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TARO (*COLOCACIA ESCULENTA*) AS A PROTEIN SOURCE FOR GROWING PIGS FED A BASAL DIET OF RICE BRAN

MASTER OF SCIENCE THESIS IN AGRICULTURAL SCIENCES ANIMAL HUSBANDRY

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AN APPROVAL OF THE SCIENTIFIC EVALUATION COMMITTEE

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COMMITMENT

I assure that this thesis is a scientific work which was implemented by myself. All the figures and results presented in the thesis are true and not published in any previous theses.

Author

Nouphone Manivanh

Dedication

To

My husband Phoneouthai Tiphavanh

My families

And

My country

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Contents

Abstract

The objectives of the thesis were to study the use of ensiled Taro foliage (leaves + stems) as the main source of protein for growing pigs fed rice bran as the basal diet

Paper 1:

Four crossbred castrated male pigs (Duroc x Large White), weighing on average 10.5 kg were allotted at random to 4 diets within a 4*4 Latin square design, to study effects of Taro silage (*Colocasiaesculenta*) alone and in combination with rice bran (75:25, 50:50 and 25:75 silage: rice bran) on digestibility and N retention of growing pigs. The trial was conducted in the experimental area of Angang University (AGU), in Angang province, Vietnam, from 24 August to 16 October, 2010.

The objectives of the study were to measure the digestibility and N retention of growing pigs when fed rice bran supplemented with Taro silage (leaves + stems) alone. Diets with 50% of taro silage plus 50% rice bran (DM basis) supported higher rates of feed intake (49.9 g DM/kg LW/day) than diets with more or less taro silage. Apparent digestibility coefficients of DM, OM and crude protein were high and tended to increase as the proportion of taro silage in the diet was increased from 25 to 100% (from 85 to 89% for DM and OM and from 81% to 88% for crude protein). N retention was higher with 50% taro silage in the diet than with 25 or 100% with intermediate values for 75% taro silage. However, when N retention was corrected for differences in DM intake, the highest N retention was on the 100% taro silage diet with no differences among the diets that contained rice bran. Urine excretion was increased threefold by raising dietary taro silage intake from 25% to 100% of the diet.

Paper 2:

The experiment was carried out in the area of Souphanouvong University (SU), the farm of faculty of agriculture (Animal science department), situated about 7 Km from Luang prabang City, Luang prabang province, Laos PDR.The objectives of the study were to measure the digestibility and N retention of growing pigs when fed rice bran supplemented with Taro silage (leaves + stems) alone or together with rice distillers' by-product. Four crossbred castrated male pigs (Duroc x Large White), weighing on average 25 kg, were allotted at random to 4 diets within a 4*4 Latin square design, to study effects on digestibility and N retention of level of rice distillers' by-product (0, 10, 20, 30 % in DM) replacing ensiled Taro (leaves and stems) in a basal diet of rice bran.

Feed intake and N retention were increased, but apparent digestibility of DM and CP were reduced, as the rice distillers' by-product replaced taro silage. Daily retention of N and N retained as percent of N digested increased linearly with replacement of Taro silage by rice distiller's by-product and rice bran. It appears that the biological value of the distiller's by-product is superior to that of Taro silage.

Paper 3:

A growth trial was conducted with 16 cross-bred pigs (Duroc x Large White) with average 23.4 kg mean initial live weight in a Randomized Complete Block Design (RCBD), with four replications of four treatments. The treatments were rice distillers' by-product (RD) at 0, 10, 20 and 30 percent of the diet DM replacing taro leaf-stem silage in a basal diet of rice bran.

The objectives of the study were to measure the growth performance of growing pigs when fed rice bran supplemented with Taro silage (leaves + stems) alone or together with rice distillers' by-

product. There were positive curvilinear responses in live weight gain and feed conversion when rice distillers' by-product partially replaced taro leaf-stem silage in a basal diet of rice bran fed to growing pigs. It appears that part of the benefits from the rice distillers' by-product arises from the superior biological value of the protein compared with that in the taro silage. Another possibility is a probiotic effect arising from the residual yeast in the rice distillers' by-product. It is concluded that either the biological value of the protein in rice distiller's by-product is superior to that in taro silage, or that the rice distiller's by-product provides other nutrients or compounds (eg: probiotics) that promote better growth rate and feed conversion, or a combination of both factors.

