified that they would have preferred the workshop to be run over a longer period.
- The workshop had enabled them to identify the critical factors impacting on their business. These included market potential, storage facilities, packaging, trained staff particularly engineers, backup generators, back up hammer mills, lack of three phase power and quality control.
- NARI extension and research scientists recommended there should be more detailed training in business planning.

Guest speakers

To support the business workshop Mike Quinn and Dr Lily Sar were invited to give presentations. Mike Quinn has lived in PNG since 1975 and worked initially as an agriculture extension officer and currently as a real-estate agent. Dr Lily Sar is an extension specialist and has lectured at PNG University of Technology for 15 years on extension methodology and adoption of agriculture technology in PNG.

Mike Quinn (ML FRASC) gave a presentation on governance and how to operate a sustainable business. Mike Quinn indicated the personal skills required in PNG include being able to read, write and calculate costs and income, knowing the product you are selling, having an enquiring mind, a good work ethic and ambition and to be consistent and reliable. The management abilities include being able to control costs, keep records, avoid credit and debt, have good stock control and have an equipment maintenance program. It is important in the business that PNG statutory commitments are adhered to for a business generating 100,000 Kina. These include registering for GST, paying wages and payroll tax, registering the company, paying income tax and adhering to labour requirements.

Gender issues were presented by extension specialist Dr Lily Sar. She indicated that women have an important role in PNG agriculture. They are heavily involved in care and sale of livestock, planting, harvesting and selling crops but need to have a greater role in the control and use of household finances.

7.3.2 Progress in Establishing Mini Mills

Domil Mill

The Domil Mill is part of a Community Development Group. The mill has contract broiler farmers who are supplied feed from the mill. The birds are grown to 6 weeks and then processed in the small slaughter processing plant attached to the mill. The dressed birds are packaged in plastic bags and sold to shops in Mount Hagen. The mill has a flake machine, hammer mill, mixer and pelleter. Domil are keen to establish a resource centre in Jiwaki province to promote the feed technology and to increase their market. Current constraints include lack of a backup generator and hammer mill. Domil mill has received funds from the provincial government to expand its production.

Tambul mill

The Highlands Farmers Association plans to establish a mini mill to meet the demand for poultry concentrate, pig and aquaculture feed in the Western Highlands Province and create income for SP growers especially women. The Tambul mini feed mill currently produces a small amount of pig grower and broiler finisher but requires a large scale pelleter and storage facilities. The Government has provided funds to assist farmers in the Highlands Piggery and Farmers Association to promote pig production and further develop the mini feed mill.

NARI Mill at Labu

The equipment available at the NARI mill includes a hammer mill, grater, flake mill, feed mixer, boiler, pelleter, solar drier and ancillary equipment which included knives, axes, buckets, trays, canvas, scrapers, mortar and pestle, weighing scales and bags. An on-station local poultry concentrate diet was developed which comprises 26.8% fish meal, 32.2% soybean meal, 15.8% cassava leaves, 14.7% maize, 3% copra meal, 2.3% kikuyu leaves, 5.2% micro ingredients and premix. Approximately 400 kg of feed can be processed through the flake mill, hammer mill, mixer and pelleter in 3.5 hours after sun drying of ingredients for 3 days. Labu mill has the capability to prepare local concentrates and proposes to sell pig, poultry and fish feed and to farmers located close to the mill.

NFA mill at Goroka

Goroka feed mill can produce 200 kg of feed per day at a subsidised cost of 4.69 K/kg and 1070 kg feed of tilapia feed at a 2.96K/kg. They are also able to clean, wash, chop, dry and mill sweet potato into flour for mixing with a fish concentrate. All equipment is housed in a feed production shed and all feed ingredients and processed feed are stored in a 6 m container. The mill has 2 pellet machines, 2 mixers and a hammer mill

Kales Mills

The Kales family mill was developed to make sweet potato silage and includes a shed and silage pits. The sweet potato tubers, vines and leaves are cleaned, chopped up and processed through a diesel operated flake machine. The mill is able to process 600 kg of sweet potato over a day using the diesel operated flake mill and up to 1 tonne with 2 flake machines operating.

Commercial Industry Support

The commercial feed mills in PNG have provided micro ingredients and supplied the mini mills pig and poultry concentrates that can be mixed directly at the farm level with sweet potato or cassava or provided to mini mills for further blending with other local ingredients. The Universal Concentrate or separate species concentrates as well as the premixes can also be supplied by importing from suppliers in Australia.

7.3.3 Media and communication campaign

Communication Strategic Plan to encourage use of Mini Mills and Concentrate Feeding System for Pigs, Poultry and Inland Aquaculture in PNG

On the basis of the benefits obtained from using mini mills and the results obtained from feeding trials with pigs, poultry and inland aquaculture a communication strategic plan was developed. The plan aims to ensure that the PNG central government and provincial government, research institutes, universities, rural banks, agriculture aid donors are made aware of the benefits of mini mills and the concentrate feeding systems for pigs, poultry and inland aquaculture. In addition the plan also outlines strategies to communicate benefits and improve adoption of the use of mini mills and feeding systems to semi commercial and smallholder farms using demonstration activities and multimedia.

