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Utilisation of local ingredients in commercial pig feeds

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2 Executive summary

The long-term competitiveness of the both the Vietnamese feed and pig production industries are constrained and under pressure whilst the industry is dependent on the use of imported feed ingredients in diets for animal production. These cost pressures are a result of import taxes, transport costs, currency fluctuations and feed supply limitations. By undertaking studies on available resources which are currently under-utilised and with potential as local feeds, we can prove their suitability for use as feedstuffs in pig diets and as replacements for imported feed ingredients. In undertaking this process we can lower feeding costs for pig production in Vietnam by the use of local feeds which are cheaper, generate new industries in Vietnam harvesting or processing these feeds and increase the incomes of Vietnamese workers who are involved in producing these by-products.

Our project has shown that rubber seed, when processed correctly to lower the hydrogen cyanide content, is a safe and suitable protein meal feedstuff for use in pig diets with the potential to replace significant quantities of imported soybean and fishmeal in Vietnamese pig diets as long as diets are balanced for any amino acid shortfalls. Our peanut studies have shown that use of binders can help alleviate pig production problems with aflatoxin content in peanut meals. Further work is needed to characterise the fate of the bound aflatoxin to see if there is any meat residue risk. Cassava residue is a resultant by-product from starch extraction in both large and small cassava processing factories. Sub-samples from these two mill types were collected and evaluated for residue HCN. Analyses has shown that the processing and sun drying results in a product with relatively consistent low HCN content. Chemical analyses also reveal that significant residual starch also remains in this by-product. Digestibility studies and pig performance feeding studies have shown that cassava residue can be included in diets at 30% with no adverse effect, although the higher fibre content of this product means that strategically, cassava residue is more suitably used in finisher and sow diets.

Research has examined the digestible energy content of a number of sunflower meal types available in Australia and identified major differences in their energy value based on processing, additionally, amino acid analysis has shown a significantly lower lysine content than previous reported. We also examined the digestible energy content of a number of Australian stylo forage legume harvest batches and identified the differences in their energy value based on age/harvest time of the forage legume. Analysis results of various stylo cuts showed that the early cut stylo has a higher starch content and lower fibre fraction content than observed in late and recut stylo which were allowed to grow longer. As a result the faecal digestible energy content was higher for the early cut stylo than for the subsequent cut stylo material which had been allowed to become woody. The results have shown that feeding of stylo meal does provide some nutritive value to the pig with increased energy and nitrogen supply, with a portion of the nitrogen presented which the pig is able to retain. Based on nutrient and fibre content stylo could have a useful role in sow feeding and satiety under non-stall housing situations.

With increasing Vietnamese investment in rubber production seen with larger areas under plantations the amounts of rubber seed available for animal feeding will grow significantly over the next 15 years and the importance of the by-product ie rubber seed meal as a protein source in diets for Vietnamese pigs.

3 Background

3.1 Partner Country and Australian research and development issues and priority

3.1.1 Pig industry in Vietnam

Pigs are of great importance in Vietnam because of their contribution to human nutrition, their role in agricultural production systems and their economic function. Vietnam's pig herd is the largest in Southeast Asia and during the ten years prior to 2002, the pig population increased by 5% annually to total 22 million. More recently the population has increased to over 30 million. Of this production more than 70% of this is from smallholder herds of 1-10 pigs. Traditionally, pig feeding was mainly based on the utilization of locally available feed resources such as broken rice, rice bran, cassava, copra meal, and groundnut meal.

However with changes in market demand for leaner meat (seen with higher prices) this has accelerated the shift from traditionally fatty breeds to new imported leaner genotypes or crossbreeds, which corresponding need better quality and consistent diets rich in nutrients to maximise performance and lean meat yield. Thus commercial feed production has expanded greatly both locally and with international investment in new large-scale feed mills in recent years to a level of about 2.5 million tonne/year in 2002 and of 3.0 million tonne /years in 2008. Unlike other pig production nations in Vietnam commercial complete diets meet 30-35% of the total feed requirement of pig production throughout the country the remaining 65-70% of feed is provided by pig farmers using locally available feed (by-product) resources to which are added protein concentrates. These concentrates predominantly use imported protein sources such as fishmeal and soybean meal.

3.1.2 Origin of project

ACIAR Project AS2/1994/023: Breeding and feeding pigs in Australia and Vietnam, has been a highly successful project, with benefits estimated at about $500M by 2010 (Tisdell and Wilson, 2001) and a more recent assessment (Fisher and Gordon, 2008) indicated increased benefits to nearly $2.0 billion. The majority of the original benefits came from the adoption of improved pig genotypes from Australia by smallholder farmers through a highly successful breeding and AI program. Additionally about $50M of benefits was attributed to the adoption by feed production mills of more appropriate diet formulations for the improved genotypes.

During the course of the project 94/23 the chemical quality of many hundreds of locally available plant and animal feed ingredients were assessed for their potential inclusion in pig diets. Many of these were used by smallholders for pig feeding, despite the limited knowledge about how best they might be used, and only some fishmeal, corn and cassava are used commercially generally by locally-owned feed mills. Internationally-owned feed mills still tend to rely on the use of imported feed ingredient in pig diet because of concerns on nutrient quality and variability of local feed ingredients. Few local protein sources are effectively utilized for animal feeding at all, while cassava, a high energy feed, is used only in limited amounts, primarily because of concerns about possible anti-nutrient factors and a lack of good production data on maximum inclusion levels which can be used. Resolving these issues of limited nutritive information and the suitability of local feeds in pig diets was identified as the one of the highest priority in consultations with feed mill managers in southern Vietnam prior to the project commencing. They recognised that the competitiveness of the both the Vietnamese feed and pig production industries are constrained and under pressure whilst the industry is dependent on imported feed ingredients which are more costly due to transport costs, currency fluctuations and supply limitations.

3.1.3 The problem, its solution and the role of research

The continuing consumer demand trends in Vietnam for lean meat and lower financial returns for fat, together with a push for development of export markets have pushed the need to maximise performance and meat quality. The use of improved pig breeds achieved via either importation, AI and breeding has successfully accomplished higher lean meat yields. To maximise the benefits from genetics an accompanying improvement in feeding precision is required. As a result of this nutritional need there has been a greater shift to the use of commercial complete diets and concentrates based on imported feeds to more effectively meet genetic needs for nutrients. Even smallholders are increasingly becoming participants in this commercial arena, using improved pure breeds or crossbreeds and feeding them either entirely or partially with commercial diets.

However with the WTO admission, the long-term viability of all pig production sectors in Vietnam is threatened by the high and rising costs of these feeds on the international market as world demand for grains and other high quality feeds (particularly proteins) increases. Increased use of cheaper local feedstuffs is a solution to the problem in pig feeding. But for various reasons this was not happening, research was needed in some cases to overcome both real and perceptions of limiting anti-nutrient factors, also to examine how these possible feed ingredients can be formulated into a complete or concentrate diet. Additionally the feed-milling sector needed data to demonstrate the suitability of these ingredients and the economic advantages in their use by the mills and the Vietnamese pig producers in the long-term.

3.1.4 Occurrence of the problem

WTO participation in international agricultural markets means pig producers in countries like Vietnam need to become internationally competitive very quickly otherwise cheaper imported meat products will gradually replace domestic production, causing collapse of the local industry. As feed costs account for 60-70% of pig production cost, close access to cost competitive feed ingredients is seen as being essential for ensuring the long-term viability of the pig industry.

Currently the Vietnamese pig industry has a cost of production which is 25% higher than neighbouring SE Asian countries, due in a large part to the high cost of imported ingredients used in diets. To date, a 30% import tariff on imported products and the preference by Vietnamese consumers for fresh meat product has minimised the potential threats from imports of frozen or chilled pork. Nevertheless, as the economy develops and consumer demands and preferences changes, this situation will, and is already showing signs of change. Clearly ensuring cost competitiveness of the local pig producer is necessary to retain their place both in production and in the market. This situation is occurring worldwide and is also important in Australia. The Australian industry has responded to this competition by increasing pig farm sizes and reducing pig producer numbers, and the formation of feed buying co-operatives. In addition, research through the Pork CRC is examining alternative or cheaper feed sources and focusing on maximising the effective utilisation of existing feed ingredients via supplements, rapid quality assessment tools or via changes to processing methods.

3.2 Why the project was appropriate for Vietnam.

The project was appropriately located because Vietnam:

Was predicted to have a 18% pig industry expansion in the next 7 years (Quirke et al. 2003)

Already had a significant demand, and incurred trade cost, for imported protein feedstuffs;

Has a financial risk of a 20% greater feed cost for pork production than neighbouring country pig producers;

Has a significant risk of a large local pig industry destabilization with WTO participation;

Had limited current options for sourcing additional local protein feeds to replace imports without research;

Had Government plans and support for further expansion of rubber production, which would significantly increase the supply of a potential by-product which could be suitable as an animal feed.

3.3 Why particular feedstuffs were examined and their issues.

Following in country consultation with IAS staff and various local Vietnamese feed milling enterprises prior to the commencement and design of the project, a number of feed ingredients were identified for examination. These were listed in order of priority based on a number of factors:

- availability in sufficient quantities to enable the development of by-product processing industry leading to their use in diets
- currently under-utilised resource i.e. not recognised as a feed ingredient
- increased future production
- cheaper than imported nutrients
- large quantities produced but industry reluctance for animal feeding due to:
    1. anti nutrient concerns; or
    2. lack of knowledge of appropriate inclusion levels; or
    3. lack of demonstrated usefulness.

From this priority listing five major feeds in Vietnam were identified for potential investigation and only the first three were examined:

- Cassava residue - as a energy feed ingredient and by-product of human food starch production, it has limited information on higher inclusion levels and there were concerns on HCN risks
- Rubber seed - as a protein feed ingredient which could be available in large quantities, it is cheap, currently not utilised, but there were concerns on HCN risk, also it needed development of processing protocol for production of a safe feedstuff
- Peanut meal or groundnut meal -which is already a significant by-product from peanut oil production but which has major issues in animal feeding from risk of aflatoxin contamination and how it could be managed
- Cottonseed meal -which was a locally produced product with perceived anti-nutrient problem for pigs but as the project progressed was seen as a less suitable feed for pigs with most available material used in beef production
- Sesame meal -again a locally produced material but with limited amount available in pig production areas

The major issue with regards to these three feeds, which were examined and which needed resolution, were:

- what were the potential toxic risks and how could they be eliminated or managed; and
- what are the energy and protein (amino acid) values of these feeds to provide nutrient values for use in computer diet formulation package to enable commercial feed manufacture; and
- what feeding level (inclusion) recommendations can be provided to the pig industry to maximise the use of these feed to replace more costly imported feed and still achieve good pig performance.

4 Objectives

Adoption of outputs from this project are intended to help reduce or at least contain the cost prices of commercial complete and concentrate diets by reducing the reliance upon, proportion of and amounts used of more costly imported diets components.

Specifically, the objective of this project was to assess the suitability of some locally available protein and energy sources as components of commercial pig diets.

Activities conducted to achieve this objective were:

Laboratory assessment of the nutrient and anti-nutrient content of some local protein and energy sources.

Development of methods to overcome anti-nutrient factors appropriate for Vietnamese circumstances.

In vivo assessment of the nutrient value (digestibility and amino acid availability) of local protein and energy sources post-treatment.

Performance testing (growth, carcass quality, economics) of diets containing local protein and energy sources.

On-farm assessment and demonstration of performance using diets containing local protein and energy sources.

5 Methodology

Objective 1: Content- Laboratory assessment of the nutrient and anti-nutrient content of some local protein and energy sources

Cassava residue

A total of 35 cassava residue starch processing mills from Daklak, Binh Phuoc, Tay Ninh and Dong Nai provinces were surveyed. The 16 larger-scale mills (i.e. 300 – 450 tonnes fresh root/day) ranged from 4 mills in Daklak and Dak Nong province and 3 mills from Binh Phuoc, 2 mills from Dong Nai and 7 mills from Tay Ninh provinces. The smaller-scale mills (i.e. 30 – 100 tonnes fresh root/day) were located in the Tay Ninh (12 mills), and Dong Nai (7 mills) provinces. Fifteen mills were surveyed about production data and over two week period 5 production sub-samples were collected of cassava residue for compositional analyses. A total of 80 cassava residue samples were assessed for cyanide and dry matter content. All samples were sent to Australia for HCN evaluation as part of an in-house laboratory training program for the Vietnamese lab staff. With 29 representative sub-samples undergoing further detailed proximate chemical analyses in Australia.

Rubber seed

Survey protocols and sample yield collection

A short interview was taken with some technicians and managers of Viet Nam Rubber Corporation as well as Viet Nam Rubber Research Institute to obtain data on total planting area, harvesting time of rubber seed and factors affecting seed yield. A interview survey questionnaire was conducted with 50 rubber householders; 6 rubber plantations; 03 rubber seed collection agents; 10 rubber seed collectors and 05 rubber seed processing enterprises in Dong Nai; Binh Duong; Binh Phuoc; Tay Ninh province and suburb of Ho Chi Minh city. The information collected related to crop planting, harvesting, variety, productivity, product quality; by-products; method of collecting, processing technology, price, market and use of rubber seed products in animal husbandry. In addition about 50 samples (40 from householders; 10 from processing enterprises) were collected for nutritional and toxin analyses in the raw materials and processed products.

Rubber seed yield using seed-drops from trees (2005 survey)

The seed-drop rubber seed yield study was conducted from August to November 2005 (16 weeks) at the Tra Thanh and Loi Hung plantations which belong to Binh Long Rubber Company in Binh Phuoc province. The experiment was a factorial design with two factors of rubber tree variety (RRIM600 and GT1) and age of tree (10-15 year old and 16-24 year old) with 3 replications and hence a total of 12 experimental units. Each experience unit was a standard area of ~5,000 m2, (width: 7 rubber tree rows wide with the inter-row distance = 7m i.e. 49M; length: 34 rubber trees with inter-tree distance = 3m i.e. 102M). Experiment area was surrounded by rope. The test areas were initially cleared of all old seed material and leaf matter. Rubber seeds were collected beside the area, weighed and recorded each day.

Rubber seed yields using number of fruit and seed on trees (2006 survey)

This rubber seed yield study was conducted in August 2006. Cut tree yield measurements were carried out at 1 tree/day over 6 days at small-holder rubber tree farm at village 6, Vu Hoa commune, Duc Linh district, Binh Thuan. Three sites with different ages of trees were examined. At these sites initially the tree density per ha was recorded, concurrently each tree was classified on a visual estimate of quantity of fruit bodies on each rubber tree. Then selected trees from each classification and age group were cut down to enable the collection and precise counting of all fruit on the tree to get seed number on plant. The resultant seed harvest was weighed the collected number of seed on tree and calculating a number of seed /kg. This value was used to estimate rubber seed yield tons /ha based on tree number per ha.

Fresh rubber seed were also harvested from these same plantations in Vietnam by collection within one day of dropping. These were frozen and bulked together. Sub-samples of these underwent a number of treatments using heat, pressure, washing and sun-drying following which the seeds were chemical analysed for presence of residual hydrogen cyanide (HCN) by the method of Haque and Bradbury (2002). Samples of rubber seed were sent to Australia to be also assessed for detailed proximate chemical composition and amino acid content as well as fatty acid composition.

Peanut meal

Both ingredient samples and diet used in the inclusion study were sent to Australia for detailed proximate chemistry and amino acid analysis

Objective 2: Treatment- Development of methods to overcome anti-nutrient factors appropriate for Vietnamese circumstances.

This study examined a number of simple processing protocols which could be used in Vietnam to reduce the hydrogen cyanide content of rubber seed and cassava residue in large quantities in a semi-industrial process. With pre-existing knowledge of the role of sun-drying for reducing HCN in cassava and with it being particularly useful in yielding a storable feed component the majority of treatments examined for rubber seed processing were focused on derivatives or additions to this accepted treatment. Studies were conducted in Vietnam at the IAS and the SIAEPHT and also in Australia examining a number of treatment protocols and their impact on residual HCN level in rubber seed and cassava residue.

An early study was conducted on HCN levels and the dry matter values of cassava residue collected from the mill survey. The results revealed that the current protocol of sun-drying the cassava residue after the starch extraction process successfully reduced HCN level to acceptable level and hence no further work was warranted.

Rubber seeds both fresh and older material were examined for residue HCN following various processing treatments. Fresher seeds were particularly important as they had higher HCN levels and higher moisture content so that a successful treatment would need to both reduce to low enough levels the HCN but also minimise the risk of mould damage with storage of the rubber seeds. Older seed on the other hand have a lower HCN level and moisture content but an increased risk of being already mouldy. The treatments examined were based on simple and cheap technology which could easily be successfully applied in Vietnam such as:-

- Prolonged storage at ambient temperature
- Sun drying for 1, 2, 3 and 4 days
- Immersion in boiling water for a range of times
- Oven drying at 110 and 120^{o}C
- Oil extraction processing
- Extrusion
- Ensilage
- Grinding
- Steaming
- Soaking

- Washing
- Fine-tuning combinations of homogenisation, wash and sun-drying cycles

Following identification of successful HCN reduction protocol, samples of bulk processed rubber seed were sent to Australia for proximate chemistry and amino acid analysis.