Key words: biological value, diuretic effect, feed conversion ratio, feed intake, live weight gain, N retention, protein, urine volume

General conclusions

Ensiled taro foliage has a high nutritive value for growing pigs and can be the major protein supplement in diets based on rice bran. However, pig performance is further improved by including up to 30% rice distillers' by-product in these diets.

Abbreviations

ANOVA	Analysis of variance
AOAC	Association of Official Analytical Chemists
DM	Dry Matter
ADG	Average daily gain
N	Nitrogen
OM	Organic Matter
Mekarn	Mekong Basin Animal Research Network
RCBD	Randomised Complete Block Design
SEM	Standard error of the mean
Sida/SAREC	Swedish International Development Agency-Department for Research Cooperation
RD/RDB	Rice distillers' by-product
TS	Taro silage
RB	rice bran
CF	Crude fibre
CP	Crude protein
Kg	Kilogram
g	Gram
m	Meter
h	Hour
FCR	feed conversion ratio
LWG	live weigh gain
LW	live weigh
cm	centimetre

Contents of the thesis

This thesis is based on the following papers, which are referred to by the numbers 1, 2, 3

1. **Manivanh N and Preston T R 2011** Taro (*Colocacia esculenta*) silage and rice bran as the basal diet for growing pigs; effects on intake, digestibility and N retention. *Livestock Research for Rural Development. Volume 23, Article #55.* Retrieved January 27, 2012, from http://www.lrrd.org/lrrd23/3/noup23055.htm

2. **Manivanh** N, **Le Duc Ngoan and Preston T R 2012** Apparent digestibility and N retention in growing pigs fed rice bran supplemented with different proportions of ensiled Taro foliage (Colocacia esculenta) and rice distillers' by-product . Submitted to *Livestock Research for Rural Development.*

3. **Manivanh** N, **Le Duc Ngoan and Preston T R 2012** Effect of rice distillers' by-product on feed intake and growth performance of crossbred pigs fed mixtures of ensiled taro (Colocacia esculenta) leaves and stems and rice bran. Submitted to *Livestock Research for Rural Development.*

Introduction

Pig production in the tropics is constrained by seasonal feed deficits, high costs of feed, erratic supply of feed ingredients and competition between humans and pigs for ingredients used in livestock feed (Makkar 1993; D'Mello 1995; Halimani et al 2005).

The present production system for pigs in Lao PDR is commonly subsistence with low inputs. The main constraints for this kind of farming are disease and feed supply, both in terms of quality and quantity. Local breeds are still predominant in the rural production systems and the preference for local breeds is high throughout the country. Feed supply relies mostly on crop residues and wastes from the households, and chickens and pigs are let loose to scavenge in the villages (Bouahom 1997).

The farmers in Laos almost all are raising the local pigs (Knips 2004). A small number of farmers use exotic breeds or crossbreeds (Stur et al 2002). Farmers report that many sows only have 1 litter per year with 6-8 piglets per litter. Imported breeds, such as Landrace and Large White and their crosses are used by a small number of farmers, particularly in semi-commercial pig farms near population centers (Vongthilath and Blacksell 1999). Gibson and Wilkie (1998) noted that imported breeds, introduced to small-holder farmers in Bokeo province, did not perform as well as local breeds in these conditions. Feeds include rice bran, broken rice, banana pseudostem, taro, yams, maize, cassava, by-products (especially rice distillers' by-product) and vegetation collected in fallow fields and forests (Stur et al 2002).

Rice bran is regarded as an energy source which can be used to supply the energy requirements for animals especially pigs (McDonald et al 2002). Rice bran consumption has shown to be successful in reducing cholesterol level in pigs (Roy and Lundy 2005).

Colocasia esculenta var. *antiquorum* known as Taro or Cocoyam is widely distributed in the humid tropics including India and South East Asia. Taro is recognized as a large coarse herb with crowns of large oblong-oval leaves and an abundance of large spherical underground tubers. Taro can be grown under flooded or upland conditions and it is one of the important crops for poor resource farmers in the tropics. In Cambodia, Taro is known in Khmer as 'Trao'. It is planted for home consumption of both tubers and petioles. However, when there is production in excess of household needs, Taro leaves and petioles are cooked and fed to pigs (Pheng Buntha et al 2006). Taro leaves are rich in protein, minerals and vitamins (AFRIS 2004).