Vision and Mission

Promote development of mini feed mill enterprises in PNG by implementing a communication plan to encourage use of mini mills and greater use of local feed in semi commercial and smallholder pig, poultry and inland aquaculture enterprises.

Vision

A viable mini feed mill enterprise sector supporting the expansion of the semi commercial and smallholder pig, poultry and inland aquaculture enterprises in PNG.

Mission

To ensure there is an effective communication of the benefits of the use of mini mills and feeding systems to semi commercial and smallholder farms that leads to greater use of local feeds in mini mill enterprises and expansion and improvement of profitability in the smallholder monogastric sector in PNG

The Mini Mill Communication Strategic Plan

Overall Objective:

NARI and the PNG University of Technology and their PNG Industry and NGO collaborators are committed to ensuring that there is continued communication of the benefits of mini mills and the concentrate feeding system that leads to the development of profitable and well operated feed mill enterprises in PNG with a focus on developing the market to supply cheap feed to support the expansion of the monogastric sector in PNG.

Objective One: Communicate benefits of mini feed mills in PNG to government and institutions

Activities

- Key NARI executives arrange meetings with Universities, various government departments in Port Moresby and provincial agencies, PNG Universities and Rural Banks to discuss benefits of mini feed mills and the monogastric feeding system.
- Presentations and brochures developed to outline improvements to rural livelihoods, farm profitability, and employment and consumer benefits.

Targets

- Meetings held with the central and regional government departments by end of 2016.
- Meetings held with each of the PNG universities and Rural banks by end of 2016
- NARI and Unitech officer appointed by end of 2016 to market the benefits of mini mills and monogastric feeding systems to the government, University and rural banking sector.

Performance indicators

- Loans provided by government and rural banks to 10 enterprises to set up mini mills by end of 2016.
- Each of the Universities include mini mill business planning in their curriculum for start of 2017 academic year.

Objective Two: Communicate benefits of mini feed mills to Rural Aid Donors, International Agriculture Research Development Corporations and NGO's in PNG

Activities

- Key NARI executive organise meetings with Rural Aid Donors, Agriculture Research Funders and NGO's to encourage funding to enable continued research, demonstration and extension of the feeding systems using mini mills in PNG.
- Presentations and brochures developed to outline the benefits of R&D&E to improve livestock and aquaculture production and reduction in rural poverty.

Targets

- Meetings held with five Rural Aid Donors, 3 Agriculture Research Funders (eg ACIAR, EU) and 5 NGO's by the end of 2016.

Performance indicators

- 3 new research project established by 2017 to further refine the monogastric feeding systems using a broader range of local ingredients in diets prepared by mini mills.

Objective Three: Demonstrate and communicate the benefits of the monogastric feeding systems with diets prepared by mini feed mills to smallholder and semi commercial pig, poultry and aquaculture farmers.

Activities

- Develop participatory demonstration activities to provide information on feed mill operations and on farm use of diets via watching, listening or practising using model farms and study tours.
- Produce extension aids (Tok Pisin posters, leaflets, brochures, booklets (words and pictures) and videos in hard copy and on NARI website for access by feed mill operators and farmers.
- Conduct 'road shows' at village markets, field days at institutions and NGO sites, and use of sms to mobile phones about feed mills and concentrate diets.
- Write articles for local and national newspapers and conduct radio interviews about feed mill operations and on farm use of diets

Targets

- Five participatory demonstration activities conducted by end of 2016.
- Extension aids (Tok Pisin posters, leaflets, brochures, booklets (words and pictures) and videos in hard copy available and placed on NARI website by end of 2016.
- Five 'road shows' conducted at village markets on feeding systems by end of 2016 and NARI field day demonstrating mini mills conducted in Nov 2016.
- Five articles for local and national newspapers written by end of 2016 and five radio interviews held about feed mill operations and on farm use of diets

Performance indicators

- 1000 posters, leaflets, brochures and booklets distributed to village farms and entrepreneurs by end of 2016.
- 500 hits on NARI website to view website on mini mills and feeding systems by end of 2016.
- 100 downloads of NARI feeding systems video by end of 2016.

7.4 Objective 4. Consolidate research outcomes with project partners; involve SARDI junior scientists and interact with a broader range of PNG stakeholders.

7.4.1 Include SARDI junior research scientists in the project

At the request of Dr Caroline Lemerle in 2010 ACIAR provided funds in the feed mill project for SARDI to employ a junior scientist to work with Dr Phil Glatz as part of his succession plan. ACIAR had a concern that there were lack of junior scientists in Australia being supported by Institutions to undertake research in developing countries. SARDI appointed a scientist to work with DR Phil Glatz over the last 18 months of the project following interviews with 3 candidates. However the scientist concerned was offered a professorial position and did not accept the SARDI position. The other 2 scientists interviewed were not considered suitable for the position.