Objective 3: Feed value - In vivo assessment of the nutrient value (digestibility and amino acid availability) of local protein and energy sources post-treatment

Vietnam
Due to issues with quarantine and biosecurity, all animal work related to the digestibility studies on Vietnamese feeds was carried out in Vietnam.

Cassava residue digestibility studies
Cassava residue produced in the Tay Ninh province was purchased from a local feed mill enterprise associated with the Thong Nhat pig farm. The digestibility study was also conducted at Thong Nhat pig farm, Thai My commune, Cu Chi district, Ho Chi Minh City, under direct supervision and monitoring by IAS experimental technicians from March 2006 to June 2006. Four castrated male pigs, of a three-way cross (Duroc, Yorkshire x Landrace) and of 35-40 kg initial body weight were individually housed in digestibility crates (0.4 m x 1.0 m). Two diets were prepared, firstly a basal digestibility diet (based on 90% maize and 10% minor components consisting of casein, vitamins, minerals, lysine and oil) and an experimental digestibility diet which was the basal diet with an additional 30% cassava residue added on top. Determination of digestibility coefficient, in growing pigs, for various nutrient fractions of cassava residue was calculated based on total faeces collection method and also with the use of an indigestible marker Chromic oxide (Cr_2O_3). The difference method was used for calculation of the digestibility of cassava residue nutrients. All feed ingredient and faeces chemical and marker analysis were conducted in Vietnam.

Rubber seed digestibility studies
Whole rubber seeds were harvested over the period of 9-11 October 2007 from 10 plantations in Cam Duong Commune of Cam My district in Dong Nai province. This material underwent processing via the specially developed HCN reduction processing protocol to produce IAS rubber seed. Additionally commercial rubber seed meal was purchased from a local feeding mill. Then at the IAS Binh Thang research farm twenty-four castrated male pigs (Vietnamese Yorkshire or LW) of similar weight range of 22-25 kg were fed one of four digestibility diets: - a cassava basal diet (CBASAL diet 1), a cassava/USA soy bean meal diet (CUSASBM diet 2), a cassava/IAS rubber seed meal diet (CIASRSM diet 3) and a cassava/commercial rubber seed meal diet (CCOMRSM diet 4). Cassava was the major starch providing ingredient of the diet and it comprised 65% of the diet with one of three test protein meals being the main protein source at a 30% inclusion level, the other minor components and markers at 4.85% were added to the diet. Celite, titanium dioxide and barium sulphate were used as indigestible markers for digestibility assessment. Phase one of the trial entailed faecal digestibility evaluation using both total collection and via use of markers to provide total tract digestibility values for energy and amino acids. Phase two entailed slaughter of pigs and collection of intestinal digesta to enable determination of ileal digestibility values for amino acid and energy. Samples of diets, ingredients, faeces and digesta form SI4 and SI3 were all dried and sent to Australia for detailed chemical analysis together with all 23 amino acids and Ti, Ba, AIA analysed. This was primarily to ensure analytical precision and confidence.

Australia
Due to drought and limited availability of new crops and the prolonged delays with regards to the start-up of the sorghum biofuel plant at Dalby which should have provided distiller grain for evaluation the alternative feed option for study were very limited. Hence, following consultation with an industry expert the Australian component was refocused on two other feeds of interest. Sunflower was selected for evaluation as there is no recent Australian data on the nutritive value of sunflower meals currently available for use in pig diets. This is despite the fact that over the last decade sunflower production in Australia has shifted significantly as a result of market demands from production of sunflower seed varieties for poly-unsaturated oils to those of mono-unsaturated oil production. Sunflower breeding programs and commercial processing of sunflower into either expeller or solvent meals may have also influenced the nutritive value of the meals. The current study examined whether the very old values are still relevant. Secondly linkage with ACIAR project LPS/2004/046 provided an opportunity to undertake detailed digestibility and chemical analysis on Stylo which could not be achieved in Laos due to lack of capacity while providing valuable information on fibre impacts on digestibility of nutrients. Additionally as intensive pig industries move from stall housing of dry sows into group housing, due to legislative changes in response to welfare concerns, the high yields, bulkiness and fibre level of stylo could be a viable crop option to develop new feeding regimes and diets enabling increased sow satiety without over-supplying nutrients to the dry sow and that stylo may have a niche in this over other feeds so early studies seemed worthwhile.

Sunflower digestibility studies
Sixteen entire male pigs (LW) of weight 22-25 kg were fed four diets based on either sorghum-casein diet (control) or three sorghum-sunflower casein options. The 2 part component of the diet was 60% sorghum with one of three new sunflower meals as the main protein source at 30%. The sunflower meals examined were 2 solvent extracted meals sourced from Cargill Aust Ltd with the base sunflower seed used either mono-unsaturated or poly-unsaturated and an expeller mono-unsaturated extracted meal from Oleo Aust Ltd. Phase one of the trial entailed faecal digestibility evaluation using both total collection and via use of markers to provide total tract digestibility values for energy and amino acids. Phase two entailed slaughter of pigs and collection of intestinal digesta to enable determination of ileal digestibility values for amino acid and energy.

Stylo digestibility studies
A half portion of *Stylosanthes guianensis* grown from seed at a DPI&F Research Station at Walkamin in northern Queensland was collected twelve weeks post-planting (early cut) and dried at a low temperature in a fan-forced oven. At 18 weeks post-planting the other half of the original crop was harvested (late cut) and similarly dried. Also at 18 weeks post-planting the section of the crop which had been harvested at 12 weeks (and now having 6 weeks of regrowth) was recut (recut) and dried. The dried material was hammer milled and incorporated in a sorghum basal digestibility diet. The digestible nutrient value of the dried stylo cut and harvested at different times (early cut, late cut, recut) post-planting was assessed. Treatment diets consisted primarily of 65% sorghum, and a 10% basal component consisting of casein, vitamins, minerals, lysine and oil. To this was added 25% of one of the three cuts of dried stylo meals or in the case of the basal control diet another 25% sorghum inclusion. Diets were fed as a meal to sixteen entire male Large-White pigs with an initial weight of ~ 15.5 kg to assess pig performance over 4 weeks. Pigs were housed individually in expanded metabolism crates.

Phase one of the trial entailed faecal digestibility evaluation using both total collection and via use of markers to provide total tract digestibility values for energy and amino acids. Phase two entailed slaughter of pigs and the entire digestive tract of each pig was removed and rapidly separated into Stomach, four Small Intestine segments SI_1 Si_2 Si_3 Si_4, Caecum and the hindgut was divided into two Large Intestine segment Li_1 Li_2 and a

Colon sections the collected intestinal digesta was used to enable determination of digestibility values for amino acid and energy.

Objective 4: Inclusion- Performance testing (growth, carcass quality, economics) of diets containing local protein and energy sources.

Vietnam

Due to issues with regards to Australian quarantine and biosecurity all work related to the pig growth inclusion studies on Vietnamese feeds, was carried out in Vietnam.

Cassava residue inclusion

One hundred and ninety-two (96 castrated males and 96 females) Yorkshire x Landrace pigs of 20 ± 0.5 kg initial body weight were selected from a larger pool of pigs after ranking on live-weight and discarding a few that were weight outliers (light or heavy). Pig allocation was completely randomized into 4 treatments with 4 pen replicates and 12 pigs in each pen as the experimental unit. The study was conducted at Thong Nhat pig farm, Thai My commune, Cu Chi district, Ho Chi Minh City, under direct supervision and monitoring by IAS experimental technicians from March 2006 to July 2006. Pigs were fed pelleted diets based on one of four feeding treatments. Treatment 1 was a control diet based on corn, rice bran, wheat bran, soybean meal and fishmeal with 0% cassava residue inclusion. Treatment 2 was a similar balanced diet with wheat bran and corn replaced by cassava residue inclusion at 10% in the grower diet and at 15% in the finisher diet. In Treatment 3 the cassava residue inclusion was at 15% in the grower diet and at 25% in the finisher diet.

Whilst in treatment 4 the grower diet had an inclusion level of 20% cassava residue while the finisher diet had a 35% cassava residue inclusion. Diets were formulated, using these inclusion levels of cassava residue, with the Ultramix diet formulation package and nutrient specifications for Vietnamese pigs to yield grower diets (12.96 MJ ME/kg; total lysine 0.9%) and finisher diets (12.12 MJ ME/kg, total lysine = 0.8%). Initial body weight of pigs on commencement of the trial at ~60d of age was recorded. Individual pigs were weighed again after 8 weeks on the grower diet (116 d of age) and following another 8 weeks on the finisher diet (172 d of age). Weight gain over the grower and finisher period was calculated. Feed consumption was monitored daily and at termination of the experiment, 4 pigs (2 males and 2 females) from each of the treatment groups were slaughtered for carcass evaluation. This consisted of live body weight, carcass percentage, lean meat percentage, fat percentage, bone percentage, backfat thickness: at P_2 position of the carcass (mm) and loin muscle area (cm^2).

Rubber seed inclusion

Sixty four Yorkshire x Landrace castrated male pigs of 30 ± 0.5 kg initial body weight. Pigs were individually housed in grower pens (2.4m x 1.2m). Pigs were fed one of eight experimental diets. Six diets were based on a corn/rice bran/soybean meal with four inclusion levels of IAS rubber seed (*Hevea brasiliensis*) meal (IAS-RSM) (0 (control), 10, 20 and 30%), or alternatively two inclusion levels of a defatted commercial rubber seed meal (COM-RSM) (10 and 20%). In addition two cassava-based diets with and without IAS-RSM supplemented at a 30% inclusion level were also examined. The grower diets contained 13.17 MJ ME/kg and total lysine 1% while finisher diets contained 13.17 MJ ME/kg and total lysine 0.8%.

This study was conducted to examine the performance of pigs feed corn or cassava-based diets with various inclusions of rubber seed meal. A comparison was also made between commercial rubber seed meal available in Vietnam and various inclusion levels of our specially processed rubber seed meal to imported commercial soybean meal so as to provide data to enable effective use in pig production.

Peanut meal inclusion

A total of three hundred 10 week old commercial hybrid Duroc, Pietrain x (Yorkshire x Landrace) pigs with body weight of 25 from the Biopig farm, Nhuan Duc commune, Cu Chi district, Ho Chi Minh City were allocated completely randomized into 5 treatments with 5 replications and 12 pigs per pen. Treatment 1 was a diet without peanut cake (control) based on corn, rice bran and soybean meal, Treatment 2: the same diet with 10 % peanut cake (GNM) Treatment 3: same diet with 15 % peanut cake Treatment 4: same as treatment 2 + 0.1% Mtox Treatment 5: same as treatment 3 + 0.1% Mtox. Individual pigs were weighed at beginning, at 56 days after start and at the end of experiment (after 112 days experiment). At termination of the experiment, 2 pigs (1 castrated male and 1 female) of each treatment were slaughtered for carcass evaluation. The study was conducted from March 2008 to July 2008.

Australia

Due to issues with obtain sufficient quantities for inclusion studies as a result of drought, crop seasonality and increased costs and details in analyses of other project activities it was not possible to undertake pig growth inclusion studies on Australian feeds. Instead in their place in was felt that AUSPIG simulations could be carried out utilising the result of recent digestibility data and providing just as useful data. This can be done under the licence agreement for Australian feeds but is not allowed to be applied to Vietnamese feeds as they are not currently permitted use of AUSPIG.

Sunflower simulation

Using actual research data derived from this project, nutritive values were given for the important formulation components for various sunflower varieties examined. Simulations were conducted on the basis on this nutritive data and these were compared to traditional book values which have been used until now.

Stylo simulation

Using actual research data derived from this project, nutritive values were given for the important formulation components for various stylo cuts examined. Simulations were conducted on the basis on this nutritive data and pig performance results were compared with poor genotype pigs and with ad lib and restricted feeding.

Objective 5: Promotion-On-farm assessments and demonstration of performance using diets containing local protein and energy sources.

As the project initially progressed slowly it soon became clear that delays in the project and rubber seed seasonality would make the conduct of on-farm assessment difficult to achieve especially within the time-frame of the project and especially without adequate incentive for commercial producers to risk pig performance. Hence the Vietnamese project team decided that some inclusion trial with larger numbers of animals would be carried out on commercial farms under semi-commercial condition but with IAS staff overall supervision. Hence both the peanut meal and cassava residue growth trial have been conducted as such and as outline above.

The rubber seed meal inclusion trial was conducted on the IAS research farm with single stall animals. This was necessitated by the limited quantity of rubber seed ingredient available. Early project work had revealed that rubber seed can rapidly become mouldy if not adequately processed and stored soon after harvest. We were limited to five ton of fresh rubber seed due to the difficulty to both to organise a fresh harvest, the cost of collection, transportation and the inability to process any larger amounts of rubber seed rapidly without industrial scale equipment.

6 Achievements against activities and outputs/milestones

Objective 1: Content- Laboratory assessment of the nutrient and anti-nutrient content of some local protein and energy sources

no.	activity		outputs/ milestones	completion date	comments
1.1	Literature review	A	Decision on best treatment	Sept 05	Draft Review completed
1.2	Toxin testing				
	1.2.1 training	A	HCN training	Sept 05	HCN training finished
	1.2.2 survey	PC	Representative Viet	April 07	All survey samples completed
	1.2.3 process sample	APC	Chemical analyses	Dec 08	New sample pre treatment
	1.2.4 toxin analyses	APC	Toxin analysis	April 08	Current bulk lot
1.3	Pre treatment analyses				
	1.3.1 toxin testing	PC	Complete toxin	Dec 07	Current batch tested
	1.3.2 prox chem	APC	Gross chemistry	Dec 08	Sent to Australia
	1.3.3 aa analysis	APC	Aa analyses	Dec 08	Sent of Australia
1.4	Post treatment analyses				
	1.4.1 toxin testing	APC	Post treatment toxin	Mar 08	Lab scale samples tested
	1.4.2 prox chem	APC	Gross chemistry	Mar 09	Sent to Australia
	1.4.3 aa analyses	APC	Retest aa analyses	Dec 08	Sent to Australia
1.5	NIR feed service				
	1.5.1 Capacity build	A	Purchase 2 NIR	May05	
	1.5.2 NIR training	A	In-house training	April 08	Both dpi and NIR systems contribution
	1.5.3 NIR installation	PC	Transfer to Vietnam	May 08	
	1.5.4 NIR calibration	PC	Input Vietnam data	continuing	Collection of Vietnam calibration samples

PC = Partner Country, A = Australia

Objective 2: Treatment- Development of methods to overcome anti-nutrient factors appropriate for Vietnamese circumstances.

no.	activity		outputs/ milestones	completion date	comments
2.1	Engineering and processing Heat treatment	PC	Heat treated feed for trials	Dec 06	Lab scale system completed
2.2	Extrusion	PC	Extruded feed for trials	Dec 07	Bulk processing completed for trials
2.3	Solvent extraction	PC	Solvent treated feed for trials	Pending	Seeking link to biofuel operator
2.4	Supplements	PC	Dietary supplement prepared	Discarded	Not required for rubber seed

PC = Partner Country, A = Australia

Objective 3: Feed value - In vivo assessment of the nutrient value (digestibility and amino acid availability) of local protein and energy sources post-treatment.

no.	activity		outputs/ milestones	completion date	comments
3.1	Cassava digestibility	PC	Completion of trial	Aug 06	Conducted at same time as growth trial
3.2	Rubber seed digestibility	PC	Completion of trial	Feb 08	Conducted at same time as growth trial
3.3	Sesame digestibility	PC	Completion of trial	Discarded	Lower priority in Vietnam
3.4	Groundnut digestibility	PC	Completion of trial	Discarded	No available project finance
3.5	Sunflower digestibility	A	Completion of trial	Nov 06 Mar 09	Trial conducted Final digesta analyses
3.6	Stylo digestibility	A	Completion of trial	Nov 07 Mar 09	Trial conducted Final digesta analyses
3.7	Alternative feed	A	Completion of trial	Discard	No feed identified no available facility

Objective 4: Inclusion- Performance testing (growth, carcass quality, economics) of diets containing local protein and energy sources.

no.	activity		outputs/ milestones	completion date	comments
4.1	Cassava inclusion	PC	Growth trial	Oct 06	Completed
4.2	Rubber seed inclusion	PC	Growth trial	Set 08	Completed
4.3	Ground nut inclusion	PC	Growth trial	Dec 08	Completed
4.4	Cottonseed	PC	Growth trial	Discard	Low production
4.5	Sunflower	A	Growth trial	Mar 09	sourcing problem use AUSPIG instead
4.6	Alternative feed-stylo	A	Growth trial	Mar 09	lack of available facility/ingredient sourcing problems use AUSPIG instead