Most Taro varieties contain an irritating or acrid agent and cannot be eaten fresh. Traditionally, the tubers are cooked before being fed to pigs. Uncooked Taro contains substances which irritate the digestive tract and may cause poisoning if fed in large quantities. It has been reported that the dried and ground Taro root has been used as a feed for poultry; with no toxic effects being observed, but at high levels of inclusion growth was poor (AFRIS 2004). Although cocoyam is widely cultivated in the rural areas of Cambodia and traditionally has been fed to pigs, there is a lack of information regarding its nutritive value as animal feed (Buntha et al 2006).

Hypotheses

It is hypothesized that (i) ensiled taro foliage (leaves + stems) can provide most of the supplementary protein needed to balance rice bran based diets for growing pigs; and (ii) there will be benefits from inclusion of rice distillers' by-products in this feeding system.

Objectives

The objectives of the study were to measure the growth performance, digestibility and N balance, of growing pigs when fed rice bran supplemented with Taro silage (leaves + stems) alone or together with rice distillers' by-product.

Review of literature

Pig production in Lao PDR

Some 16 per cent of the gross domestic product (GDP) of the Lao PDR arises from the livestock sector. Almost all output - live animals and products - is from traditional small scale production and about 90 per cent of all households in the country keep one or more species of livestock. Industrial or large scale production is of very minor importance even for pigs and poultry. Buffalo (1.1 million heads in 2004) and cattle (1.3 million heads) are the main ruminant species with goats and sheep (140 000 head) occupying a very minor position. Both pigs (1.7 million) and poultry (19.6 million) are major contributors to the household and national economies. Pigs and poultry produce meat and poultry provide eggs.
http://www.springerlink.com/content/m538082036p17320/. The indigenous pig population numbered 1,432,000 in 1998. They accounted for about 92% of the total pork production with the balance of 8% from exotic pigs (Phonvisay Singkham 2003).

The Lao PDR government has given highest priority in its rural development strategy to improving livestock production systems, given the potential of livestock production to alleviate poverty and reduce shifting cultivation. Rearing pigs is a widespread smallholder livelihood activity in the northern mountainous regions, but productivity is low mainly due to poor nutrition. The introduction of forage legumes into the farming system was suggested by Phengsavanh and Stür (2006) as an opportunity to improve pig nutrition and to reduce the time spent by women in gathering and preparing feed.

According to http://www.nsc.gov.la/nada/ddibrowser/?id=1, the two main purposes of raising pigs (all native breeds) are: (1) piglet production and (2) fattening pigs. The main feeds are rice bran, maize, cassava, broken rice and green feed occurring in nature. Almost all producers reported that they feed rice bran and some green feed (fresh leaves) to their pigs. In Lao-loum villages (lowland rice producers), producers fed mainly rice bran, sometimes mixed with broken rice or brewery waste and green feeds. Maize and cassava were used by most Hmong producers, while Khmu producers used maize and some cassava. Labour requirements for collecting and cooking feed were 3 hours per day and the average daily gain of growing pigs was 110 g per day.

The local feed resources

Pigs are a very important component of smallholder farm households in the uplands of Lao PDR. About 60–80% of households in upland areas raise pigs and smallholder pig production accounts for more than 80% of the total pig population in the country. Pigs are commonly kept in three production systems: Free scavenging (seasonally or year-round), confined in enclosures and penning. The main constraints in pig production are disease epidemics and low animal productivity due to lack of feed, both quality and quantity.

Monogastric animal production, especially pigs, has to be carefully considered, because they often compete with humans for food, and these feeds are generally the most expensive diet ingredients, particularly protein feeds. However, a potential solution is instead to use farm products and by-products that are locally available. Preston (2006) reported that the leaves from shrubs such as cassava and mulberry, sweet potato, and water plants such as duckweed (*Lemna* spp) and water spinach (*Ipomoea aquatica*), can be used successfully in diets for pigs to replace at least half the protein usually supplied as soya bean and fish meals. In animal production, the utilization of unconventional feeds for animal feeding will contribute to the reduction of food deficiency in the future.