However during this period the South Australian Government had recommended that additional staff be appointed to undertake pig and poultry research in South Australian given the huge expansion in the pig and poultry industries in recent years. Subsequently SARDI appointed 5 junior pig and poultry scientists in 2015. Phil Glatz discussed the possibility of including these scientists in the project with Dr Caroline Lemerle as he felt that they would be able to make a positive contribution to the feed mill project before it

concluded. ACIAR supported a project variation with carry over funds set aside for the original position being used to fund the contribution of the 5 staff toward the project over the period July 1, 2015-30 June 2016.

Use of the carryover funds would achieve the original aim of giving junior scientists in SARDI experience with an ACIAR project. The SARDI junior scientists; Dr Kelly Drake (poultry production), Dr Cameron Ralph (pig production), Dr Carolyn deKoning (livestock pasture); Dr Kate Plush (pig nutrition and reproduction) and Dr Reza Barekatain (pig and poultry nutrition) worked on the project from July 1 to Dec 14, 2016 under the mentorship of Phil Glatz. The scientist were involved in project administration, reviewing findings of the project, editing scientific papers submitted to the feed mill project monograph and contributing to the feed mill manual. Dr Kelly Drake was appointed as feed mill project leader on July 1, 2015 given her experience working in Africa and Cambodia. However Dr Kelly Drake was offered a position in NZ and left SARDI in January 2016. As a result Dr Carolyn Dekoning was appointed leader of the feed mill project. Phil Glatz had commenced long service leave with SARDI on December 14, 2015 but offered to provide support to ACIAR to ensure the monograph, feed mill manual and final report is completed on time when the project ends on June 30, 2016. *[Note that Dr Phil Glatz had trained Dr Kelly Drake to take full responsibility to complete the monograph, feed mill manual and final report. However her sudden departure gave little time for Dr Phil Glatz to give the necessary support to Dr Carolyn Dekoning to take on full responsibility for these tasks. Phil subsequently indicated that he would continue to support SARDI scientist while on long service leave to ensure these project tasks were completed].*

7.4.2 Consolidate research outcomes by having additional meetings with a broader range of stakeholders through the annual review meeting and the final review meeting.

Another aspect of the project variation was to interact with a broader range of stakeholders in PNG in a new project “Improving opportunities for economic development for women smallholders in rural Papua New Guinea” managed by Professor Barbara Pamphilon and Associate Professor Katja Mikhailovich from the Australian Institute for Sustainable Communities, University of Canberra. Dr Caroline Lemerle had requested that Dr Phil Glatz communicate with Professor Barbara Pamphilon and Associate Professor Katja Mikhailovich and provided them extension information on pig, poultry and aquaculture feeding systems developed in the feed mill project. There are many PNG women smallholders involved in the on-farm trials evaluating the feeding systems developed in the feed mill project and using diets for pigs, poultry and fish mixed by small scale feed mills. In addition contact details of all the feed mill project partners including the NGO partners who had conducted trials with village farmers were provided to Barbara and Katya for use in their project.

Two of the SARDI junior scientists were scheduled to travel with Dr Phil Glatz to PNG in December 2015 to attend the feed mill project annual review meeting. The aim was for Dr Phil Glatz to introduce SARDI scientists to PNG partners involved in the feed mill project. However security issues in PNG resulted in the December 2015 meeting being postponed. Subsequently ACIAR decided that the final review meeting be brought forward and held early in 2016. However the final review meeting was postponed on two occasions and finally held from March 21-22, 2016. The two SARDI junior scientists were unable to travel given the change in dates. They had already planned the start of their Australian pig, poultry and sheep research trials funded by APL, AECL, Poultry CRC, Pork CRC and Sheep CRC.

It was intended that two junior scientists would accompany Dr Phil Glatz to PNG to meet with feed mill project partners before the project was completed on June 30, 2016. The

SARDI scientists are also involved in a proposed ACIAR PNG one health project (AH/2012/032) due to commence in July 2016. Most of the current partners in feed mill project will be at the project inception meeting for the one health project (pending funding) which may be a more appropriate time for SARDI scientists to meet the PNG project partners and become familiar with the PNG research environment.

8 Scientific impacts – now and in 5 years

The science impact of the findings from the PNG research scientists and students supported by the project is likely to lead to an improvement in the mini feed mill industry and the regional manufacture of a greater range of feed stuffs for livestock feeds throughout PNG.

The socio-economic studies have provided a basic understanding of the social issues impacting on feed mill value chains and livestock production systems. The studies that compared egg production and feed costs of commercial layer hens fed cassava and sweet potato based diets compared with hens fed a standard commercial layer diets showed that sweet potato and cassava diets are a viable alternative to commercial diets.