Objective 5: Promotion-On-farm assessments and demonstration of performance using diets containing local protein and energy sources.

no.	activity		outputs/ milestones	completion date	comments
5.1	5 Diet comparisons	PC	Commercial demo trials	See inclusion trials	Have been bundled into inclusion trial to cut costs
5.2	Workshop	PC	Workshop promotion of project outcomes	Discard	No available funding was better achieved with AAAP 2008

6.1 Outputs

3.3.a. Original Flow Chart based on April 2004 start and with revised actual start after 9months

Objective	Activity	Activity detail		Time line	Actual Original Months	Revised Months*9mth late	Status	Milestone
1. Content	**1.1 Literature Review**		A	Yr 0, m8 to m12	Jan 04- Mar 04	Sep 04-Nov 04	Completed Sept 05	Decision on best treatment and inclusion levels options
	1.2 Toxin testing	1.2.1 Training 1.2.2 Survey and Collection 1.2.3 Process samples 1.2.4 Toxin analysis	A V AV AV	Yr1, m1 to Y1 m3 Yr0, m9 to Y1 m6 Yr1, m1 to Y1 m3 Yr1, m1 to Y1 m6	Apr 04- Jun 04 Jan 04- Sep 04 Apr 04- Jun 04 Apr 04- Sep 04	Dec 04- Feb 05 Sep 04- May 05 Dec 04-Feb 05 Dec 04-May 05	Completed Sept 05 Completed April 07 Completed Dec 08 Completed April 08	Completion of cyanide testing training Collection of representative feed sample for Vietnam Samples ready for chemistry Detailed toxin analyses
	1.3 Pre-treatment analysis	1.3.1 Five samples-toxin test 1.3.2 Five proximate analyses 1.3.3 Five amino acid analysis	V V V	Yr1, m1 to Y1 m6 Yr1, m1 to Y1 m6 Yr1, m1 to Y1 m6	Apr 04- Sep 04 Apr 04- Sep 04 Apr 04- Sep 04	Dec 04-May 05 Dec 04-May 05 Dec 04-May 05	Completed Dec 07 Continuing Dec 08 Continuing Dec 08	Complete toxin analysis on test feed ingredient Gross chemical composition evaluated Detailed amino acid analysis
	1.4 Post-treatment analysis	1.4.1 5 x 2 samples-toxin test 1.4.2 5 x 2 proximate analyses 1.4.3 5 x 2 amino acid analysis	V V V	Yr1, m6 toY1 m12 Yr1, m6 toY1 m12 Yr1, m6 to Y2 m3	Sep 04- Mar 05 Sep 04- Mar 05 Sep 04- Jun 05	May 05- Nov 05 May 05- Nov 05 May 05- Feb 06	Lab scale completed Rubber seed Mar 08 Completed Mar 09 Completed Mar 09	Post treatment toxin analysis Reconfirm gross chemical composition Retest amino acid analyses
	NIR feed service	1.5.1 Capacity building 1.5.2 NIR training 1.5.3 NIR installation 1.5.4 NIR calibration	A A V V	Yr1, m1 to Y2 m3 Yr2, m3 to Y2 m6 Yr2, m6 to Y2 m9 Yr2, m9 to Y3 m3	Apr 04- Jun 05 Jun 05- Sep 05 Sep 05- Dec 05 Dec 05- Jun 06	Dec 04- Feb 06 Feb 06- May 06 May 06- Aug 06 Aug 06- Feb 07	Completed 05 Completed April 08 Completed May 08 Continuing	Purchase of 2 NIR Compete in house training on NIR Transfer instrument to Vietnam Input Vietnam feed information with scans
2.Treatment	**2.1Engineering and processing**	2.1.1 Heat treatment 2.1.2.Extrusion 2.1.3 Solvent extract 2.1.4.Supplement	V V V V	Yr1, m3 to Y1m12 Yr1, m6 to Y1m12 Yr1, m6 to Y1m12 Yr1, m6 to Y1m12	Jun 04- Mar 05 Sep 04- Mar 05 Sep 04- Mar 05 Sep 04- Mar 05	Feb 05- Nov 05 May 05- Nov 05 May 05- Nov 05 May 05- Nov 05	Lab tests Dec 06 Bulk Dec07 pending -Link to biofuel Discarded unviable	Heat treated feed for digestibility/performance trials Extrusion treated feed for digest/performance trials Solvent treated feed for digest/performance trials Dietary supplements prepared for addition
3.Feed Value	**3.1 In vivo digestibility**	3.1.1 Cassava trial 3.1.2.Rubber seed meal trial 3.1.3.Sesame seed meal trial 3.1.4.Groundnut meal trial # 3.1.5 Sunflower meal trial # 3.1.6 Alternative feed A * 3.1.7 Alternative feed B*	V V V V A A A	Yr1, m9 to Y2 m3 Yr2, m1 to Y2 m6 Yr2, m3 to Y2 m9 Yr2, m6 to Y2m12 Yr1, m3 to Y1 m9 Yr1, m6 to Y1m12 Yr1, m9 to Y2 m3	Dec 04- Jun 05 Apr 05- Sep 05 Jun 05- Dec 05 Sep 05- Mar 06 Jun 04- Dec 04 Sep 04- Mar 05 Dec 04- Jun 05	Aug 05- Feb 06 Dec 05- May 06 Feb 06- Aug 06 May 06- Nov 06 Feb 05- Aug 05 May 05- Nov 05 Aug 05- Feb 06	Completed August 06 Completed Feb 08 Discarded Discarded Completed Nov 06 Mar Stylo Completed 07 No feed indentified	Completion of digestibility trial and analyses Digestibility results for performance diets formulation Completion of digestibility trial Digestibility results for performance diets formulation Completion of digestibility trial Digestibility results for performance diets formulation Completion of digestibility trial
4. Performance	**4.1 Inclusion Levels**	4.1.1 Cassava 4.1.2 Rubber seed meal 4.1.3 Ground nut meal# 4.1.4 Cottonseed# 4.1.4.Sunflower # 4.1.5 Alternative feed A/B*	V V V V A A	Yr2, m3 to Y2 m9 Yr2, m6 to Y2m12 Yr3, m1 to Y3 m6 Yr3, m3 to Y3 m9 Yr2, m1 to Y2m6 Yr2, m6 to Y2m12	Jun 05- Dec 05 Sep 05- Mar 06 Apr 06- Sep 06 Jun 06- Dec 06 Apr 05- Sep 05 Sep 05- Mar 06	Feb 06- Aug 06 May 06- Nov 06 Dec 06- May 07 Feb 07- Aug 07 Dec 05- May 06 May 06- Nov 06	Completed Oct 06 Completed Sep 08 Completed Dec 08 Low production-discard Completed Auspig May 09 Completed Auspig May 09	Completion of growth trial Performance results for commercial demonstration Completion of growth trial Performance results for commercial demonstration Completion of growth trial Performance results for commercial demonstration
5. Promotion	**5.1Commercial demonstration –on farm**	5.1.1 Five new diet comparison 5.1.2 Workshop	V V	Yr3, m6 to Y3m12 Yr3, m9 to Y4 m3	Sep 06- Mar 07 Dec 06- Jul 07	May 07- Nov 07 Aug 07- Mar 08	Bundle into inclusion trials Use AAAP2008 for promo	Completion of commercial demonstration trial Workshop promotion of project outcomes

- based on project official start date 01/04/04 but due to delayed signing in Vietnam and illness the project started 1/12/04

\# changes in alternative feeds to be investigated

* Alternative feed to be selected post the Pork CRC alternative feed workshop

7 Key results and discussion

Objective 1: Content- Laboratory assessment of the nutrient and anti-nutrient content of some local protein and energy sources

Cassava residue

A survey was conducted of cassava starch processing plants on the starch manufacturing process from cassava and of the production levels of cassava residue to provide information on quantities (Table 7.1) and quality of this feedstuff. Sub-samples from both small and larger scale mills were also collected and evaluated for residue HCN, dry matter content. Analyses has shown that the processing and sun drying results in a product with relatively consistent low HCN level. Samples also were further chemically analysed for a nutritive assessment (Table 7.2).

Table 7.1 Cassava Processing capacity of surveyed mills and available cassava residue

	Larger mills			Small scale mill			
Designed capacity (tonnes root/day)	450	400	300	100	70	50	30
Number of mills	6	5	5	4	5	5	5
Operation duration (day/year)	130	140	145	165	170	195	200
Total input (tonnes root/year)	351,000	280,000	217,500	66,000	59,500	48,750	30,000
Estimated fresh cassava residue yield (tonnes/year)	210,600	168,000	130,500	40,260	36,295	29,250	18,300

Table 7.2 Analysed chemical composition (DM basis) of cassava residue from various size mills

Parameter	Unit	Large mills	Small mills	Fresh cassava residue	Dry cassava residue	Cassava peel Air dry basis
N=		15	14	2	2	
DM	%	89.5	88.5	15.38	88.80	86.5
Ash	%	2.1	3.5	0.27	1.77	6.5
Nitrogen	%	0.3	0.44	-	-	
Protein (N x 5.7)	%	2.16	2.72	0.28	2.2	6.5
Fat	%	0.4	0.8	0.08	1.02	1.0
Crude Fibre	%	14.1	13.3	2.46	12.3	10
ADF	%	17.0	16.3	-	-	
NDF	%	21.2	20.0	-	-	
lignin	%	2.9	2.9	-	-	
Amylose	%	-	-	-	-	
Amylopectin	%	-	-	-	-	
Starch	%	59.9	62.0	-	-	NFE 62.5
GE	MJ/kg	17.0	16.9	2.48	15.06	
GE	Kcal/kg	4063	4039	594	3602	3950
Cal ME	Kcal/kg	-	-	338	1967	2460*
Acid insoluble ash	%	-	-	0.054	0.45	
HCN	Mg/kg	3.8	4.3	3.4	2.80	

- source (Sonaiya and Omole, 1977) calculated

Cassava residue production

Cassava (*Manihot esculenta Crantz*) residue is the solid waste produced as a consequence of starch production. Operation of cassava starch processing mills depends on the cassava harvesting season. Our survey found that larger-scale mills with their greater designed capacity only operated for 4 to 5 months per year due to shortages and seasonal supply of raw material. The survey revealed that all large scale mills operated at their designed capacity during the main cassava harvesting season. Towards the end of the harvesting season most of the large scale mills collected raw material over a few days to enable one day's full operation. Whereas the duration of operation of the small-scale mills were 1-2 months longer than larger-scale ones primarily as a result of the lower harvest of cassava root at the end of the harvesting season being more suited to the daily capacity of these smaller mills.

Waste materials from cassava starch processing factories can be divided into four categories: a) peelings from initial processing b) fibrous by-products from crushing and sieving (pulp waste) c) starch residues after starch settling and d) waste water (effluent) (Ubalua, 2007). Cassava residue is the main by-product of these starch production mills and it is estimated that it yields about 60% of the quantity of the raw material used. We found that the cassava residue yield from large scale mills (60% of total root processed) was slightly lower than the yield from the smaller scale mills (61% total root) which is probably a result of the bigger mills having more modern processing equipment. Fresh cassava residue is collected from processing mills by middlemen and sun dried on cleared post-harvest cassava fields. The time for sun-drying of cassava residue ranges from 7 to 8 days in good sunny weather; whereas during the rainy season sun-drying may take longer, 15 to 20 days. The yield of dry cassava residue product as estimated by survey of middlemen to be about 10% of fresh cassava residue from mill, this dried material is then ground and then on sold to animal feed millers.

Cyanide content

Cassava contains the cyanogenic glucosides linamarin and lotaustralin (bound cyanides) which when the cellular structure of the plant is damaged are hydrolysed to hydrogen cyanide by the plant's endogenous enzyme linamarase (EC 3.2.1.21). Thus by the use of various processes to cause cellular breakdown is how cassava starch factories process cassava to both extract the starch and to eliminate any cyanide present in cassava. The process of cassava starch extraction consists of wet-milling the washed roots, washing the starch from this milled pulp and either via sedimentation in concrete tanks or via centrifugation the cassava starch is extracted, this high value component then dried by artificial means or by sun-drying. Whereas the low value fibrous by-product component i.e. cassava residue, is generally sun-dried to facilitate storage and keeping quality.

This homogenisation process allows the endogenous enzymes access to most of the cyanogenic glucosides (bound cyanide) in the roots which are then converted to free cyanide during the milling operation. A number of studies (Jones et al., 1994) and (Agbor-Egbe and Lape Mbome, 2006) have shown that the success of glucoside elimination or conversion to free cyanide is dependent on the degree of cellular disintegration and the period of time for which water activity permits enzyme activity. It has also been reported (Arguedas and Cooke, 1982) that between 40 and 70% of the total cyanide appears in the water used to wash the starch from the disintegrated tissue, and between 5 and 10% remains in the fibrous residue used in animal feed. Arguedas and Cooke (1982) also reported that the dried product contains less than 1% of the quantity of cyanide present in the raw material.

Our testing of samples obtained from over 35 mills has shown following the traditional sun-drying process, that the cassava residue residual cyanide content was successfully reduced, to ~ 4 mg HCN/kg. This is well below the generally accepted animal feed target of 50mg HCN/kg of diet, reported to be European community consensus (Okafor and Nwabuko, 2003).

More recently, the EU legislation on HCN in feed material has been reported (SPCFC, 2007), in which a maximum content of 100mg HCN /kg for cassava products intended for animal feeds and a maximum content of 50 mg HCN/ kg of complete animal feed was set, except for chicks where this limit for complete feed was set at 10 mg HCN/ kg. The WHO safe level for cyanide in cassava flour for human use is 10mg HCN/kg

(FAO/WHO, 1995),(FAO/WHO, 1991) as reported by (Cardoso et al.(2005) and our data shows that the current cassava milling processes employed, together with sun-drying produce a safe low cyanide by-product for animal feeding.

Composition

Our studies have found that the cassava residue or pulp material after starch extraction still contains a substantial quantity of starch (50-60% dry basis) which is similar to that previously reported (Arguedas and Cooke, 1982, Balagopalan et al., 1994, Pandey et al., 2000). It would appear that this is due in part to the inefficiencies in processing practice. We also found that the cassava residue of large scale mills had lower remaining starch content (3.5%) compared to that of smaller mills (4.5%), this being seemingly related to overall processing efficiency and yields.

The original cassava pulp, remaining after starch extraction was completed, was found to have very high moisture content (60-70%) similar to that reported by Sriroth et al. (2000). It is for this reason that all mills employ middlemen to remove and sun-dry the cassava residue. Drying provides a number of advantages which are: - reduced transportation costs when the material is dry, suitability to be used in dry and pelleted mixed rations, the sun-drying process further aids in reducing any remaining residue HCN, it improves keeping quality and minimises microbial and mycotoxin risks. Following the sun-drying the resultant dry matter value of the final cassava residue product averaged 89.1%.

The chemical analysis also showed that cassava residue contains a significant level of fibre (27%, dry basis). This high fibre content will have a significant role in determining the nutritive value of cassava residue for animals. It acts both as a diluent, of poorer nutrient value, and it probably also retards the efficiency of starch extraction from the cassava residue as the fibrous network holds starch granules together. Len et al. (2008) reported cassava residue as having a low protein content (<2 %) and the crude fibre content being 16.3% while the level of NDF was similar to rice bran at 45.6%. Based on such high level of fibre the use of cassava residue in pig diets would be most effective in situation where energy dilution is required and more bulk, i.e. in finisher diet to avoid fat penalties and in dry sow diet to boost sow satiety

Rubber seed

During 2005 detailed characteristics of the Vietnam rubber production industry were surveyed, data was collected from industry sources, plantation, small holders and via measurements on rubber seed yields over time, for different varieties and ages of rubber trees. Fresh rubber seed were also harvested from plantations in Vietnam by collection within one day of dropping. These were frozen and bulked together. Sub samples of these were assessed for proximate chemical composition and amino acid content. Then larger samples underwent a number of treatments using heat, pressure, washing and sun drying following which they were chemical analysed for presence of residual hydrogen cyanide (HCN).

Table 7.3 Area (ha) of rubber tree production and the state /private ownership levels in Viet Nam for 2003-2005.

Year	Whole country	In which,			
		State	Percent (%)	Private	Percent (%)
2003	440.800	218.323	49.53	222.477	50.47
2004	450.900	219.935	48.78	230.965	51.22
2005	465.000	226.503	48.71	238.497	51.29

Source: Viet Nam General Rubber Corporation

Table 7.4 Area (ha) of rubber tree production in various provinces of Vietnam for period 2003-2005.