In Laos, commercial pig farms are found near population centres such as Vientiane. These agribusinesses are small cottage industries with few employees. In general, production costs tend to be high, since intensive pig production is dependent on concentrate feed which, in many cases is imported from Thailand. Concentrate feeds are often mixed with locally available feeds such as rice bran and brewers' grains to reduce production costs (Stur et al 2002). The type of feed given depends on the farming system, the availability of labor and suitable vegetation. Feeds include rice bran, broken rice, banana pseudostem, taro, yams, maize, cassava and vegetation collected in fallow fields and forests (Phonvisay Singkham 2003). In view of the high production costs, because of the increasing prices of concentrate feeds, and especially protein concentrates such as soybean and fish meal, recent research in Laos, Cambodia and Vietnam has been directed to the use of leaves from crops such as taro (*Colocasia esculenta*) (Teguia et al 2007) sweet potato (Chittavong and Preston 2006), water plants such as water spinach (Lotchana and Preston 2010; Men et al 2000; Ly 2002,), mulberry (Chive P et al 2003), and cassava (Du Thanh Hang and Preston 2005; Chhay and Preston 2005) to provide protein. New sources of energy that have been investigated are sugar cane juice, cassava root, palm oil and broken rice (Rodríguez et al 2006; Chhay and Preston 2006; Kea et al 2003). All these energy feed resources are very low in protein and as a consequence of this all the amino acids in the diet have to be supplied in a protein supplement (Preston 1995).

When using forages in pig feeding it is also important to look at the energy sources and select those that are highly digestible and easily obtained in the rural areas. Green feed or vegetable matter is traditionally collected from forest margins and fallow fields and includes *Colocasia esculenta, Alocasia macrorrhiza, Crassocephalum crepidioides,* paper mulberry leaves and several other herbs, depending on local availability. Some farmers also feed the residues from making rice wine and spirits, maize, cassava root, and in some cases broken rice. In all situations the main feed ingredient is rice bran of varying quality. Many micro rice mills are not able to effectively separate rice husks from the bran, resulting in a lower-quality product with reduced protein and high fibre content. Rice bran tends to be available for most of the year, except for a short period in July to September before the new rice is harvested. The use of *Stylosanthes guianensis* CIAT 184 as a supplement to traditional feeds has great potential for resource-poor smallholder farmers in the uplands of Lao PDR. Legumes can be grown on farm, save labour and increase the productivity of pigs (Phengsavanh and Stur 2006; Keoboualapheth 2003). Recent research in Laos has focused on local protein feed resources from crop and fishery products for feeding pigs, such as sweet potato leaves and water spinach (Chittavong and Preston 2006), *Stylosanthes guianensis*, dry cassava leaves (Koutsavang 2005) and Golden Apple Snail (*Pomacea* spp) (Kaensombath 2005).

Local feed resources, especially the natural green leaves and herbs needed to supplement basal feeds (such as rice bran, maize and cassava) used to be abundant. These have become scarcer through overuse. Farmers (predominantly the women) have to spend several hours a day collecting sufficient material for their pigs. Time is a very valuable commodity on smallholder farms and having to spend a lot of time feeding pigs makes pig production a less attractive livelihood activity with poor returns to labour. On the other hand, households have little choice but to continue to raise pigs, as these are needed as part of the family reserves.
http://www.ilri.org/InfoServ/Webpub/fulldocs/Pig%20Systems_proceeding/CH_06_Phengsavanh_Stur.pdf

Requirement of protein and amino acid for growing pigs

The quality of the protein in pig diets is often limited by a deficiency of one or two of the indispensable amino acids. The concept of limiting amino acids refers to the most deficient amino acid, and for pigs it is likely to be lysine. There are twenty amino acids required by animals, but some of these cannot be synthesized by the animal or are synthesized at an insufficient rate to meet its requirement. For optimum performance the diet must contain adequate amounts of the essential amino acids, energy and other indispensable nutrients. Protein requirements may be stated in terms of the "ideal protein" (McDonald et al 1995).