The nutrient digestibility and utilization in pigs fed sweet potato or cassava roots when prepared as boiled or ensiled or milled and blended with a complementary protein concentrate were highly digestible and improved nutrient utilization, higher growth rates and feed efficiency in pigs compared to wheat based pig grower feed.

The metabolizable energy of sweet potato diets can be improved when a multipurpose enzyme is included in the diet. The work has shown for the first time that there is a decrease in gut levels of E. coli and Enterobacteriaceae in birds fed sweet potato when an enzyme is included. In addition bird performance was influenced by non starch polysaccharide content of sweet potato varieties. Dietary fibre was once considered to be a nutrient diluent in monogastric diets. Little emphasis was placed on the effect of fibre on bird performance. However, analysis of the soluble and insoluble fibre of PNG sweet potato cultivars has shown varying proportions of these fibre components.

8.1 Capacity impacts – now and in 5 years

The collaboration of key participants, NGO's and farmers from all the sectors in this project has enabled the respective industries to learn from each other and to encourage farmers to diversify in the monogastric sector. This project has strengthened the capability of NARI, Unitech, NFA and NGO's to promote the use of mini mills in PNG and the conduct of on-station and on-farm feeding trials with aquaculture, pigs and poultry.

A number of workshops on business modelling, value chains, feed mill operations and strategic planning have been run with all participants during the project. Two PNG students, Eleo Dowa (social science) and Fred Besari (layer nutrition) have completed their post graduate studies at Unitech while JAF students, Janet Pandi (PhD broiler nutrition) and Michael Dom (PhD- pig nutrition) are close to completing their PhD. Jimaimah Nathaniel is currently completing a Master of Technology in Mechanical Engineering which evaluated mini mills and strategies to achieve best practice mini feed milling in PNG.

8.2 Community impacts – now and in 5 years

At the community level the establishment of improved supply chains for the livestock sector is likely to generate increased business activity in the monogastric sector and allow more villages to purchase livestock products to meet their nutritional needs.

The value chain analyst has developed strategies to improve the supply chains for the Domil mill, Goroka mill, Pikosa community mill and Tambul private mill. This was enhanced by running the feed mill business workshop in July 2015 for current feed mill owners, and other groups wishing to set up mini mills. The continued efforts by NARI, Unitech and NGO's to train village farmers in best practice feeding systems and management of livestock will lead to changes in attitude of small scale farmers and their ability to contribute to the village economy. Implementation of the strategies is likely to

generate increased business activity in the monogastric sector and allow more villages to purchase livestock products to meet their nutritional needs.

8.2.1 Economic impacts

The PNG monogastric sector comprises approx 600,000 farmers turning over $190.5m/annum. There is potential, with full adoption, to generate an extra A$47m/annum for the PNG economy as result of the project.

8.2.2 Social impacts

At the community level the establishment of improved supply chains for the livestock sector is likely to generate increased business activity and allow more villages to purchase livestock products to meet their nutritional needs. Training of village farmers in best practice feeding systems for livestock and use of feeds from mini mills will lead to changes in attitude of small scale farmers and their ability to contribute to the village economy. The flow on benefits from the feed mill business workshop will encourage new entrants into the feed mill business. NARI, Unitech and NGO's are trained to assist potential investors in feed milling to develop business plans and to be able to make sound decisions on their investment.

The link of the feed mill project with the ACIAR project "Improving opportunities for economic development for women smallholders in rural Papua New Guinea" will provide more women in PNG agriculture to be involved in the financial aspects of livestock production and contribute to improve family income.

8.2.3 Environmental impacts

There are no expected changes to the environmental status of smallholder livestock and the aquaculture sectors. Feeds produced by mini mills do not contain antibiotics and livestock waste is a fertiliser source which delivers agricultural and environmental benefits well beyond those provided by conventional inorganic fertilisers. The manure is used as fertiliser in village gardens. There will be an increase in productivity of crops grown with fertiliser derived from pig and poultry production and enhanced carbon sequestration in soil through efficient nutrient cycling. Other benefits will include value-added products from livestock waste reducing odour impacts on nearby households and reducing PNG's contribution to climate change. The project will encourage village farmers to house their livestock. This will result in reduced damage to crops and the environment by scavenging pigs and village poultry and prevent pollution of water courses with livestock waste.