Province	2003	2004	2005
	Southern east regions		
Binh Duong	100,125	102,574	104,200
Binh Phuoc	-	-	53,263
Dong Nai	-	-	36,334
Tay Ninh	33,030	36,214	40,000
Ba ria	-	-	8,523
Binh Thuan	-	-	3,070
Sub total 1			**245,390**
	Highlands regions		
Gia Lai	57,307	56,177	59,348
Kon tum	16,583	17,934	19,834
Sub total 2	**73,890**	**14,111**	**79,182**
	Southern Central regions		
Quang Ngai	1,280	1,471	1,972
Phu Yen	868	1,142	1,542
Sub total 3	**2,148**	**2,613**	**3,514**
	Northern Central regions		
Ha Tinh	**5,575**	**3,780**	**4,095**
Other Provinces	**-**	**-**	**132,819**
Total			**465.000**

Source: *Viet Nam General Rubber Corporation*

Table 7.5 Rubber production survey results for plantation farms and householder concerns

Parameters		Unit	Plantation	Household
Number			6	50
Rubber production area	**Average**	ha	2015±317	14.8±23.4
	Min		1635	2.5
	Max		2540	115.0
Rubber area		ha	12.090	740
Rubber tree age	1-6 years	%	2.20	8.39
	7-16 years		36.30	83.91
	15-25 years		61.50	7.70
Density		tree/ha	550	400-600
Variety	GT1	%	15.25	2.45
	RRIM 600		30.42	46.25
	PB 235		17.45	22.14
	VM 515		34.48	28.61
	Other *		2.40	0.55
Latex yield from trees	7-10 year old	kg/ha/year	755 ± 25	788 ± 16
	11-15 year old		1425 ± 112	1384 ± 116
	16-25 year old		1672 ± 95	1520 ± 125
Latex price		vnd /kg	9500	9500
Number of working month		month/year	10	10
Currently collecting rubber seed			0	2

* (RRIV4; PB 260…)

Table 7.6 Survey data from 3 agents and 10 collectors in Binh Phuoc, Binh Thuan and Dong Nai provinces on current rubber seed collection

Parameters		*Unit*	*Response*
Time of seed falling		months	July-Nov
Peak month		month	Sept
Seed collecting interval		days	2.0±1.0
Seed collection estimates		kg/day/head	
	Beginning of season		5.0±1.5
	Middle of season		25.0±2.7
	End of season		7.0±1.8
Estimation of seed yield		kg /ha	Unknown
Buyer		-	Collector
Seed price		$VND/kg	600±50
Time period of storage seed before sale		day	7.0±2.0
Seed quality evaluation			Light-brownish, new seed, white kernel, black stripe along cover, no germination in seed
Germination after falling		day	7.0±1.0

Table 7.7 Questionnaire responses on aspects of rubber seed processing

Parameters		Unit	Result
Number		enterprise	5
N^0 of month production in year		month	2.5±0.5
Yield		ton/year	15.0±2.5
Storage time before processing		month	2.5±0.5
Storage condition	Packing	type	Sack bag, polymer bag
	Warehouse	type	Cement with roof
	Temperature	^{0}C	At ambient
	Humidity	%	At ambient
	Lost rate	%	25.0±5.0
Processing	Machine	-	Industry
	Processing method	-	Press machine
	Input ingredient	-	Rubber seed with coat
	Press temperature	^{0}C	120
	Press time	minute	5
Products	Rubber oil (main product)	%	20.0±2.5
	Rubber seed meal (extra product)		65.0±5.0
	Lost rate		15.0±3.0
Price	Rubber seed with coat	$VND/kg	1,000 ±200
	Rubber oil		8,000±1000
	Rubber seed meal		800±200
Use of	Rubber oil	-	Paint; soap production
	Rubber seed meal	-	Animal feed, fertilizer

Table 7.8 Rubber seed weekly yield evaluation over time (kg/ha) based on seed drop assessment

Week	Month	Rubber seed yield (kg)			
		Rubber tree of 15 year old		Rubber tree of 20 year old	
		GT 1 variety	RIM600 variety	GT 1 variety	RIM600 variety
1	Aug	0	0	4.2 ± 0.42	0
2	A	5.0 ± 1.6	0	15.7 ± 1.68	8.1 ± 2.56
3	A	12.3 ± 2.05	3.2 ± 0.14	17.6 ± 2.69	8.6 ± 1.84
4	A	15.7 ± 1.20	7.1 ± 2.05	19.8 ± 1.41	12 ± 0.57
5	S	25.5 ± 1.84	16.0 ± 0.83	22.9 ± 1.82	17.2 ± 0.91
6	S	21.8 ± 2.26	14.8 ± 1.98	24.0 ± 5.66	20 ± 0.28
7	S	20.2 ± 1.56	22.8 ± 1.56	21.3 ± 2.33	21.3 ± 6.15
8	S	50.8 ± 3.01	42.0 ± 6.66	52.0 ± 7.20	29.6 ± 4.20
9	O	46.1 ± 2.05	39.3 ± 2.33	51.1 ± 2.05	41.9 ± 3.61
10	O	50.0 ± 4.42	45.3 ± 0.49	45 .0± 1.27	49.1 ± 1.48
11	O	47.4 ± 4.46	39.2 ± 1.76	43.9 ± 0.35	52.4 ± 1.15
12	O	36.2 ± 3.54	28.0 ± 1.98	32.7 ± 1.06	31.5 ± 0.64
13	N	23.6 ± 0.71	23.9 ± 4.74	22.0 ± 1.84	22.9 ± 1.20
14	N	24.3 ± 4.45	26.0 ± 3.15	15.4 ± 1.80	17.9 ± 3.36
15	N	7.4 ± 1.98	12.8 ± 0.57	11.8 ± 0.28	13.2 ± 4.1
16	N	1.6 ± 0.92	10.6 ± 1.37	5.4 ± 0.56	10.5 ± 2.36
Total		**387.9**	**332.8**	**404.8**	**357.7**

Table 7.9 Rubber tree density (trees /ha) based on age of tree together with ground level visual assessment of fruit density.

Rubber tree Age Classification	Density (trees/ha)	Ground level visual assessment					
		Tree without fruit		Trees with little fruit		Trees with many fruit	
		No. trees	%	No. trees	%	No. trees	%
12 year	406	264	65.03	123	30.30	19	4.68
18 year	391	234	59.85	133	34.02	24	6.14
22 year	361	169	46.81	172	47.65	20	5.54
Average	386	222.3	57.23	142.6	37.32	21.0	5.45

Table 7.10 Number of fruits, seeds and the seed yield (kg) per tree based on cut-tree method for rubber trees visually assessed as having many or little fruit.

Sample	Age of tree	Trees with many fruit			Trees with little fruit		
		Fruit/tree	Seed/tree	Kg seed /tree	Fruit/tree	Seed/tree	Kg seed /tree
1	12	632	1896	6.47	115	345	1.18
2	12	930	2796	9.54	264	792	2.70
3	18	409	1227	4.19	306	918	3.13
4	18	455	1365	4.66	265	795	2.71
5	22	860	2580	8.81	187	561	1.91
6	22	620	1860	6.35	231	693	2.37
Average		651.33	1954	6.67	228	684	2.33

Table 7.11 Estimated rubber seed yield (kg/ha) for various age classes of rubber trees*

Rubber tree Age Class	Area	Trees with little fruit	Trees with many fruit	Seed yield kg seed /ha
12 year	1ha	123	19	413.85
18 year	1ha	133	24	470.54
22 year	1ha	172	20	534.91
Average	1ha	142.67	21	473.10

- Composite estimate based on data from Table 9 & 10 (Liem et al., 2002)

In Vietnam a substantial area of rubber trees is grown which is mainly located in the South-Eastern regions accounting for 52.77% of the total planted area, with the highland regions having 17.03% and remainder spread throughout the Southern central and Northern central regions. Rubber latex collection occurs for 10 months of the year, will rubber seed oil processing plants operate for 2.5 months per year, from October to December. Currently little rubber seed harvesting is occurring and what is tends to be spontaneous and is mostly carried out by children in spare time after schooling. Based on two separate methods of derivation the average yield of rubber seed was about 370-412 kg/ha and it can vary as a result of variety and age of rubber trees, weather conditions and time of latex production. Using this value for yield with the total planted area of rubber trees. The potential harvested yield of rubber seeds in Vietnam with planted area of 700,000ha (as of 2008) would be ~ 280,000 metric tons which could yield ~140,000 metric tons of rubber seed meal which would have major impact on animal diet costs being a replacement for expensive imported feed.

Chemical composition studies on various rubber seed types (table 7.12 and 7.13) have shown that the degree of rubber seed processing can have substantial impact on the nutritive value of the rubber seed aside from any residual HCN level. This processing can be as little as prolonged storage at ambient temperature which will lower the moisture content so that the relative level of protein and fat levels appear to increase

Table 7.12 Vietnam chemical composition comparison between fresh and old whole rubber seed, decorticated kernel, rubber seed meal and rubber seed coat.

Parameter	Kernel	kernel	Whole seed	Whole seed	Meal with coat	Coat
Coat	decorticated	decorticated	corticated	Corticated		
Period of storage	5d	240d	5d	240d		
N	2	2	2	2	2	2
DM	61	89.9	64.5	91.4	91.5	87.2
Ash	4.23	3.39	2.08	1.93	3.22	0.78
Protein	20.84	20.11	14.76	13.24	16.99	2.66
Fat	43.52	46.16	36.67	34.46	10.11	0.65
Fibre	10.16	9.73	38.14	35.67	30.22	75.34
Ca	0.45	0.55	0.31	0.28	0.38	0.01
P	0.13	0.13	0.09	0.10	0.16	0.08

Table 7-13 Rubber seed categorisation based on summary of Australian proximate chemical compositional studies and comparison to soybean meal

Parameter	Rubber seed						soybean
coat	hulled			partial dehulled	dehulled		dehulled
Fat level	full fat	part fat	defatted	Partial defatted	full fat	Partial defatted	defatted
N=	3	1	2	3	9	3	2
DM	93.0	88.8	93.0	94.6	81.1*	76.7*	90.1
Ash	1.8	3.9	3.3	3.3	3.3	5.4	7.0
Nitrogen	2.0	3.4	2.4	3.7	3.6	4.7	8.4
Protein	12.7	21.4	15.2	22.9	22.6	29.3	52.3
Ether Extract	27.7	13.0	9.3	23.6	34.3	16.5	1.3
Crude Fibre	34.4	39.5	37.1	16.6	5.2	5.4	4.2
NDF	25.9	39.9	37.8	19.2	8.8	9.5	5.9
ADF	44.3	53.5	49.9	24.8	8.5	11.5	8.9
GE	25.4	22.3	21.7	24.3	28.9	24.6	19.5
Calcium	0.0	<0.1	0.1	0.1	0.1	0.1	0.4
Phosphorus	0.2	0.4	0.3	0.4	0.5	0.6	0.6

* includes some fresh seed

Aside from this change, commercial processing of the seed i.e. both de-hulling (de-cortication) and fat extraction will significant affect the nutritive value of the seed. Most commercial processing of rubber seed is primarily for fat extraction with use of the oil for other industrial processes, hence the hull level is high and this elevated fibre content will affect its suitability for class of animal fed. Also higher fibre content acts a diluent reducing the concentration of other nutrients in the saleable product. More effective dehulling improves the nutrient concentration of both protein and energy of rubber seed. Such variability of rubber seed types means it will be critically important to have either some quality control over product labelling or rapid means for assessing likely nutritive content to ensure its effective use and for accurate formulation of animal diets. Table 7.14 gives a more detailed assessment of the nutrient composition of the IAS rubber seed meal, rubber seed kernels and the commercial rubber seed meal allowing a comparison to the USA and Argentina soybean meals types. From this it can be seen that rubber seed provides ~41% of the protein supply of soybean while only supplying 16% the lysine, in the case of methionine, tryptophan and threonine it only provides 40% of the amount that soybean can. Thus in diet formulation such nutrient shortfall need to be compensated for to ensure optimum growth response.

Table 7.14 Detailed nutrient composition and amino acids content of rubber seed, commercial rubber seed and IAS rubber seed compared to soybean meal (DM basis)

Parameter	Unit	Soybean meal Argentina	Soybean meal USA	Rubber seed kernel Dong Nai Full fat	Rubber seed kernel Dong Nai Full fat	Rubber seed meal IAS	COM rubber seed meal Tay Ninh mill	COM rubber Seed meal HCM oil mill 1
DM	%	90.1	90.1	86.6	89.1	95.4	93.6	94.3
Ash	%	7.8	6.2	3.2	3.0	2.9	3	4.1
Nitrogen	%	8.38	8.37	4.04	3.24	3.48	2.31	4.02
Protein (N x 5.7)	%	52.38	52.31	25.25	20.25	21.75	14.44	25.13
Fat	%	1.4	1.2	45.6	49.1	27.3	10.5	17.2
Crude Fibre	%	5.9	2.4	7.9	6.8	15.1	37	19.1
ADF	%	8	3.8	24.4	6.8	17.7	38.3	23.3
NDF	%	11.6	6.2	9.5	6.5	23.2	50.1	27.3
Amylose	%		1.3	-	-	7.4		5.0
Amylopectin	%		0.3			1.6		1.9
Starch	%	1	1.6	7.6	7.3	9.0	4.6	6.9
GE	MJ/kg	19.4	19.62	30.26	30.06	25.00	21.98	22.73
Calcium	%	0.55	0.34	0.1	<0.1	0.14	0.11	0.14
Phosphorus	%	0.55	0.65	0.52	0.45	0.29	0.32	0.49
Acid Insoluble ash	%		0.4			0.5		0.5
Aspartic Acid	g/kg	58.9	57.48	12.71	11.68	15.87	12.71	17.16
Threonine	g/kg	20.07	20.09	6.62	6.40	6.65	4.21	6.81
Serine	g/kg	25.71	25.13	8.50	8.53	9.01	5.5	8.99
Glutamic Acid	g/kg	94.67	90.76	19.29	18.39	24.22	17.56	25.61
Proline	g/kg	27.38	26.11	7.69	7.99	8.30	5.7	9.32
Glycine	g/kg	21.72	21.04	7.82	7.89	8.47	5.13	8.41
Alanine	g/kg	22.36	21.90	7.25	7.08	8.97	6.2	9.24
Valine	g/kg	23.13	22.52	11.83	11.76	12.90	7.85	12.42
isoLeucine	g/kg	23.16	22.81	5.58	5.54	6.34	3.95	6.21
Leucine	g/kg	38.53	38.27	10.70	10.65	12.28	7.71	12.20
Tyrosine	g/kg	17.47	17.02	5.33	5.47	4.35	2.31	4.51
Phenylalanine	g/kg	25.68	25.58	7.78	7.97	8.02	4.92	7.83
Lysine	g/kg	30.86	30.63	4.31	4.00	4.81	3.73	5.36
Histidine	g/kg	13.2	12.95	4.29	4.42	4.06	2.47	4.16
Arginine	g/kg	39.39	38.94	22.55	22.57	20.11	12.09	20.41
Tryptophan	g/kg	6.45	7.11	2.79	2.64	2.32	1.38	2.66
Cystine	g/kg	7.42	8.05	3.40	3.43	3.71	2.32	3.93
Methionine	g/kg	7.36	7.86	2.55	2.42	2.99	1.67	2.91
Total amino acids	g/kg	503.46	494.25	151.00	148.84	163.38	107.41	168.12
Amino acids: protein	%	0.961	0.944	0.60	0.74	0.75	0.74	0.67

Table 7.15 gives the detailed nutrient composition and amino acid content of stylo forage at various cutting stages. This shows that dry early cut stylo leaf has higher protein, starch, lysine and fat content than late cut material which has lower protein, lower level of animal important amino acids and higher crude fibre, ADF and NDF due it having a more woody late growth.