According to Church (1979) the usefulness of a protein source depends on its amino acid composition, because the real need of the pig is for amino acids and not protein as such. Protein quality is a term used to describe the amino acid balance of a protein. A good quality protein contains all of the essential amino acids in the amounts and proportions necessary for the particular need of the animal, i.e., growth, fetal development, lactation etc. A poor quality protein is one that is deficient in either content or balance of the essential amino acids. It is possible for a 12% protein diet that is well balanced in the essential amino acids to support better growth of weanling pigs than a 16% protein diet that has a poor balance of these amino acids. However, combinations of most common feed ingredients do not provide this superior balance of amino acids. The pig's requirements for total proteins are usually determined in feeding trials in which growth rate is the main criterion of adequacy, and are stated as the concentration of protein in the diet. The pig has specific requirements for ten essential amino acids, and the ratio of amino acids to lysine is particularly important. NRC (1998) and NIAH (1998) recommend a ratio of methionine + cystine to lysine of 50%, and of the threonine to lysine of 60%.

Table 1: Major essential AA in the "ideal protein", soybean meal and leaves of selected protein-rich leaves

	Ideal protein(1)	Soybean meal (2)	Water spinach (3)	Cassava leaves (4)	Sweet potato leaves (5)	Duckweed (7)	New cocoyam (6)	Mulberry (3)
g AA/kg N*6.25								
Lysine		63.2	42.7	56-65	39	43	46	50.6
Methionine			13.5	18-21	16.3	27.9	14.3	16.5
Cystine			10.3	15-16	5.27	7.38	12.6	12.0
Met+Cys		28.3	23.8	33-37	39	35.3	26.9	28.6
Threonine		38.9	39.5	47	51	42	39.5	45.1
As proportion of lysine = 100								
Lysine	100	100	100	100	100	100	100	100
Met+Cys	59	44.8	56	53-57	55	82	58.5	56.4
Threonine	75	61.6	92	76	114	98	85.6	89.1
Composition of fresh leaves, g/kg fresh matter								
DM			83	320	161	62	180	261
Composition, g/kg DM								
Crude protein		51.8	267	245	282	370	248	222
Crude fibre		31	155	156	128	77	142	172
Ash		62	142	84	109	16	133	126

(1)Wang and Fuller 1989; (2) Martin 1990 ; (3) Phiny et al 2003; Phiny 2006, personal communication; (4) Eggum 1970; (5) Woolfe 1992; (6)Rodríguez et al 2006; (7) Le Thi Men 2006

Foliages as sources of protein in pig diets

Preston (2006) has suggested that the leaves from shrubs such as cassava and mulberry, and from vegetables such as sweet potato and cocoyam, together with water plants such as duckweed (*Lemna spp)* and water spinach (*Ipomeoa aquatica)*, can be used successfully in diets for pigs, replacing at least half the protein usually supplied as soybean and fish meal.

Taro

Taro (*Colocasia esculenta* (L.) Shott) is a member of the Araceae family (AFRIS 2005; Lee 1998) that originated in India and South East Asia. It is presently cultivated in many tropical and subtropical countries, primarily as a food for its edible corm, and secondarily as a leaf vegetable (http://www.fao.org/docrep/003/w3647e/W3647E05.htm). Taro is a tropical food crop with high potential because of the high yield of the roots (or corms) and foliage, the average taro yield in Africa is about 5.1 t/ha as compared with 1.6 t/ha for maize (Raemaekers 2001). However, in general, taro corm has a poor post harvest storage quality. In Cameroon, the high rate of post harvest loss and lack of proper scientific attention to this problem has been associated with more than 70 % drop in annual production (MINAGRI 1981, MINAGRI 1999).

Nutritive value of Taro

Taro leaves are rich in vitamins and minerals, and are a good source of thiamin, riboflavin, iron, phosphorus, and zinc, and a very good source of vitamin B6, vitamin C, niacin, potassium, copper, and manganese. Taro is a locally available feed resource with good potential for animals, especially for pigs, because of its nutritional quality. According to FAO (1993) the leaves of taro contain 8.2% DM, 25% CP, 12.1% CF, 12.4% Ash, 10.7% EE, 39.8% NFE, 1.74% Ca, and 0.58% P (on DM basis). However, there are difficulties in using taro as animal feed because of its content of oxalic acid cause the mouth and throat of animals consuming it to itch. Oxalic acid may be present in the corm and especially in the leaves (http://en.wikipedia.org/wiki/Taro). However, some local farmers traditionally reduce the oxalate content by boiling