8.3 Communication and dissemination activities

8.3.1 Project meetings

- The inception meeting took place in Lae, PNG from 20-21 February 2012. The meeting was attended by 31 participants in the project but also Emily Flowers (ACIAR PNG country manager) and representatives from New Guinea Table Birds and Zenag Poultry.
- The year 1 six monthly review meeting was held in Lae, PNG on 4 October 2012. The meeting was attended by 17 participants representing all the partners in the project.
- The year 1 annual review meeting was held in Lae, PNG from 12-13 March 2013. The meeting was attended by 21 staff including Dr Caroline Lemerle (ACIAR ASEM Project Manager), Ms. Rebecca Bogosia (ACIAR PNG) and project partners.
- The year 2 six monthly review meeting was held on 2 October 2013 and the midterm review meeting was held from 24-28 March, 2014 in Lae. The highlights

of the two meetings were workshops for project participants on value chain analysis, strategic planning and business modelling. A seminar was held at NARI on 26 March 2014 with 25 presentations by PNG and Australian scientists on the ACIAR nutrition and socio-economic research conducted over the last 5 years in the PNG smallholder pig, poultry and aquaculture industries.

- The year 3 six monthly review meeting was held from 29-30 October 2014. The meeting was used to discuss progress on; 1) the proof of concept trials for crossbred village layers at Madang; 2) the proof of concept trials for commercial layer and broilers with farmers at Tambul and Domil cooperative; 3) the proof of concept trials for aquaculture and 4) the proof of concept trials at Kales farm involving a silage based diet fed to local pigs. Plans at the year six monthly meeting were also made for the feed mill business workshop to train feed mill owners and prospective owners on the business aspects of establishing a feed mill.
- Staff from the Entrepreneurship, Commercialisation and Innovation Centre at the University of Adelaide brought their business experience and teaching skills to run a business planning workshop in Lae, PNG from July 28-30, 2015 for 30 participants including farmers, NGO's and representatives from the PNG National Agricultural Research Institute and PNG University of Technology. The workshop participants were trained to develop a draft of a real-world business plan for their feed mill incorporating market research, SWOT analysis, business governance, capital purchases, fixed and variable costs, profit and loss forecasting, budget and cash flow statements, costing and pricing strategy, financial projections and risk analyses. The participants created a basic draft of a business plan for their own circumstance, using actual figures or estimates as appropriate. At the end of the workshop oral reports were given on the business plans. The participants reported the business workshop had increased their understanding of the business tools that are available and how it can be applied in their business.

8.3.2 Media articles published on use of local feeds for poultry, pigs and fish in PNG

NARI media releases related to the project.

Mini feed mills to promote smallholder livestock; http://www.nari.org.pg/node/270

Enhancing the role of small scale feed milling to develop PNG's monogastric industries; http://www.nari.org.pg/node/264

Innovative development of smallholder livestock sector; http://www.nari.org.pg/nari-focus

NARI strengthens ties with SARDI; http://www.nari.org.pg/node/183

Livestock Research and Development; http://www.nari.org.pg/livestock-research

SARDI media release on project.

http://www.sardi.sa.gov.au/information_and_news/2012_media_releases/Food_security_project_enhances_pig_and_poultry_industries

PNG newspaper articles

- K2.6 million research on stock feed, PNG National newspaper, 2015
- Focus on quality, affordable feed, PNG National newspaper, 2015
- High feed prices main problem for farmers, PNG National newspaper, 2015
- Building the resilience of rural farming communities in the highlands of PNG for climate change, PNG National newspaper, 2015
- What feed is available for small livestock Production? PNG National newspaper, focus column, 2015

- Feed R&D among top 20 innovations in ACP countries, NARI Nius, 2014
- Utilization of sweet potato as a livestock feed in PNG. PNG National newspaper focus column, 2014
- Adding value to agro-industrial by-products is one way of reducing feeding costs of smallholder livestock farmers. PNG National newspaper focus column, 2013
- Strategies to reduce feed cost for smallholder livestock producers in PNG, PNG National newspaper focus column, 2013

A series of five focus articles were prepared by NARI for the PNG daily newspapers in 2013 and 2014 highlighting the benefits of the ACIAR feed mill research project. This was initiated in response to a heated debate in the PNG parliament about cheap poultry imports and the high feed costs.

1. Janet Pandi, NARI Livestock Projects. Promoting the use of sweet potato as animal feed in monogastric diets for rural smallholder livestock farmers.
2. Workneh Ayalew, NARI Livestock projects. Strategies to reducing feed cost for smallholder livestock producers in PNG.
3. Fred Besari. NARI Livestock projects. Can egg production from village chicken be increased at village level?
4. Pikah Kohun, NARI Livestock Projects. Adding value to agro-industrial by-products is one way of reducing feeding costs of smallholder livestock farmers.
5. Michael Dom, NARI Livestock projects. Cassava is as good as wheat for pigs and poultry.