Table 7.15 Detailed nutrient composition and amino acid content of various harvest cuts of Stylo compared to sorghum grain (DM basis)

Parameter	Unit	sorghum	early cut stylo	recut stylo	late cut stylo
Timing of cut			12wk*	6wk post 1st cut	18wk
Dry Matter	%	88.5	90.2	89.9	90.7
Ash	%	1.5	7.6	8.3	7.7
Nitrogen	%	1.78	3.41	3.60	3.11
Protein (N x 6.25)	%	11.13	21.31	22.50	19.44
Fat	%	3.8	2.2	1.9	1.7
Crude Fibre	%	1.2	12.4	18.0	21.3
Acid Detergent Fibre	%	5.9	25.6	29.6	34.5
Neutral Detergent Fibre	%	3.5	16.9	22.1	26.8
Starch	%	70.5	9.8	2.5	3.0
GE	MJ/kg	18.79	18.55	18.6	18.53
Calcium	%	<0.1	1.05	1.19	1.18
Phosphorus	%	0.33	0.21	0.23	0.2
Aspartic Acid	g/kg	7.28	19.89	22.13	21.30
Threonine	g/kg	3.44	8.53	8.40	7.49
Serine	g/kg	4.81	8.48	8.69	7.66
Glutamic Acid	g/kg	23.40	20.89	19.99	18.16
Proline	g/kg	8.73	9.67	10.83	9.62
Glycine	g/kg	3.39	9.81	9.68	8.71
Alanine	g/kg	9.74	10.73	10.25	9.33
Valine	g/kg	5.08	9.90	9.86	8.81
isoLeucine	g/kg	4.05	8.42	8.35	7.32
Leucine	g/kg	13.78	15.44	15.12	13.40
Tyrosine	g/kg	4.15	6.74	6.49	5.72
Phenylalanine	g/kg	5.17	9.92	9.79	8.80
Lysine	g/kg	2.34	10.54	10.40	9.45
Histidine	g/kg	2.48	4.59	4.54	4.11
Arginine	g/kg	4.98	12.31	11.62	10.37
Tryptophan	g/kg	1.38	3.23	3.38	2.82
Cystine	g/kg	2.17	2.71	2.69	1.93
Methionine	g/kg	1.82	4.73	4.01	3.07
Total Amino acids	g/kg	108.19	158.06	176.53	176.22

* Stylo was cut at 12wk (normally cut at 6wk) due to extended period of slow initial growth due to weather at Walkamin

Objective 2: Treatment- Development of methods to overcome anti-nutrient factors appropriate for Vietnamese circumstances.

Repeated analyses have shown that HCN in rubber seeds slowly declines with storage at ambient temperature to less than 50% of the initial level after 150 days. It was also observed that the there was an accompanying substantial loss of water from the seed over time. Unfortunately this natural decline in HCN cannot be utilised to make the rubber seed suitable for animal feeding as the high initial moisture content means the rubber seeds are highly susceptible to mould growth. One particular batch of rubber seed from Vietnam which had been delayed due to Australian customs provided a dramatic example of this. When seed initially examined they appear on the surface to be visually fine but then when they were halved and examined over 30% needed to be discarded due to mould growth. This inherent mould contamination problem with prolonged storage then presents its own risk when the seeds are processed for animal use, as currently no information is available on the presence of any mycotoxins with this mould presence. Another issue of importance noted is that fact that rubber seed material can be highly variable, we detected lower HCN for supposedly freshly dropped seed, but following detailed examination it was revealed that these were not harvested fresh and contained older seed (exhibiting mould infection).

Initial processing studies focused on the use of a traditional method of cyanide reduction used with cassava i.e. sun-drying. We observed that the presence of the rubber seed hull limited the reducing effect of sun-drying on the cyanide content, with only the decorticated seed showing any decline in cyanide with sun-drying, to about 16% of initial HCN level. The removal of the hull prior to HCN reduction processes would appear to be one way to enhance cyanide reduction responses. Sun-drying did not reduce more than 50% of the HCN unless there was an additional pre-processing procedure employed, causing maximum cellular rupture allowing full contact between the cyanide containing compounds and the endogenous HCN releasing enzymes present in the seed.

Heat processing studies have shown that a number of high temperature processing methods, which utilised either wet or dry heat for period between 10-35 minutes, on both decorticated seed and un-decorticated rubber seed failed to significantly reduce the cyanide content of the rubber seed. This is not surprising as most HCN reduction procedure rely on the release of cyanide from within the cell by endogenous enzymes. Excessive heat application has the problem that it causes denaturation of these endogenous enzymes so that they no longer are functional and the cyanide remains in compounds within the cells. Our studies showed although that the boiling treatment caused a lowering of the residual cyanide in the decorticated rubber seed but we believe that this could an artefact resulting from the leaching of HCN from the kernel into the boiling water, especially as the oven-drying of both new and old rubber seeds at 120^{o}C or at 110^{o}C was ineffective at reducing the rubber seed kernel HCN content.

Preliminary results using combinations of treatments in lab scale studies showed that if seeds were first either homogenised with water or crushed to extract the oil and moisture followed by sun drying then the cyanide content declined significantly with increased time in the sun. It was observed that after the water wash and 1 d sun-drying there was a significant reduction in HCN in chopped seeds, whereas after 1 d sun-drying there was only a lesser reduction in crushed seeds without the wash step. The greatest reduction of cyanide in rubber seed was achieved in seeds that were initially decorticated then crushed to remove oil and water followed by a homogenisation (wash) in water with a period of 2-5 d of sun-drying to yield a dry meal product with almost complete elimination of the HCN content. Studies with water immersion together with steaming suggest that they may also be effective for reducing HCN level in seed.

However the preference for use of the water homogenisation and sun-drying procedure was based on the fact that it resembles the processing and equipment types currently used in cassava starch extraction and hence cassava residue production, also it is more suited to bulk processing volumes and is a lower energy input system with it use of solar radiation.

Following consultation with collaborators in Vietnam, both equipment and processing protocol were designed to enable an industrial processing of bulk quantities to achieve similar HCN reduction. This equipment has now been manufactured and can be used to process larger lots of rubber seed to yield sufficient quantity for further in vivo studies. A part of this was used in the production of the IAS rubber seed used in the growth and digestibility studies below.

Table 7.16 Summary table of HCN reduction by various treatments employed with rubber seed.

Rubber seed HCN reduction treatments examined	**% reduction of HCN level**		**% reduction of HCN level**
	Fresh		Old
	decorticated	With hull	decorticated
Storage at ambient temperature up to 150d	54%	-	-
Sun drying for 3-7d	72-83%	23%	47%
Boiling for up to 35minutes	66%	0%	66%
1hr immersion plus steaming	60%		86%
14hr immersion plus steaming	97%		81%
Oven drying at 110°C for up to 20 minutes	27%		0%
Oven drying at 120°C for up to 20 minutes	16%		0%
Oil extraction	54%		
Oil extraction and 5d sun-dry	71.2%	38%	-
Milling, oil extraction, homogenisation and 5d sundry	98%		
Mill, homogenisation and 5d sun-dry	98%	82%	-
Milling, 1:5 water homogenisation and 5d sun-dry	94%	82%	94-97%
Milling, 1:1.5 water homogenisation with temp effect	~95%		
Milling, 1:10 water homogenisation and 5d sun-dry	99%		95%
Milling, with variable water ratio and 5d sun-drying	97-99%		
Short post-grind storage and 60oC dry	-		42-60%
1 week storage, grind and dry	-		70-77%
2 week storage, grind and dry	-		72-78%
Soaking and temperature	50-68%		
3d water soaking and oven dry	99%		
7d ensilage	95%		

In the case of cassava residue, previous studies on HCN levels from survey sample collected revealed that HCN level were low and that further reduction of HCN was not warranted hence no further processing studies were conducted.

Figure 7.1a Various water soaking treatments of rubber seed kernels

Fig 7.1b Rubber seed kernel water soaking 0d

Fig 7.1c Rubber seed kernel water soaking 2d

Figure 7.1d Sun dried rubber seed kernels post water soaking

Objective 3: Feed value - In vivo assessment of the nutrient value (digestibility and amino acid availability) of local protein and energy sources post-treatment

Pig digestibility studies provide valuable information on the nutritional value of feed crops and by-products and they also can provide indication on the levels at which they can be effectively and safety used.

Cassava residue energy digestibility assessment

The digestibility of nutrients of the experimental diet (containing tested ingredient: dry cassava residue) tended to be lower than those of basal diet (from 1 to 4.4%). This difference in digestibility between these two diets was used to determine digestibility of cassava residue based on difference. The faecal digestible energy content of cassava residue was found to be relatively high and that this was due a large proportion of the starch present in cassava root still remaining even after processing, confirming inefficiencies in extraction process for cassava starch production. Digestible energy value of cassava residue of the present study of 11.06-11.5 MJ/kg (2644-2749 Kcal/kg) was much higher than that determined by regression equation method of Kinh (2003), which yielded 8.39 MJ/kg (2006 kcal/kg). Previous studies (Wu, 1991) have shown cassava meal to have high digestibility and energy value with the gross energy being 16.91 MJ/kg with a DE of 14.99 MJ/kg (DM basis). In early studies with maize and ground nut diets Sonaiya and Omole (1977) found no consistent effect on energy digestibility with increasing inclusion of cassava peel. It was seen that as cassava peel level increased from 0 to 10%, energy digestibility declined but this lowering in digestibility did not follow through for the 15% cassava peel diet, this inconsistency may have been due in part to the energy contribution from the other dietary components which were used in formulating that diet which was also used for a growth assessment.

They observed no effect of the increasing levels of inclusion of cassava peel on diet dry matter digestibility values. Obioha and Anikwe (1982) observed that for cassava peel which was sun-dried, that the dry matter digestibility of diets declined significantly with 21.8 and 43.6% inclusion of cassava peel. While the digestible energy intake was only significantly lower in the 43.6% cassava peel inclusion diet. Tewe and Pessu (1982) and Iyayi (1994) observed in diets with 40% cassava peel replacement of maize that the apparent digestibility coefficients of protein, fibre, organic matter and energy were similar to the maize basal diet.

Both the total faecal collection and the marker method employed here for determining digestible energy and digestibility of organic matter and nutrients of cassava residue provided similar results. The lower digestibility value of the experimental diet that we observed with the addition of cassava residue indicates that cassava residue reduced the digestibility of the basal diet. We also observed that the digestible energy, digestibility coefficients of crude protein, crude fat of cassava residue determined in the trial were quite high. While the digestibility coefficient of crude fibre determined in the present study was much lower than these other nutrients. This suggests that the high fibre in cassava residue is the main factor limiting the digestion and absorption of nutrients by the animal. This is in agreement with other studies showing that in the young pig that fibre digestibility is undeveloped. Other studies have also suggested that gastro-intestinal juice of pigs do not contain endogenous enzymes which can hydrolyse non-starch polysaccharides (NSP) and lignin components of the cell wall (Gene and Partridge, 2002).

Rubber seed energy digestibility assessment

A comparative in vivo digestibility trial on the IAS processed rubber seed, soybean and commercially available Vietnamese rubber seed was conducted in Vietnam using project manufactured digestibility crates (based on the Australian design) see below. The trial conducted over 21 days evaluated the digestible energy and amino acid value of a number of diets with various treated rubber seed meals.

Figure 7.2 Rubber seed digestibility study underway in Vietnam

Table 7.17 Interim results on the apparent digestibility of dry matter, energy, of experimental rubber seed diets as determined by total collection

Parameter	Units	Diet 1	Diet 2	Diet 3	Diet 4
		Cassava basal	Cassava US soybean meal	Cassava IAS rubber seed meal	Cassava Commercial rubber seed meal
	DM basis	CBASAL	CUSASBM	CIASRSM	CCOMRSM
Dry Matter digestibility		0.788	0.8424	0.774	0.777
Digestible Energy	MJ/kg DM	14.40	15.43	14.77	14.10
Digestible Energy	MJ/kg As Is	12.69	13.84	13.60	12.76
Energy digestibility		0.880	0.893	0.792	0.785

It was found that the diet with normal commercial rubber seed meal had a lower total digestibility of dry matter, and energy compared with the new IAS rubber seed meal and a soybean diet. The digestibility of dry matter and energy of the basal cassava chips diet and a soybean diet were similar and higher than the two rubber seed meals.

Amino acid availability indicators

Table 7.18 Interim preliminary results on the apparent ileal digestibility coefficients of amino acids of experimental rubber seed diets using titanium marker

Amino acid	DIET1	DIET 2	DIET 3	DIET 4
	Cassava basal	Cassava US soybean meal	Cassava IAS rubber seed meal	Cassava Commercial rubber seed meal
	CBASAL	CUSASBM	CIASRSM	CCOMRSM
Threonine	0.75	0.91	0.70	0.76
Serine	0.53	0.94	0.81	0.82
Glutamic Acid	0.64	0.95	0.88	0.87
isoLeucine	0.71	0.90	0.73	0.73
Leucine	1.13	0.91	0.79	0.79
Tyrosine	0.80	0.91	0.71	0.81
Phenylalanine	0.89	0.91	0.76	0.78
Lysine	0.25	0.98	0.83	0.84
Tryptophan	0.18	0.94	0.77	0.80
Cystine	0.19	0.89	0.72	0.81

Digesta sample for the rubber seed trial have undergone initial amino acid analyses in Australia with calculation of ileal amino acid digestibility values. Very preliminary summarised results are given above but these still require rechecking and validation of marker values used in their derivation.

Sunflower digestibility

Research has examined the digestible energy content of a number of sunflower meal types available in Australia and identified major differences in their energy value based on processing, additionally, amino acid analysis has shown a significantly lower lysine content than previous reported. Further results will examine these apparent changes in more detail and assess the impact of such nutritive changes on the value of this feed in pig diet formulations.

Table 7.19 Nutritive and digestible energy content of various sunflower meals compared to sorghum

	Ingredient content (DM basis)					
Sunflower Type	DM	Protein	Fibre	Fat	GE	(As fed basis) DE *
	%	%	%	%	MJ/kg	MJ/kg
Mono unsaturated expeller meal	93.5	32.6	21.7	14.9	22.5	12.1[b]
Mono unsaturated solvent meal	90.0	36.3	22.9	1.9	20.0	9.0[c]
Poly unsaturated solvent meal	90.1	37.0	24.2	1.8	19.9	9.6[c]
Sorghum	89.3	10.4	2.4	3.6	18.7	14.7[a]
SEM	-	-	-	-	-	0.47

Stylo digestibility

The chemical analysis results of various stylo cuts showed that the early cut stylo has a higher starch content and lower fibre fraction content than observed in late and recut stylo which were allowed to grow longer.

Table 7.20 The apparent digestibility of dry matter, energy, nitrogen, and nitrogen retention of experimental diets as assessed with CTTD.

	Units	Diet 1 Basal sorghum	Diet 3 Sorghum & 25%Early cut stylo	Diet 4 Sorghum & 25% Recut stylo	Diet 2 Sorghum & 23% Late cut stylo	LSD (P=0.05)
Dry Matter digestibility		0.87a	0.79c	0.73d	0.75b	0.017
Gross energy	MJ/kg DM	18.35	18.26	18.3	18.34	-
Digestible Energy	MJ/kg DM	16.1a	14.2b	13.2d	13.7c	0.37
Digestible Energy	MJ/kg As Is	14.6a	13.0b	12.1d	12.5c	0.34
Energy digestibility		0.88a	0.78b	0.72d	0.74c	0.02
Metabolisable Energy	MJ/kg DM	15.8a	13.9b	12.8d	13.3c	0.38
Intake Nitrogen	g/d	30.6b	35.5a	35.9a	34.1a	1.95
Faeces Nitrogen	g/d	6.8c	9.6b	11.7a	10.5ab	1.62
Urinary Nitrogen	g/d	5.5	5.4	6.0	5.4	1.68
Total N excreted	g/d	12.3b	15.1ab	17.7a	15.9a	2.84
Nitrogen digested	g/d	23.8b	25.9a	24.2b	23.6b	1.44
Nitrogen retained	g/d	18.3	20.5	18.2	18.2	2.13
Nitrogen retention[A]		0.77	0.79	0.75	0.77	0.069
Nitrogen digestibility[B]		0.78a	0.73b	0.67c	0.69bc	0.041

[A]Nitrogen retained as a proportion of nitrogen digested
[B]Nitrogen digested as a proportion of nitrogen intake
Means within a row followed by a different superscript letter are significantly different at P=0.05

As a result, the faecal digestible energy content was higher for the early cut stylo than for the subsequent cut stylo material which had been allowed to become woody, as indicated by the higher NDF and ADF content. The overall energy digestibility coefficient of the diet was observed to be less for the different stylo cuts (0.72-0.77) compared to the basal sorghum diet (0.88). The nitrogen data indicates that stylo inclusion provided a higher overall nitrogen intake and also an increased faecal nitrogen excretion only in the case of the early cut stylo did the results show an increase in nitrogen retained by pigs.

Overall nitrogen digestibility of diets was reduced with increasing fibre levels of the stylo, although the overall nitrogen retention was less affected. The results have shown that feeding of stylo meal does provide some nutritive value to the pig with increased energy and nitrogen supply, with a portion of the nitrogen presented in a form which the pig is able to retain. Work was also carried out to see what occurs at the ileum with regard to energy and amino acids to better gauge the true benefit to the pig from nutrients in stylo.

Table 7.21 Preliminary results of apparent ileal and faecal digestibility coefficients of dry matter, energy, nitrogen, and nitrogen retention of stylo experimental diets as assessed with Titanium.