Leaves from taro (*Colocasia esculenta* (L.) Schott), giant taro (*Alocasia macrorrhiza*), and New Cocoyam (*Xanthosoma sagittifolium*) are traditionally used in pig diets by small-scale farmers in many tropical countries. A preliminary report from Colombia (Rodríguez et al 2006) showed that weight gains in young pigs fed a sugar cane juice diet were the same when the supplementary protein was from a 50:50 mixture of fresh leaves of New Cocoyam and soya bean meal compared with soy bean meal as the only protein source. Also results from Tiep et al (2006) show that including 10% ensiled *Alocasia macrorrhiza* leaves (replacing fish meal and soybean meal) with 45% *Alocasia macrorrhiza* root meal in diets for crossbred (Yorkshire x Mong Cai) pigs had no negative effects on performance, and resulted in higher benefit for the farmers in mountainous areas in Northern Vietnam.

Ensiling Taro

Traditionally, some taro species especially *Colocasia esculenta* can be used both as human food and animal feed. However, in common with other species of the Aracae family, an anti-nutritional substance, calcium oxalate, is found in all parts of the plant, causing irritation in the throat and mouth epithelium and indirectly affecting the feed intake. The "itching" characteristic of Taro plants is caused by the presence of crystals of calcium oxalate (Jiang Gaosong 1996), Oscarsson and Savage (2006) reported that there are two forms of oxalate in taro, one soluble and the other insoluble. The oxalate content was higher in young leaves (589±36 mg/100 g fresh basis) than in older leaves (433±15 mg/100 fresh basis) and that soluble oxalate was 74% of the total oxalate in the leaves. In the study of Mårtensson and Savage (2008)**, t**aro leaves were reported to contain

524±21.3 mg/100 g fresh weight of total oxalates (presumably as calcium salts) and 241±21 mg/100 g fresh weight in the soluble form.

Ensiling is the preservation of forage (or crop residue or by-product) of high moisture content based on a lactic acid (ideally) fermentation under anaerobic conditions (Moran 2005; McDonald et al 2002). Ensiling can also render some previously unpalatable products useful to livestock by changing their chemical nature (Chedly and Lee 1998). The leaves of taro can be made into silage for feeding to pigs (Malavanh et al 2006). Recent research has shown that the roots and leaves of giant taro (*Alocasia macrorrhiza*) can be fed successfully to pigs, provided they are cooked or ensiled (Tiep et al 2006). The leaves of New cocoyam (*Xanthosoma sagittifolium*) were successfully fed in the fresh state to pigs in experiments reported by Rodriguez et al (2006 a,b).

The leaves can be chopped and ensiled to considerably reduce undesirable substances in Taro, which thus becomes more palatable. It is not difficult to ensile Taro leaves. A specific advantage of the Taro plant is the high sugar content in the stems. By ensiling the combined leaves and stems there was no need to add an additional source of sugar (Rodríguez and Preston 2009).

Ensiling not only preserves the foliage of Taro, it also decreases the level of oxalates (Du Thanh Hang et al 2011).

Rice distillers' by-product

Rice distillers' by-product is produced when sticky rice, maize, sweet potato, cassava or bananas are fermented to make alcohol. Usually sticky rice is cooked and yeast is added to the cooked rice for fermentation. The alcohol is distilled from the fermentation liquor, after which the waste, locally called "Kilao" is used as a feed for pigs. In the villages of Sang Hai and Don Mai in Luang Prabang province, it is a traditional feed for the pigs especially fattening pigs. This by-product is cheap, very palatable for pigs and available all year round. Using "Kilao" for fattening pigs is a way to get better economic returns. Typical diets for growing pigs are based on rice bran or concentrate, "Kilao" and vegetables. Sometimes the farmers exclude "Kilao" from the diet, which results in environmental pollution because the "Kilao" is dumped in the river. It is recommended that rice distillers' by-product should be mixed with other feeds such as rice bran and broken rice (Oosterwijk and Vongthilath 2003).