9 Conclusions and recommendations

9.1 Conclusions

Sweet potato and cassava are important root and tuber crops that play a significant role in PNG maintaining food security and enhancing human nutrition, providing income earning or cost saving options. While the two crops remain as important staple foods to smallholder farming households their use as a convenient livestock feed has increased in recent times. In PNG the traditional dual purpose use of sweet potato and cassava is an advantage to village and smallholder farmers producing poultry, pigs and fish, where excess harvest and waste forage is converted from a relatively cheap feed resource into more valuable food protein as meat and eggs. The research in this project was aimed at adapting existing and viable new methods of production, supply, storage and processing of sweet potato and cassava for animal feed using mini mills. Sweet potato and cassava are valuable garden crops for the majority of village farmers and can be utilised by the use of mini mills to process the tubers into flour and dried chips. Alternatively waste sweet potato and cassava roots, vines and leaves can be processed at mill sites into silage which can be fed to pigs. Socio economic research in the project showed the farmers are willing to purchase feeds from mini mills. Likewise village groups are willing to invest in mini mills but need to undertake business and financial planning to ensure the establishment of mini mills is viable.

Feed is the major cost in livestock farming and using the major local feeds, sweet potato and cassava, to farm pigs, poultry and fish is technically feasible, provided the feed rations are balanced with other ingredients to balance essential amino acids and micronutrients which are lacking in the root crops. Moreover, the practical and economic implications of value chains, which supply feed to farms and food from farm to fork, suggest that small-scale production of feed and livestock may be more competitive at the District or Provincial level than in large scale enterprises. Experience on village and peri-urban farm settings demonstrated that local pig and poultry production may become more profitable when provided with suitable facilities, such as mini feed mills, local slaughter houses, transport services and packaging and freezer operators. Experience at community run mini-mills demonstrated that small-scale production was feasible within limitations determined by the market and socio-economic constraints.

9.2 Recommendations

To improve adoption of mini mills in PNG there is need to improve the maintenance and equipment repairs in mini feed mills, improve operational protocols for mills and ensure the feed mill user manual is used in the mini mill industry to train mill staff.

To further support the adoption of mini mills there is a need to improve business skills of current PNG mini mill managers and provide advisory service to new mill investors on capital, equipment, business planning and record keeping.

The livestock and fish value chains associated with mini mills could be improved with better methods of production, processing, delivery and sale of products to consumers. In particular cooperatives could develop new value added products and develop more effective, market-oriented value chains developed. This would lead to an increase in output, quantity, quality, prices and distribution of pigs, poultry and fish products in enterprises associated with feed mills.

The feed trials using mini mill feed showed that there is a need to expand the use of local feed ingredients in the small holder sector through evaluation of the digestibility and production efficiency of pigs, poultry and fish fed a greater range of novel concentrates blended with local feed ingredients. This would involve evaluating digestibility and production efficiency of pigs, poultry and fish fed Universal Concentrate and super

concentrates blended with local feed ingredients and establishing the role of PNG feed ingredients on gut health, nutrient retention and partitioning in pigs, poultry and fish. The nutrition research would allow the formulation of diets that more effectively meet the nutrient requirements of pigs, poultry and fish based on digestibility, efficiency and gut health studies.

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10.2 List of publications produced by project

10.2.1 Journal papers

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Dom M.T., Ayalew W.K., Glatz P.C., Kirkwood R.N. and Hughes P.E. 2016. The Feeding Value of Sweet Potato and Cassava to Grower Pigs in Papua New Guinea. In preparation.

Dom M.T., Ayalew W.K., Glatz P.C., Kirkwood R.N. and Hughes P.E. 2016. Nutrient Utilization in Grower Pigs fed Boiled, Ensiled or Milled Sweet Potato Roots Blended with a Wheat based Protein Concentrate. Submitted to Animal Feed Science and Technology.

Dom M.T., Ayalew W.K., Glatz P.C., Kirkwood R.N. and Hughes P.E. 2016. Effect on Nutrient Digestibility and Nitrogen Balance in Grower Pigs fed Three Forms of Blended Cassava Roots. Submitted to Journal of South Pacific Agriculture.

Dom M.T., Ayalew W.K., Glatz P.C., Kirkwood R.N. and Hughes P.E. 2016. Nutrient Utilization in Grower Pigs fed a Protein Concentrate Blended with Sweet Potato Roots either Boiled or Ensiled With or Without Vines. Accepted by Animal Production Science.

Dom M.T., Kohun P.J., Ayalew W.K., Glatz P.C., Kirkwood R.N. and Hughes P.E. 2016. Nutrient Utilization and N-Balance in Local Mixed Genotype Grower Pigs fed Boiled Sweet Potato or Cassava Blended with a Complementary Protein Concentrate. In preparation.

Dom M.T., Kohun P.J., Ayalew W.K., Glatz P.C., Kirkwood R.N. and Hughes P.E. 2016. Nutrient Utilization in Local Genotype Grower Pigs fed Two Different Protein Concentrates Blended with Sweet Potato Roots Ensiled With or Without Vines. In preparation.

Dom M., Tarabu J., Pewa T., Moui K., Amben S., Kohun, P., Ayalew W., Glatz P., Kirkwood R. and Hughes P. 2016. Effect of Blended Sweet Potato Silage and Pig Concentrates on the Growth Performance of Local Mixed Genotype Grower Pigs Under Restricted Feeding. In preparation.