	Units	Diet 1 Basal sorghum	Diet 3 Sorghum & 25%Early cut stylo	Diet 4 Sorghum & 25% Recut stylo	Diet 2 Sorghum & 23% Late cut stylo
Dry Matter digestibility	ileal	0.72	0.49	0.45	0.50
	faecal	0.87	0.76	0.70	0.71
Organic Matter digestibility	ileal	0.74	0.53	0.49	0.53
	faecal	0.88	0.79	0.73	0.74
Nitrogen digestibility	ileal	0.77	0.45	0.44	0.53
	faecal	0.78	0.70	0.64	0.64
Starch digestibility	ileal				
	Faecal	0.99	0.97	0.94	0.97
Energy digestibility	ileal	0.72	0.52	0.48	0.53
	faecal	0.88	0.75	0.69	0.63

Objective 4: Inclusion- Performance testing (growth, carcass quality, economics) of diets containing local protein and energy sources.

Cassava residue

The pig performance results for cassava residue inclusion levels in diets of 0; 10; 15; 20% for the growing period and 0; 15; 25; 35% inclusion for the finishing period showed that feeding cassava residue in diets at inclusion levels up to 10% and 15% for growing pigs (live weight 20-50 kg) and at 15% and 25% for finishing pigs (live weight 50–100kg) resulted in no adverse effects. Growth performance, feed efficiency and carcass quality were observed to be similar to the control at these inclusion levels for cassava residue.

Only at the highest level of cassava residue inclusion i.e. 20% for growers was performance affected (both ADG and FCR) and although the accompanying finisher period displayed no effect of the higher 35% cassava residue inclusion the carry over of the lower grower performance result in a significantly lower performance for this diet combination for the entire trial. Daily feed intake was not affected by the various levels of cassava residue inclusion.

This indicates that the performance effect was more a response to nutrient concentration in diet rather than any feed refusal or toxicity. Thus it is possible to replace wheat bran and corn in Vietnamese pig diets with cassava residue without any negative effect on performance but with the advantage that use of cassava residue will reduce the feeding cost per kg of weight gain. An assessment of feed cost per kg weight gain showed that treatment 3 (with a cassava residue inclusion rate of 15% for growers and 25% for finisher) was found to be the lowest, with a 300 VND (3.3%) significantly lower cost ($P<0.01$) compared to the control diet

Table 7.22 Grower performance of pigs fed various inclusions of cassava residue (CR) in corn, rice bran, wheat bran, soybean meal fishmeal based diets

Treatment group	Cassava residue inclusion level Grower phase	Average daily gain (kg/day)	Daily feed intake (kg/h.day)	Feed Conversion Ratio (feed:gain)
Diet 1 control	0% CR	578.5a	1.475	2.55a
Diet 2	10% CR	568.6ab	1.478	2.60a
Diet 3	15% CR	559.5b	1.467	2.62a
Diet 4	20% CR	533.3c	1.475	2.77b
l.s.d. (*P* = 0.05)		17.89	.0494	

Table 7.23 Finisher performance of pigs fed various inclusions of cassava residue in corn, rice bran, wheat bran, soybean meal fishmeal based diets

Treatment group	Cassava residue inclusion level Finisher phase	Average daily gain (kg/day)	Daily feed intake (kg/h.day)	Feed Conversion Ratio (feed:gain)
Diet 1 control	0% CR	773.1	2.420	3.13
Diet 2	15% CR	765.3	2.433	3.18
Diet 3	25% CR	776.8	2.424	3.12
Diet 4	35% CR	774.9	2.406	3.11
l.s.d. (*P* = 0.05)		19.00	0.0588	

Table 7.24 Carcass characteristics at slaughter of pigs fed various inclusion of cassava residue in grower and finisher phase.

Treatment	Live-weight kg	Empty body weight %	Carcass %	Lean %	Fat %	Bone %	Skin %	Backfat mm	Loin area cm^2
Diet 1 control	90.38	83.24	74.65	53.79	27.28c	14.36	4.43	15.38	50.16
Diet 2 10-15% CR	89.50	81.59	74.64	53.63	27.59bc	13.95	4.72	15.75	49.81
Diet 3 15-25% CR	89.62	82.69	73.71	52.87	28.02ab	15.40	3.58	14.88	49.45
Diet 4 20-35% CR	88.25	82.86	73.61	52.51	28.61a	13.86	4.86	16.12	49.58
l.s.d. (*P* =0.05)	1.855	1.843	1.845	1.458	0.633	1.198	1.694	1.352	1.793

Rubber seed

A pig growth trial was conducted using corn/rice bran/soybean meal diets with four inclusion levels of IAS rubber seed meal and two levels of defatted commercial rubber seed meal. Results showed that the FCR and ADG of pigs given the diet with the 10% inclusion of IAS-RSM were similar to those of the soybean meal control diet. With increasing inclusion levels of IAS-RSM to 20 and 30% in diets there was a small decrease of 1.54 and 4.26% in ADG and 0.81 and 1.23% in feed efficiency respectively. with the IAS-RSM, while, commercial rubber seed meal inclusions at higher levels of 20, 30% COM-RSM reduced feed efficiency by 15.23 and 17.15% and ADG by 10 and 20%, respectively.

The results indicate that the IAS RSM treatment protocol has successfully improved the feeding value of rubber seed in pig diets when compared to the normal commercially available RSM. In the cassava diet supplemented with 30% IAS-RSM the ADG was 5.38% lower than that observed in the control diet but this was much less than the 20% lower with 30% Com RSM. Comparative analysis ascertained that a some of the reduced performance at higher RSM inclusion were due to slight amino acid imbalances in the diets as a result of formulation of diets occurring prior to having accurate information on the initial RSM amino acid content and availability. Figure 7.3 below shows the grower pig ADG relationship to the analysed total lysine content of the formulated grower diets. Figure 7.4 shows the relationship between fibre and the ADG for grower pigs. The higher fibre and lower amino acid content were response for the significantly lower ADG observed with the COM RSM. Removal of the coat in the IAS rubber seed meal improved the performance of pigs with this rubber seed inclusion type. Grower pig performance in particular is vulnerable to the effect of higher fibre levels in diets reducing the useful energy concentration and these young pigs are unable to compensate for lower energy supply by increases in feed intake due to their limited gut capacity.

HCN assessment of the dietary ingredients and of the diets, indicate that performance responses were not related to this parameter as levels were low (only 0.3-3.37 mg/kg). The rubber seed HCN particularly for the IAS rubber seed meal was low at 1.5 mg/kg, while the COM rubber seed meal was higher at 28.1 mg/kg. When analysed after the trial, the cassava chips used in this study seemed to have elevated HCN levels (42.35 mg/kg).

Using the results of the current study together with some additional refinement of the diets based on knowledge gain from our pig growth studies, especially with regards to the impact of fibre we expect further fine-tuning of pig performance when using rubber seed based diets. This would lead to greater improvements in overall profitability. These results will provide valuable information on the nutritive value of this significant Vietnamese by-product and the optimum levels and applications at which it can be effectively, safely and most importantly, profitably used.

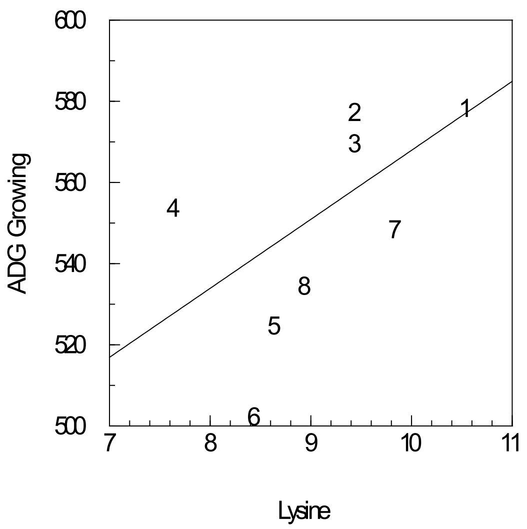

Figure 7.3 Relationship of grower ADG to analysed lysine content of grower diets
Diet 1= corn SBM, Diet 2= corn 10%IASRSM, Diet 3= corn 20%IASRSM, Diet 4= corn 30%IASRSM, Diet 5= corn 20%COMRSM, Diet 6= corn 30%COMRSM, Diet 7= cassava SBM, Diet 8= cassava 30%IASRSM

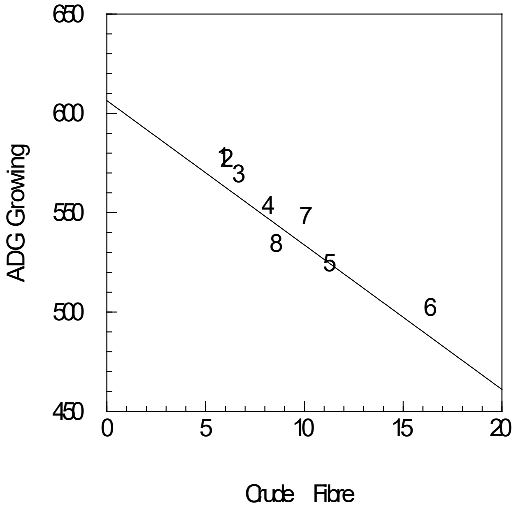

Figure 7.4 Relationship of Rubber seed growth trial grower ADG and total trial ADG to the crude fibre level of grower diets Diet 1= corn SBM, Diet 2= corn 10%IASRSM, Diet 3= corn 20%IASRSM, Diet 4= corn 30%IASRSM, Diet 5= corn 20%COMRSM, Diet 6= corn 30%COMRSM, Diet 7= cassava SBM, Diet 8= cassava 30%IASRSM

Groundnut meal

The groundnut inclusion levels in diets were 0, 10 and 15 for the growing and finishing periods. Table 7.25 and 7.26 results below show that feeding peanut meal in diets at inclusion levels of 10% and 15% for growing and finishing pigs resulted in reduced pig performance with lower ADG and poorer FCR although there was no significant effect on feed intake or carcass quality, which were observed to be similar to the control.

This suggests that the groundnut meals contain either a toxic component affecting pig growth or that it was short of a nutrient for optimum performance. The use of an aflatoxin binder in diets at 1% was beneficial in improving the performance of pigs given the two peanut meal inclusions levels, although it appears that only at 10% inclusion of peanut meal did the aflatoxin binder result in pig ADG and FCR similar to that observed in pigs fed the control soybean diet. Despite the poorer performance, these diets with peanut meal inclusions have significant economic advantages.

These results indicate that it is possible to replace soybean and rice bran in Vietnamese pig diets with 10 % peanut meal without any significant negative effect on performance, but with the advantage that this inclusion of peanut meal at only half the cost of a soybean meal will reduce the feeding cost per kg of weight gain.

Table7.25 Grower performance with various groundnut meal inclusions and with aflatoxin binder in corn, rice bran soybean meal based diets

Diet	Inclusion groundnut meal	Average daily gain (kg/day)	Daily Feed Intake (kg/h.day)	Feed Conversion Ratio (feed:gain)
Diet 1 control	SBM- 0% GNM	589.0a	1496	2.54a
Diet 2	10% GNM	560.6c	1494	2.67b
Diet 3	15% GNM	542.0dc	1507	2.78a
Diet 4	10% GNM +B	577.1ab	1484	2.57cd
Diet 5	15% GNM +B	566.2bc	1501	2.65bc
l.s.d. (*P* = 0.05)		15.91	35.75	0.079

Table 7.26 Finisher performance with various groundnut meal inclusions and with aflatoxin binder

Diet	Inclusion groundnut meal	Average daily gain (kg/day)	Daily Feed Intake (kg/h.day)	Feed Conversion Ratio (feed:gain)
Diet 1 control	SBM- 0% GNM	770.5a	2397	3.11 d.
Diet 2	10% GNM	744.0c	2391	3.21bc
Diet 3	15% GNM	723.2d	2402	3.32a
Diet 4	10% GNM +B	760.4b	2406	3.16cd
Diet 5	15% GNM +B	746.1c	2410	3.23b
l.s.d. (*P* = 0.05)		9.034	45.74	0.055

Auspig Sunflower

Our difficulty in obtaining test material from the suppliers in Australia together with the drought seriously impacted on this aspect of the project, so the pig growth studies were replaced with comprehensive Auspig simulations to predict the performance and economics of using these ingredients based on the new digestibility information that the project has collected. The industry-acknowledged accuracy of Auspig predictions means that this information will still be useful and valuable to industry.

Based on data in table 7.27 inclusion of 10% sunflower reduces finisher diet cost when Feedmania (FM), solvent mono and solvent poly sunflowers are used but the diet cost was higher with use of the expeller mono sunflower diet. In the case of dry sow diet formulations (table 7.28), costs increased with the use of the differentiated sunflower meals due to the need for additional synthetic amino acids to compensate for lower amino content of the sunflower meals obtained in this study.

Table 7 27 Impact on finisher diet costs of increased level of incorporation of the differentiated sunflower meal types into diets (with compensation for our determined changes in nutritive values) and a comparison to old Feedmania sunflower values

	Diet Cost ($) Sunflower Type			
Inclusion (%)	FM Sunflower	Expeller Mono	Solvent Mono	Solvent Poly
0	297 90	297.90	297.90	297.90
10	293.72	299.76	297.23	296.66
20	308.35	302.04	311.34	313.01
30	327.21	309.57	331.91	338.16

- FM sunflower is current Feedmania values for sunflower

- $330 /t value for sunflower meal
- Based on sorghum as the only grain and available at $205/ton
- Meat meal, soybean meat meal, minor components- typical Qld diet components
- Lower AA value of sunflowers evaluated
- Feed mania sunflower DE= 8.3 MJ/kg
- 10% is the typical sunflower inclusion level in Qld diets

Table 7.28 Impact on barley/sorghum dry sow diet costs of increased level of incorporation of the differentiated sunflower meal types into diets (with compensation for our determined changes in nutritive values) and a comparison to old Feedmania sunflower values).

	Diet Cost ($) Sunflower Type			
Inclusion (%)	FM Sunflower	Expeller Mono	Solvent Mono	Solvent Poly
0	292.63	292.63	292.63	292.63
10	292.25	299.65	293.59	295.32
20	296.79	307.83	295.89	299.98
30	324.87	316.28	320.28	320.27

- Cost without sunflower is $292.63
- FM sunflower is current Feedmania values for sunflower

Table 7.29 Auspig comparison of whole of life pig growth performance and financial returns when fed finisher diets from 98d (50kg) with 20% sunflower meal inclusion formulated with actual differentiated sunflower nutritive values replacing old Feedmania sunflower values (with no compensation for nutritive changes).

	Diet DE MJ	Diet Av Lysine %	Diet Lys/DE g/MJ	Live weight (kg)	ADG (g/d)	FCR	P2 (mm)	Profit ($)
FM Sunflower*	13.49	0.745	0.55	97.2	619	2.56	11.7	149.94
Expeller Mono	14.26	0.687	0.48	95.7	609	2.46	12.2	147.37
Solvent Mono	13.63	0.703	0.52	96.8	616	2.54	11.8	149.34
Solvent Poly	13.76	0.685	0.50	93.9	617	2.52	11.8	150.36

- FM sunflower is current Feedmania values for sunflower

The results in Table 7.29 show what would happen in diets formulated using current FM sunflower values at an inclusion level of 20% but if we replaced the FM sunflower in the diet with the differentiated sunflowers and did not correct for their changed nutritive values. In the case of the expeller mono sunflower diet, as it would contain higher energy and a lower lysine content, pigs would eat less and grow slower, with a higher P2 backfat, which under the current gradings would result in lower profit per pig. In the case of both the solvent mono and solvent poly sunflower the diets were slightly higher in DE and lower in available lysine with a corresponding lower diet lysine to DE than that of the FM sunflower. Hence pigs would have a lower finishing weight as a result of a lower ADG, but no major effect would be observed on profit as the slightly lower FCR observed would mean a lower feeding cost.

Auspig Stylo

Auspig simulations were used to assess the impact of stylo usage in finisher diet on overall pig growth performance. For this both a lower energy rice bran/barley diet and a higher energy barley based diet were examined using a poorer genotype of pig with *ad lib* feed intake and with feed intake limited to 2.2kg/d. This would provide useful information on the likely pig performance responses with feeding similar diets and under conditions of limited feeding.

Table 7.30 showed that as the inclusion of late cut stylo (LC stylo) increased in rice bran/barley diet the dietary DE slightly decreased resulting in a corresponding increase in the lysine to DE ratio, consequently there was a slight trend for pig ADG to increase up to 20% inclusion, while the P2 backfat was observed to slightly decline with increased stylo inclusion up to 30% inclusion. FCR was higher with increased inclusion of stylo as pig intakes would increase to compensate for lower dietary energy concentrations. With early cut stylo (EC stylo) a similar pattern would be observed.