The rice distillers' by-product "Kilao" is palatable and has a fairly high protein content (28% crude protein in dry matter) (Lotchana et al 2010) which is of good quality with approximately 3.9 g lysine/16 g N (Manh Huu Luu et al 2000). In addition it is a good source of B-vitamins.

Rice bran

Rice bran is one of the main by-products used in pig raising (Rozemuller 1998) and is commonly used for pigs by rural farmers in Laos. Rice is the major food grain of the world and it is the principle cereal consumed in India and other parts of Asia. Milling of paddy to obtain edible rice grain yields two major by-products of economic and nutritional importance, namely, paddy husk and rice bran. Paddy husk has no food value but has several industrial uses. Rice bran, on the other hand, can serve as an animal feed, as a human food supplement and as a valuable source of edible oil (Narasinga Rao 2000). Rice bran is the outer layer of the brown rice kernel (after separating the husk) which is removed while milling brown rice to white rice. Rice bran is a rich source of nutrients and a pharmacologically active compound and is currently used as livestock feed and for oil production (Tahira et al 2007).

Conclusions

- Using agricultural by products such as rice bran as energy sources, together with foliages or water plants as protein sources in pig diets results in a sustainable system based on locally available natural resources with a high potential for small-scale farmers.
- The foliage of Taro (leaves plus stems) appears to be one of the most appropriate sources of vegetable protein for pig feeding in Lao PDR. As it is relatively abundant and easily preserved by ensiling.
- The residue after distilling of rice wine for alcohol is widely available in Lao PDR which can be an additional source of high quality for pigs fed basal diets of rice bran and vegetables such as Taro.

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Taro (C*olocacia esculenta*) silage and rice bran as the basal diet for growing pigs; effects on intake, digestibility and N retention

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Abstract

Four crossbred castrated male pigs (Duroc x Large White), weighing on average 10.5 kg were allotted at random to 4 diets within a 4*4 Latin square design, to study effects of Taro silage (*Colocasiaesculenta*) alone and in combination with rice bran (75:25, 50:50 and 25:75 silage: rice bran) on digestibility and N retention of growing pigs. The trial was conducted in the experimental area of Angang University (AGU), in Angang province, Vietnam, from 24 August to 16 October, 2010.

Diets with 50% of taro silage plus 50% rice bran (DM basis) supported higher rates of feed intake (49.9 g DM/kg LW/day) than diets with more or less taro silage. Apparent digestibility coefficients of DM, OM and crude protein were high and tended to increase as the proportion of taro silage in the diet was increased from 25 to 100% (from 85 to 89% for DM and OM and from 81% to 88% for crude protein). N retention was higher with 50% taro silage in the diet than with 25 or 100% with intermediate values for 75% taro silage. However, when N retention was corrected for differences in DM intake, the highest N retention was on the 100% taro silage diet with no differences among the diets that contained rice bran. Urine excretion was increased threefold by raising dietary taro silage intake from 25% to 100% of the diet.

Key words: *Diuretic effect, protein, urine volume*

Introduction

In most parts of Laos, agricultural by-products, such as rice bran, and natural grasses are the main feeds for live stock (ILRI 2002). In Lao villages, where most farmers are growing paddy rice for sale, the feed for pigs is based on rice bran, which is fed together with a small amount of green feed. Thus rice bran is available in most farm households. The main problem is the supply of protein as soybean and fish meals are not available in rural areas. Phengsavanh and Stür (2006) showed that growth rates were increased from 100 to 200 g/day by providing some protein-rich forage in the form of stylosanthes. However, other forages appear to have more potential in pig diets based on rice bran (Preston 2006).

Taro (*Colocasia esculenta*) is known as a food crop which provides high yield of roots (or corms) and foliage Taro is a tropical food crop that can be grown under flooded or upland conditions (Chhay Ty et al 2007). Its leaves are rich in protein and easy to ensile (Pheng Buntha et al 2008; Rodríguez and Preston 2009). One constraint to the feeding of taro foliage is the presence of calcium oxalate which forms crystals on the surface of the leaves. These cause irritation on the skin and in the mouth, and this reduces intake (Pham Sy Tiep et al 2005). According to Du Thanh Hang and Preston (2008) and Pheng Buntha et al (2008), the farmers in Central Vietnam and in Cambodia cook the taro leaves with rice or rice bran or cassava roots, in order to reduce the concentration of calcium oxalate. Du Thanh Hang and Preston (2008) showed that ensiling was equally effective in reducing the calcium oxalate and that there were no differences in crude protein digestibility and N retention between diets with cooked and ensiled taro leaves.