Pandi J., Glatz P., Forder R., Komolong B. and Chousalkar K. 2016. Evaluation of the effects of sweet potato (Ipomoea batatas (L.) Lam) in broiler diets. Submitted to the Animal Feed Science and Technology Journal

Pandi J., Glatz P., Forder R., Komolong B. and Chousalkar K. 2016. Effects of 5 local Papua New Guinea sweet potato (Ipomoea batatas (L.) Lam) cultivars and Rovio T-Flex enzyme on diet AME, gut morphology, growth and profiles of salmonella, campylobacter and clostridium perfringens in the ceca of broiler chickens.In preparation.

Pandi J., Glatz P., Forder R., Komolong B. and Chousalkar K. 2016. Detection of Salmonella, Campylobacter and Clostridium perfringens in ceca of broilers raised on litter and fed 3 PNG sweet potato cultivars with high NSP contents – in preparation

10.2.2 Theses

Besari F. 2012. Comparison of egg production of hens fed sweet potato and cassava based diets blended with a concentrate. Master of Philosophy thesis submitted to PNG, University of Technology.

Dowa E. 2012. Socio-economic characteristics of farmers and their relationship to attitude, knowledge and constraints associated with mini feed mills in PNG. Master of Philosophy thesis submitted to the PNG, University of Technology.

Pandi J. 2017. Effects of sweet potato (Impomea batatas (l)) in diets of finishing broilers and its effect on gut parameters and the shedding of food borne pathogens. Doctor of Philosophy in preparation for submission to University of Adelaide.

Dom M. 2017. Feeding value of sweet potato and cassava to growing pigs. Doctor of Philosophy in preparation for submission to the University of Adelaide.

Nathaniel J. 2017. Evaluation of current small scale feed milling equipment and development of strategies to achieve best practice small scale feed milling in PNG. Master of Technology in preparation for submission to the PNG, University of Technology.

10.2.3 Conference papers

Dom M., Pandi J., Ramita I., Besari F., Sine M., Dowa E., Ayalew W., Kohun P. and Glatz P. 2014. 6th Research, Science & Technology Conference, Farming Poultry, Pigs and

Fish Using Local Feeds is Technically, Practically and Economically Achievable, 17th - 21st November 2014, University of Papua New Guinea, Waigani Campus.

Dom M.T., Ayalew W.K., Glatz P.C., Kirkwood R.N. and Hughes P.E. 2014. Effect on Nutrient Digestibility and Nitrogen Balance in Grower Pigs Fed Three Forms of Blended Cassava Roots, Proceedings of the 16th AAAP Animal Science Congress Vol. II, 10-14 November 2014, Gadjah Mada University, Yogyakarta, Indonesia, pp. 676-679.

Dom M., Kohun P., Ayalew W. and Glatz P. 2014. Responding to farmer's needs: efficient conservation of feed and improved production of pigs, Regional Symposium, The Territory of Wallis & Futuna, "Sustainable Agriculture: Serving the community, 24th - 28th November 2014, Mata Utu, Uvea Island.

Dom M., Ayalew, W., Glatz P., Kirkwood R. and Hughes P. 2015. Nutrient Utilization in Grower Pigs fed a Protein Concentrate Blended with Sweet Potato Roots either Boiled or Ensiled With or Without Vines. Proceedings of the 5th International Conference on Sustainable Animal Agriculture for Developing Countries (SAADC2015), 27-30 October 2015, Pattaya Thailand (Abstract).

Dom, M., Kohun P., Ayalew W., Glatz P., Kirkwood R. and Hughes P. 2016. Familiar resources, innovative techniques: sweet potato and cassava blended with protein concentrates improved nutrition and performance of commercial and local genotype pigs. In preparation for the 7th National Research, Science & Technology Conference, 8-10 November 2016, Lae Morobe Province.

10.2.4 Fact sheets

Smallholder chicken farmers make more profit by using low cost local feed (2014). A NARI fact sheet, guide book and poster. Published by Centre for Knowledge Development (CTA), Technical Centre for Agricultural and Rural Cooperation, Wageningen, Netherlands.

Equipment and Facilities required in a PNG Mini Feed Mill

How to run a mini feed mill in PNG

Site Plan and Layout of Mini Feed Mill in PNG

Nutrient requirements of fish, poultry and pigs

Feed ingredients for use in PNG Mini Mills

10.2.5 Monograph papers

The following 29 papers have been received from PNG and Australian scientists for the ACIAR monograph reporting results of the use of local feeds in PNG. The papers were submitted to ACIAR communications in December 2015.