The energy content of this EC stylo was higher than LC stylo, while lysine level was similar there would be a similar ADG pattern and P2 however FCR values would be lower with less feed eaten to meet the pigs requirement for energy. Table 7.30 also shows the performance effect of the same diet and stylo inclusion levels but with dietary feed intake limited to 2.2kg/d. This is a scenario more representative of situations of limited feed supply. In this case the reduced feed intake combined with the increases in stylo inclusion levels would result in lower overall ADG values than that observed with the *ad lib* scenario and would see the slight decline of ADG continuing even with 30% stylo inclusion with both the EC and LC stylo. P2 backfat level would decrease with each increase in stylo inclusion and be lower overall when compared to the *ad lib* scenario. FCR would be higher for each stylo inclusion level when compared to the *ad lib* scenario, but it would only change with increased inclusion levels for the LC stylo, mainly as a result of the lower energy content of the LC stylo diet compared to the EC stylo diet.

Table 7.30 The effect of increased stylo inclusion on pig growth (8-90kg) performance of a poorer genetics pig when fed a rice bran/barley based diet and the rice bran was replaced in the finisher diet with various inclusions of 10, 20 and 30% stylo meal without any changes or additions of other ingredients with a comparison between *ad lib* feeding and with feed restricted to 2.2kg/d.

	Diet nutritive values			*Ad lib* feeding			Restricted to 2.2kg/d		
	DE MJ	Av Lysine %	Lys/DE g/MJ	ADG (g/d)	P2 (mm)	FCR	ADG (g/d)	P2 (mm)	FCR
No stylo	10.99	0.525	0.477	474	15.6	2.92	463	15.3	2.97
LC stylo 10%	10.84	0.535	0.495	478	15.2	2.96	460	14.8	2.99
LC stylo 20%	10.69	0.549	0.513	482	14.9	3.01	456	14.3	3.02
LC stylo 30%	10.54	0.561	0.533	479	14.4	3.05	451	13.8	3.06
EC stylo 10%	10.97	0.535	0.487	478	15.2	2.94	463	14.8	2.97
EC stylo 20%	10.95	0.545	0.498	483	14.9	2.95	462	14.4	2.98
EC stylo 30%	10.93	0.555	0.508	479	14.4	2.97	460	14.0	2.99

- Rice bran $150/ton
- Barley $240/ton

In tables 7.31 the same stylo inclusion levels are examined for both the EC stylo and LC stylo, in poor genotype pigs but with a better quality barley based diet. Firstly it can be seen that both the DE content of these diets and available lysine were higher with corresponding higher lysine to energy ratios than the rice bran/barley diets evaluated above (table 7.30). As a result when this poor genotype pig is fed these diets, ADG and P2 backfat would be similar across both LC stylo and EC stylo no matter what inclusion level of stylo was used. The major change which would be seen would be in FCR which worsened with increased stylo inclusion level, and with the EC stylo FCR values being seen slightly lower than with the LC stylo.

This reflects the increase in feed intake by the pig which would be required to compensate for the lower energy concentration of the diets. Significantly the FCR values seen with this better quality diet are much lower than that observed in table 7.30, the values reflecting the energy content of the diets. As the energy level of this better quality diet was higher, then less feed would be required for each kg of gain whereas in table 7.30 the lower energy density of the diets meant that the pig would need to eat more feed to meet its energy needs, hence the higher FRC values.

Table 7.31 The effect of increased stylo inclusion on pig growth (20-90kg) performance of a poorer genetics pigs when fed a barley/meat meal based diet and when the barley was replaced in the finisher diet with various inclusions of 10, 20 and 30% stylo with comparison between *ad lib* feeding and with feed restricted to 2.2kg/d

	Diet nutritive values			*Ad lib* feeding			Restricted to 2.2kg/d		
	DE MJ	Av Lysine %	Lys/DE g/MJ	ADG (g/d)	P2 (mm)	FCR	ADG (g/d)	P2 (mm)	FCR
No stylo	13.00	0.630	0.484	475	14.6	2.61	481	14.3	2.85
LC stylo 10%	12.35	0.657	0.532	473	14.6	2.70	475	14.2	2.89
LC stylo 20%	11.69	0.684	0.585	474	14.7	2.81	465	14.0	2.96
LC stylo 30%	11.04	0.710	0.643	474	14.8	2.93	451	13.7	3.06
EC stylo 10%	12.48	0.655	0.525	473	14.6	2.68	476	14.2	2.88
EC stylo 20%	11.96	0.680	0.568	473	14.7	2.77	470	14.1	2.93
EC stylo 30%	11.43	0.704	0.616	474	14.7	2.86	460	13.9	2.99

Also in table 7.31 the effect of restricting intake of this better quality feed to 2.2kg/d can be seen. Both ADG and P2 backfat would be observed to decline with increased stylo inclusion, primarily as a result of decrease in dietary energy supply to the pig a result of declining diet energy content and a fixed feed intake level which prevents the animal from compensating for this lower energy content through eating more. FCR also worsens with increased stylo inclusion levels, but the change in FCR for each stylo increment for this restricted intake would be less then what was seen with *ad lib* feeding of the better quality diet. Overall the restriction of the feed intake to 2.2 kg/d results in worsening of FCR values compared to the FCR values of pigs which were fed the same diets *ad lib,* this being a reflection of feed waste/loss in the initial period of feeding.

Objective 5: Promotion-On-farm assessments and demonstration of performance using diets containing local protein and energy sources

A pig performance trial for rubber seed meal using both the IAS and the commercially available product were carried out under semi-commercial conditions with group-housed animal on a commercial farm with IAS staff overall supervision.

8 Impacts

8.1 Scientific impacts – now and in 5 years

Present

We are unaware of any specific identifiable changes in scientific practice outside the project. However, in scientific terms the project has generated:

- New and extensive data for a local feed composition database.
- Knowledge on processes and biochemistry for novel removal of toxins
- Knowledge and skills in nutritional digestive physiology and research conduct for staff who are using or plan to use the project's experimental designs, protocol and skills in PhD studies which have commenced outside of this project in Japan and Sweden.
- A focus shift from local journal publication to preparation of joint publications in international refereed journals

5 year future

- The project compositional data base will provide valuable information on optimum use of local non-traditional feeds in diet formulations for scientific studies and for their use commercially by feedmills.
- Project toxin removal and processing data will be an important guide for effective removal of toxin in the many other local feeds whose use is restricted by such issues, especially those which have cyanide concerns.
- International journal publication will give greater recognition to, and validity of, research undertake in Vietnam.

8.2 Capacity impacts – now and in 5 years

Knowledge and skills

The Vietnamese have gained practical skills in digestibility assessment using indigestible markers. This will enable them to better assess the true nutritive values for pigs of feed ingredients and to continue undertaking further nutritive studies for other feeds of particular relevance and importance in Vietnam. As a result of training provided, a number of the project staff members have gained skills which have enabled them to successfully gain additional local higher degree qualifications and for others to obtain approval and funding for further higher degree studies overseas.

Specific examples of this capacity building is seen in the following laboratory procedures:
Sample input and data management
Acid insoluble ash digestion and determination
Barium and titanium marker analysis both digestion process and measurement with UV and atomic absorption spectroscopy
Gross energy determination with Bomb calorimeter
Picric acid HCN determination
Acid digestible Fibre analysis using Fibrecap operation and principles
Residue DM determinations using classical method

Hardware

NIR

The NIR purchased as part of the project has now been transferred to Vietnam and will be available for further R& D work outside the original project. Thus the IAS team will be able to develop gradually over time, new calibrations for individual feed stuffs based on chemical analyses results of samples collected in Vietnam. In general this process of developing a calibration requires chemical data on each of over 50 individual specimens for each type of feed ingredient. Both data and sample produced by this current project and other project activities over the next few years will enable them to develop the calibration which then would enable them to provide almost real-time nutrient valuation on various untested feedstuffs. Flowing on from this research development the application of this technology into the commercial local feed milling sector would significantly improve ingredient quality assessment prior to diet formulation in Vietnam. This would follow the current developments in feed manufacture in more developed pig production areas. NIR enables improvement in diet formulation so that diet are matched to what the animal needs with the benefits of lowering costs by reducing over or under-specification and reducing wastage and potential effluent problems.

Figure 8.1 NIRS purchased for the project to enable calibration development and as a demonstration model for eventual rapid feed assessment in feed manufacturing in Vietnam.

Metabolism crates

Additional capacity building has occurred with the manufacture of twenty new digestibility crates for pigs see figure 8.2 below. These were used for the *in vivo* work assessing the energy and amino acid digestibility values of rubber seed meal. They now are a valuable resource which will allow further nutrient determinations for other feedstuffs specifically used in Vietnam and for which there is limited data and also for any further new local feedstuff or by-product which can be possibly used for pig feeding.

Figure 8.2 Metabolism crates manufactured for digestibility assessments in cassava residue and rubber seed.

Rubber seed homogenisation plant

An additional capacity building provided by ACIAR funding and resultant from (SIAEPHT) development in the project was the engineering of a water homogenisation apparatus. Our studies in this project have shown that the major processing factor which has a crucial role affecting cyanide (HCN) removal in both cassava residue and rubber seed is the degree that cellular rupturing has occurred. It was also found that the presence of additional water facilitates better distribution and access of plant tissue endogenous HCN releasing enzymes to HCN storage organelles in cells.

This piece of equipment will enable participants both at the IAS and SIAEPHT to continue further R&D at the pilot plant level, on rubber seed processing to enable:

- fine-tuning of the current rubber seed processing protocol to maximise rubber seed nutritive value
- linkage with associated processing steps to reduce residual fibre levels in the feed
- production of larger quantities of rubber seed for more performance studies in various classes of pig
- to provide technical guidance and expertise when developing a rubber seed feed processing industry
- additional studies on other local feedstuff which may require toxicity minimisation via feed processing

All of these additional activities are outside the scope of the existing project.

Figure 8.3 specifically engineered water homogenisation equipment for processing rubber seed to maximise HCN release from the seed

8.3 Community impacts – now and in 5 years

8.3.1 Economic impacts

Vietnam has a lack of adequate amounts of raw material feed ingredients for animal diets, especially protein sources. At this moment, Vietnam imports around 200,000 tons of fishmeal, 2 millions tons of soybean meal and 200,000 tons of meat and bone meal every year. Finding a locally-available feed resource is very important for the Vietnamese pig industry to reduce the cost of production especially when feed accounts for 60-70% of overall cost of pig production. Currently feed costs in Vietnam are 20-30% higher than that found in neighbouring countries involved in similar pig production. This is a result of import taxes and transportation costs.

As the project is essentially still in the scientific phase, no data is as yet available about economic impacts. To some degree this will depend on whether there exist linkages in Vietnam between the collaborating partner and relevant industry which would enable the transfer of research output and its applications and uptake in the field. As the major project achievement is identification of a process to improve the nutritive value of rubber seed meal and its safety in pig feeding. This process requires capital input into design and manufacture of processing plant to produce this material. There is a risk that the post harvest institute partners in Vietnam either do not have the links or skills to facility industry investment. Once this investment has occurred, then more precise economic impacts can be modelled.

Rubber seed meal was identified as a potentially good source of protein and is also a good option within the Vietnam current crop production system, in that there is little current alternative usage and hence it would be a better use of existing resources. Currently total rubber tree area of the country is 510,000ha and this expected to rise to over 700,000ha. With the current production having an average yield of 300 kg of rubber seed/ha, we can expect a harvested quantity of 153,000 tons of seed, which is equivalent to 70,000 tons of rubber seed meal. If we assume that 1 kg rubber seed meal is equal to ~1/3 kg soybean meal, then we can predict that rubber seed can replace 23,000 tons of soybean meal in pig diets which at a current cost of 400 USD/ton is equal to a saving of $9,200,000 of imported feed per annum.

In April 2006 contact was established with a Vietnamese company (Vina Biofuels Corp) planning/investigating the establishment of a processing plant for biofuel production in the Ba Ria, Vung Tau area of Vietnam using a significant amount of rubber seed (17,000 mt). Potentially this could also assist the pig livestock industry as it would result in the production of significant quantities of rubber seed meal as a by-product. A particular advantage of this development is that as the processing to extract the oil for Bio-diesel production would be in commercial/industrial quantities, it would be expected that the resultant rubber seed oil meal by-product would be of a relative uniform quality. In the case of peanut meal, Vietnam has 247,000 ha of peanut plantations with a yield of 462,000 tons of peanut seed. It is estimated that 60% of the total production is used for human beings, while 40% is processed to extract the oil, from this we get around 100,000 tons of peanut meal.

Due to local concerns about the aflatoxin level in peanut meal being too high, and the potential risk of toxic effects in animals most of the meal is currently produced is used only as a green fertilizer. Our preliminary feeding and performance studies using aflatoxin binders suggest that it can be used as a feed source again as there was no growth depression observed. However, further work may be required to assess if there is any risk of mycotoxin residues in the meat and by-products when peanut meal is used for pig feeding. If we assume that 1 kg peanut meal is equal to ~1 kg soybean meal, then we can predict that increased peanut meal usage can replace 100,000 tons of soybean meal in pig diets which at a current cost of 400 USD/ton is equal to a saving of $40,000,000 of imported feed per annum.

Cassava is one of the main agricultural crops of Vietnam. Each about 5.22 millions ton of cassava is produced, a portion of which used in cassava starch production. Currently the yearly production of starch is around 500,000 tons which would mean that there is around 200,000 ton/year of dried cassava residue.

8.3.2 Social impacts

Development of rubber seed harvesting businesses in rubber plantation areas provides another avenue for families located here to further supplement incomes and have higher disposable incomes. Although the current use of children in the very limited harvesting operation currently conducted probably is undesirable in the longer-term. It can however be explained that rubber seed harvesting is currently not seen as a potential income producing activity or employment option, more as a pocket-money occasional activity.

8.3.3 Environmental impacts

We anticipate that there will be a positive environmental impact from the project especially with changes in the pattern of rubber seed usage. Currently there is a situation where there is no/very little harvesting of rubber seeds and so seeds are allowed to breakdown where they fall and so act as an imprecise green manure. Having shown that rubber seed can be a viable and useful feedstuff for pigs then seeds can be now be harvested, processed and the nutritive value used as a replacement for imported feed in animal diets. Thus the harvesting of rubber seed as a feed resource will reduce the seed quantities allowed to undergo breakdown on the soil surface and especially in a country with high rainfall and surface runoff this should improve water quality through reduced eutrophication of waterways.

8.4 Communication and dissemination activities

Kinh, L.V., Thao, P.N., Vinh, D., Hoai, H.T. and Kopinski, J.S. (2009) Use of groundnut cake in grower and finisher diets in Vietnam. Australasian Pig Science Association, 12th Biennial conference of the Australia Australian Pig Science Association, Cairns, Nov 2009.

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9 Conclusions and recommendations

9.1 Conclusions

Research has shown chemically, in vitro and in vivo that in Vietnamese pig diets:

1. Cassava residue inclusion levels can be increased so it can be used as a local feed energy source.
2. Rubber seed after processing to eliminate HCN is a useful local protein source which can replace costly imported feed ingredients
3. Groundnut meal when fed with binders appears to minimise adverse performance effects of aflatoxins
4. Preliminary assessment suggest an important role for NIR in assessing rapidly feed quality difference

Research has shown chemically, in vitro and in vivo that in Australian pig diets:

5. Sunflower energy values are higher and amino acid content is lower that previously thought
6. Stylo is a possible useful feed resource which can provide some protein nutrition and that with its high fibre it especially appears to be a useful tool to increase sow satiety in non-stall dry sow feeding systems

9.2 Recommendations

Recommendation 1- Fine-tune rubber seed use

- Having successfully established the protocol to produce low HCN rubber seed and demonstrated its potential as a feed ingredient in Vietnamese pig diet some further studies would advantageous to fine-tune the use of rubber seed in diets for various classes of pigs.

Recommendation 2- Assistance to commercialise

- A protocol for processing rubber seed has been established and demonstrated to produce a new feed stuff suitable for use in pig feeding. Our co-operation with IAS was able to successfully achieve this while the SIAEPHT collaboration provided the expertise to develop pilot scale processing equipment. However the benefits and impacts of the research may be at risk unless appropriate processing industry linkages are developed. It seems that both industry encouragement and possibly some financial start-up stimulus may be required for this to occur. The scientific background and nature of the activities of the collaborating institutions in this project, means that they lack the necessary business expertise and are probably not the best options to achieve maximum commercialisation and impact of the research success achieved thus far.

Recommendation 3- Promotion of cassava residue usage

- Currently there some use of cassava residue in pig rations in Vietnam. However our research has demonstrated that there is still room for further increased inclusion levels of cassava residue in pig diets and a financial benefit from this usage. But this necessitates overcoming industry perception of problems with higher inclusion of cassava. Some support of technical industry presentation, workshops and extension should be able to get the message across.

Recommendation 4- Groundnut opportunity and health risk

- Our results have shown that groundnut meal when used in diets with an aflatoxin binder can reduce the performance problems associated with the groundnut use in pig feeds. This means that this very under-utilised feed resource in Vietnam may be a significant local feed resource for replacing imported protein meals in Vietnam. However further research is required to ensure that there is no human health risk via the presence of aflatoxin residues in pig meat and offal from the use of this feedstuff in pig diet. This will require further research both validating our results and clarifying the residues risk which is outside the scope of this funding and may be best tackled in another project either locally funded but most probably requiring both international funding and more significantly international expertise in aflatoxin residue detection.

Recommendation 5 Vietnam NIR capacity development

- The current project has provided both capacity building through equipment supply of the NIR and some training to use this technology for the staff of IAS. Further opportunity for significant impact from such technology could eventually occur with its movement from IAS and with their technical support into the feed manufacture and processing industry in Vietnam. Unfortunately this aspect of the project was not a major focus activity; its inclusion was to stimulate some self-development and recognition of its potential usefulness as a rapid feed quality assessment tool in Vietnam. It is felt that the loss of a Vietnamese staff member following the training program to private enterprise employment has had a detrimental effect on further development at IAS in Vietnam. It is recommended that consideration of further funding to maximise this new equipment capacity be considered with additional training undertaken.

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10.2 List of publications produced by project

10.2.1 Draft scientific papers

Kopinski, J.S., Kinh, L.V., Vinh, Đ., Thao, P.N., Ninh, P.H. and Burren, B. (2010) Assessment of the composition, cyanide level risk and digestible energy value for pigs of commercially produced cassava residue

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Kopinski, J.S. (2010) Patterns of energy digestion in the intestine of pigs fed cassava, maize, sorghum and barley diets

Kopinski, J.S. (2010) Rubber seed (Hevea brasiliensis) meal- chemistry, nutritive value and potential use as a pig feed

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10.2.2 Conference papers

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10.2.3 Thesis

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10.2.4 Industry Paper

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10.2.5 Project reports

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11 Appendixes

11.1 Appendix 1 Training and changes

In house training

2005
Mr Doah Vinh and Mr Pham Huynh Ninh from Vietnam as part of in-house training on protocols for digestibility assessment for this project spent three months August-November in Australia assisting in the conduct of the sunflower digestibility trial in Australia and in laboratory training and QC in HCN analysis of cassava residue and rubber seed sample form Vietnam.

2007
Soukhanh Keonouchanh from Lao as part of in-house training on protocols for pig digestibility assessment for Project AH/2004/046 spent one month May in Australia assisting in the conduct of the Stylo digestibility trial in Australia.

2008
Ms Le Thanh Thuy, Mr Nguyen Van Phu and Mr Pham Ngoc Thao from Vietnam as part of in-house training on protocols on NIR feed calibration and chemical analysis associated with digestibility marker analysis for this project spent 2 months from March 7th -May 7th in Australia for laboratory training especially for AIA ,Ti, Barium analysis via atomic absorption spectroscopy and bomb calorimetric gross energy assessment.

Variation to personnel

Miriem Santandee Borrego was appointed as a project Chemist following ACIAR approval of Variation to facilitate the completion of the large amounts of chemical analyses remaining from digestibility studies which have arisen as a result of late arrival of samples from Vietnam and staffing problems in DPI&F.

Test material supply

Problems in obtaining sufficient amounts of alternative feed material for the inclusion studies in Australia has impacted on this aspect of the project. Consequently due to limited time remaining in the project and as a result of other commitments in the limited animal facilities the pig trials were replaced with comprehensive Auspig computer simulations to predict the performance and economics of using these feeds based on the new digestibility information that the project has collected. This preliminary data is still useful and once fully validated it will be of value to industry in assessing these feeds.

Analyses delay

Due to significant delays in the receipt of digestibility and feed samples from Vietnam for analyses and with other project workloads commitments at DPI&F, together with fewer staff numbers, a formal Variation Agreement was implemented to extend of the project for initially 6 months and then 9 months to end in Mar 2009. This variation enabled utilisation of the remaining monies, primarily allocated in the project for payment for chemical analysis and training of Vietnamese, to employ a temporary chemist for 12 months to undertake these duties in DPI&F laboratories and help finalise the project analyses which were an essential requirement to prepare and complete the final report.

Hanoi Conference project promotion opportunity

Also within the project extension period funds were used to attend and present eight papers at the Asian-Australasian Association of Animal Production Societies 2008 international conference in Hanoi Vietnam which provides a good opportunity to promote and extend the project outputs both within Vietnam and to the broader Asian industry without the need for funding a costly project workshop.

11.2 Appendix 2 NIR training and initial calibration developments

The project included an introductory exposure to NIR calibration and usage in feed evaluation. The project supplied two lower-cost NIR machines to facilitate the development of NIR capability. These bench top whole grain and ground grain NIR transmission spectra analysers are suitable for measuring the parameters of protein, moisture, oil content in cereal grains, oilseeds, flour, protein meals and stock feeds. They have the advantage of whole grain and powder analysis having an automatic sample transport, simple operation and are PC compatible, and are rugged for use in countries such as Vietnam.

Project activities included initial in-housing training provision by the NIR equipment service and supplier to local and Vietnamese staff on machine operation and the basics of calibration development. This company has indicated a willingness to continue provision of calibration support in exchange for shared usage of calibrations, otherwise fee for service will allow retention of data ownership.

Following on from this local staff and Vietnamese began some initial calibration development on fishmeal sample collected from the previous ACIAR project and which had already undergone detailed chemical analyses and which had been retained by DPI &F for this possible research. Unfortunately fishmeal resulted in an unusual spectra which required the manufacture of a special thickness glass for the sample holder to obtain useful spectra, this reduced further any more training and practical application whilst in Australia. This delay combined with the limited available time in Australia for the Vietnamese chemists and the large number of analyses for the digestibility trials required a re-focus on marker and chemical parameter analysis training.

It was emphasised that the Vietnamese scientists on return to Vietnam should start a build up both samples and analyses results to enable calibration development and to maximise the potential of this capacity building with NIR. Unfortunately the chemist who displayed the maximum understanding of the technology and its potential was soon lost from IAS after returning from training in Australia to higher paid private employment in Vietnam. Ideally the application and adoption of NIR in Vietnam probably would need to be a separate project to ensure adequate training and support to maximise its outcome.

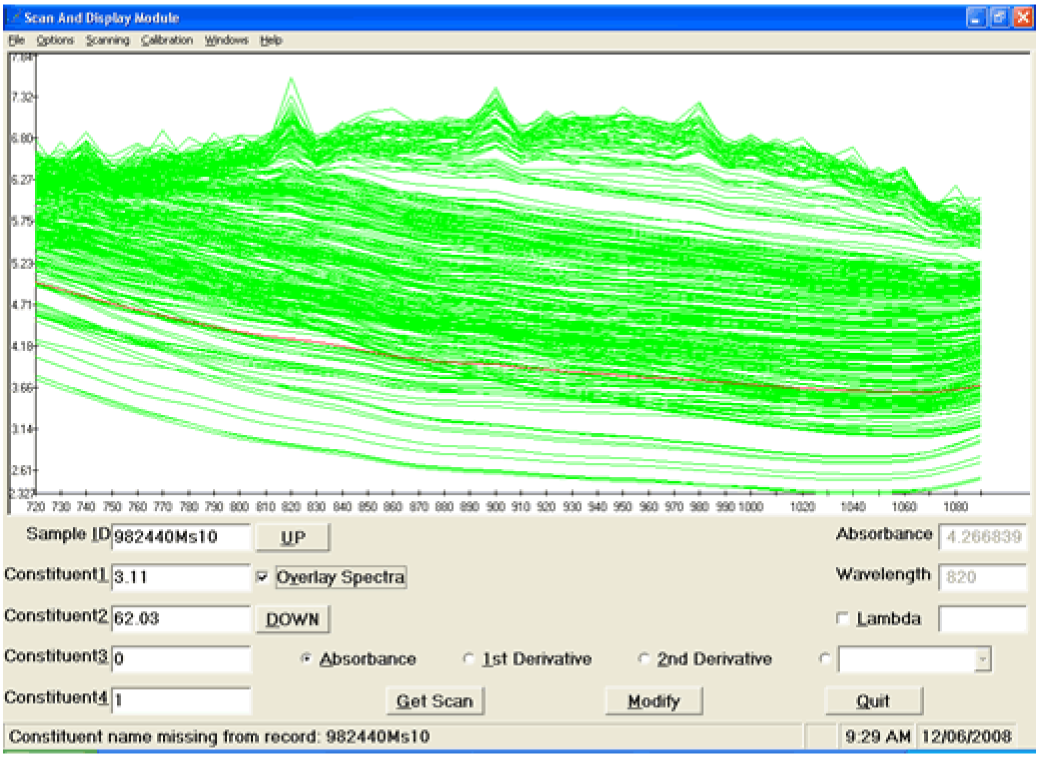

Fig10.1. Average NIR spectra, for fishmeal samples from Vietnam.

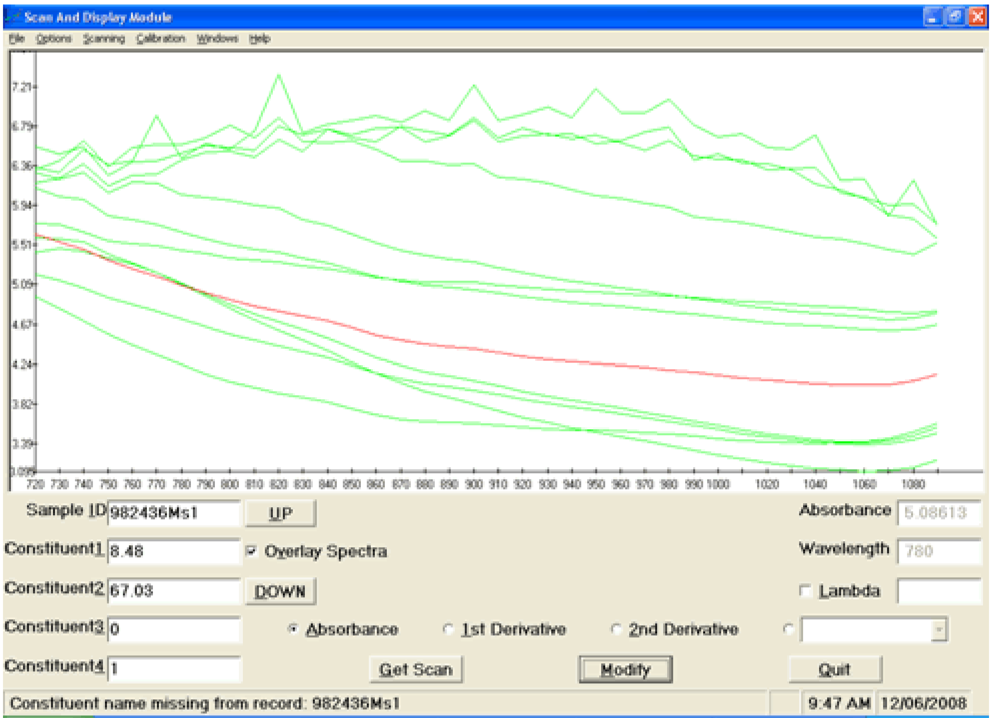

Fig10.2. Average NIR spectra, for 12 fishmeal samples from Vietnam with different absorbance high (982011**S1**, 982021**S1**, 982022**S1**, 982023**S1**), middle (982431**S1**, 982432**S1**, 982433**S1**, 982436**S1**) and low (981985**S1**, 981986**S1**, 981987**S1**, 981992**S1**)

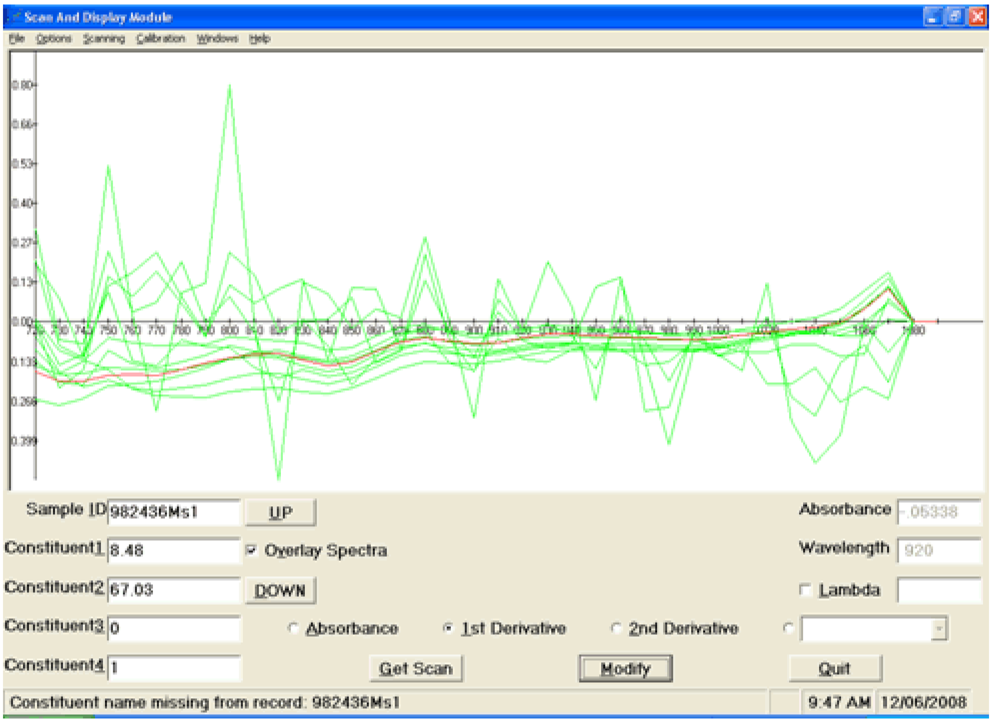

Fig 10.3. Average NIR spectra as first derivative, for 12 fishmeal samples from Vietnam.

(982011**S1**, 982021**S1**, 982022**S1**, 982023**S1,** 982431**S1**, 982432**S1**, 982433**S1**, 982436**S1,** 981985**S1**, 981986**S1**, 981987**S1**, 981992**S1**)

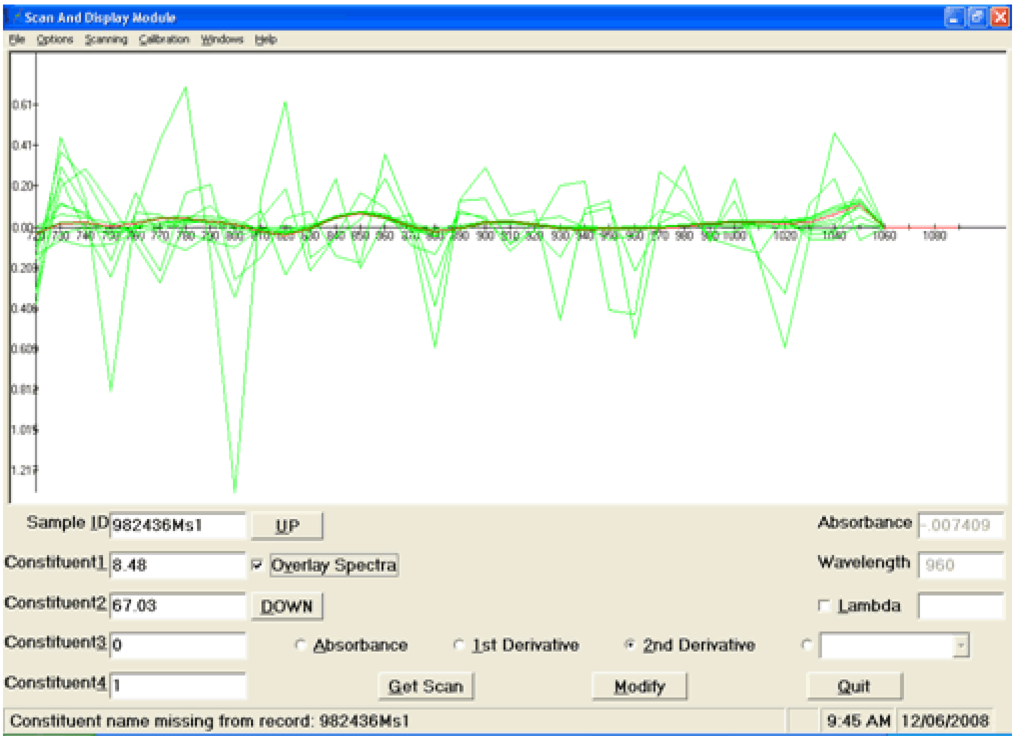

Fig 10.4 Average NIR spectra as second derivative, for 12 fishmeal samples from Vietnam. (982011S1, 982021S1, 982022S1, 982023S1, 982431S1, 982432S1, 982433S1, 982436S1, 981985S1, 981986S1, 981987S1, 981992S1)