Use of local feed resources in PNG – proceedings

Overview Papers

Kohun P., Ayalew W. and Glatz P. Enhancing Use and Assessing Options for Value Addition of Agro-industrial By-products in Livestock Feeding

Dom M., Pandi J., Besari F., Sine M., Ramita I., Dowa E., Booth M., Kohun P., Ayalew W. and Glatz P. Farming poultry, pigs and fish using local feeds is technically, practically and economically achievable.

Dom M., Kohun P., Ayalew W. and Glatz P. Responding to farmer’s needs: efficient conservation of feed and improved production of pigs.

Dom M. and Pandi J. Role of feed ingredient evaluation in PNG agricultural systems research

Dom M., Ayalew W., Glatz P., Kirkwood R. and Hughes P. The future of smallholder pig production in PNG.

Dom M. and Pandi J. Improving PNG smallholder pig and poultry production-role of research and development

Carey A. Challenges in formulating feed for pigs and poultry using local feed resources in PNG.

Booth M. Challenges in formulating feed for aquaculture using local feed resources in PNG.

Socio-Economics

Black I. Mini-mill and village enterprise cost and profitability models

Black I. A short report on the profitability of village hybrid pig farming using silage as a feed source

Black I. Mini-mill concentrate feeds and village farm business models for broiler, egg, hybrid pig and tilapia production in PNG using predominantly local feed ingredients

Dowa E. and Omot N. Using mini feed mills for chicken feed manufacture in the Domil Community of PNG: an assessment of attitude and knowledge of farmers and constraints faced

Pigs

Amben S., Dom M. and Ayalew W. A survey of pig production in the Morobe province of PNG.

Amben S., Dom M. and Ayalew W. Pig husbandry systems in Morobe Province, PNG.

Dom M., Ahizo J., Sine M. and Ayalew W. Effect of blending sweet potato silage with high energy and low energy poultry concentrate feed on performance of local crossbred growing pigs in Papua New Guinea

Layers

Besari F., Pandi J., Ayalew W., Glatz P., Mazi M. and Kohun P. Production performance of Australorp x Hy-line Brown spent layers fed a commercial layer diet compared to a local diet at smallholder farms in the Boana, lowland area of PNG.

Besari F., Danbaro G., Ayalew W. and Glatz P. Egg production performance of village chickens fed a locally formulated concentrate blended with milled cassava tuber

Besari F., Danbaro G., Ayalew W. and Glatz P. Egg production performance of village hens fed concentrates blended with sweet potato or cassava

Besari F., Danbaro G., Ayalew W., Pandi J. and Glatz P. Egg production performance of Hyline Brown hens fed on poultry concentrates blended with sweet potato or cassava in the highlands of PNG

Besari F., Pandi J., Ayalew W., Glatz P., Mazi M. and Kohun P. Evaluation of egg production performance of a Hyline Brown, a Hyline Brown x Australorp crossbred and indigenous layers fed on a sweet potato or cassava based layer concentrate diet in Papua New Guinea

Ahizo J., Kobila, K., Palau W., Ayalew W. and Glatz P. Egg production of two Crossbred strains of hens (Australorp x Shaver Brown; Shaver Brown x Hyline Brown) fed Cassava blended with a Layer Concentrate diet

Broilers

Ayalew W., Besari F., Pandi J. and Glatz P. Comparison of the performance of broiler chickens fed mashed and milled formulations of sweet potato based finisher diets in Papua New Guinea.

Solomon E., Kohun P., Ayalew W. and Glatz P. Comparative assessment of the growth performance of broiler chickens fed a standard commercial and rice bran based finisher diet.

Pandi J., Ayalew W. and Glatz P. Evaluation of the NARI Broiler Feed Concentrate on bird performance in selected sites around Papua New Guinea

Pandi J. and Glatz P. Performance of broiler chickens fed diets containing cassava or sweet potato mixed with a high and low energy protein concentrate

Besari F., Solomon E., Ayalew W., Kohun P. and Glatz P. Evaluation of broiler growth and feed costs of a locally manufactured, low energy broiler concentrate prepared at a mini feed mill in PNG

Fish

Sine M., Ayalew W., Tapat D., Booth M. and Gebo S. Comparative performance of juvenile gift tilapia fed on broiler concentrate mixed with sweet potato or cassava meal

Roberts A., Lobâo M., Sine M. and Ayalew W. Growth performance of juvenile gift Tilapia (Oreochromis niloticus) fed two levels of rice bran and a high energy broiler concentrate mixed with cassava meal.

Sine M., Roberts A., Ayalew W., Vira H. and Booth M. The Effect of combining Feed Concentrate with Cassava or Sweet Potato on Performance of Juvenile GIFT Tilapia Reared in Recirculation Aquaculture System

11 Appendixes

11.1 Appendix 1:

11.1.1 Feed Mill Manual

The feed mill manual has been completed and made available for all partners in the project. An application was sent to ACIAR communications in 2015 to publish the manual as a monograph following a recommendation from Dr Caroline Lemerle. At the time of writing this report no advice has been received from ACIAR communications on publication of the manual.