Xanthosoma sagittifolium known as New Cocoyam in South America is a member of the same Araceae family as *Colocacia esculenta* and has similar characteristics in terms of the presence of calcium oxalate. An important step in the research with this plant was the finding that the stem was quite rich in soluble sugars (Rodriguez et al 2009; Dao Thi Mai Tien et al 2010); and that combining the stem with the leaves facilitated the ensiling process (Rodriguez et al 2009), making it unnecessary to use additives such as molasses (eg: Malavanh et al 2008). The ensiling of the combined leaf and stem of Taro (*Colocacia esculenta*) is now widely employed in Cambodia (Chhay Ty et al 2010) and Vietnam (Du Thanh Hang and Preston 2008).

The purpose of the present study was to determine the optimum level of taro silage when used as the only supplement to rice bran in the diet of growing pigs.

Material and methods

Location and duration

The experiment was conducted in the experimental area of Angiang University (AGU), in Angiang province, Vietnam, from 24th August to 16th October, 2010.

Experimental design

Four treatments were compared in a 4*4 Latin Square arrangement with 4 pigs and 4 periods (Table 1). The treatments were:

- TS100: only Taro silage (TS)
- TS75: 75% TS and 25% rice bran (RB)
- TS50: 50% TS and 50% RB
- TS25: 25% TS and 75% RB

Table 1: Layout of the experiment

Period/Pigs	1	2	3	4
1	TS100	TS75	TS50	TS25
2	TS25	TS100	TS75	TS50
3	TS50	TS25	TS100	TS75
4	TS75	TS50	TS25	TS100

The duration of the experiment was 40 days with 4 periods each of 10 days, the first 5 days for adaptation then 5 days for data collection (feed residues, feces and urine).

Animals and housing

Four male castrated crossbred pigs (Duroc x Large white), with average live weight of 10 kg were housed in cages made of bamboo, designed to separate feces and urine (Photo 1). The floor area was 60*60 cm.

Photo 1: Metabolism cage made from bamboo

Feeds and feeding

The Taro foliage (leaves with stems) was collected in the vicinity of Angiang University where it was growing naturally (Photo 2).

Photo 2. Taro (*Colocaciaesculenta)* growing wild in An Giang city

The leaves and stems were chopped into small pieces (2-3 cm length) (Photo 3) and exposed to sunlight for 6 hours to reduce the moisture to about 75%, prior to packing tightly into 50 litre plastic bags where it was stored for 14 days before being fed to the pigs (Photo 4). Rice bran and taro silage were fed two times per day at 6:00 AM and 4:00 PM, the amount being based on an offer level of 40 g DM/kg live weight. For treatments TS25, TS50 and TS75, the rice bran was fed first, followed by the taro silage was adjusted so as to minimize residues. Water was supplied ad libitum through nipple drinkers.

Photo 3: Taro (Leave + stems) chopped

Photo 4: Taro silage (Leaves and stems)

Measurements and data collection

The pigs were weighed in the morning before the start of each period. Feed offered was recorded and refusals collected daily. The refusals were stored in a refrigerator (4 °C) until the end of each collection period when they were mixed and sub-samples taken for analysis of DM, ash and N. Feces and urine were collected daily. Each day 20 ml of 15 % H_2SO_4 were added to the urine container to maintain the pH of the urine below 4.0. All the feces were stored in the refrigerator until the end of the collection period when they were mixed and a sub-sample taken for analysis of DM, ash and N. A sub-sample of urine was taken daily and stored in the refrigerator until the end of the collection period when the samples were mixed and a sub-sample taken for analysis for N.

Chemical analysis

Samples of feeds offered and refused and feces were analysed for DM, ash and N using the procedures of AOAC (1990). Urine was analysed for N (AOAC, 1990).

Statistical analysis

The data were analyzed using the general linear model (GLM) option of the ANOVA program in the MINITAB software (Minitab 2000). Sources of variation were pigs, periods, treatments and error.

Results and discussion

Feed composition and feed intake

The rice bran was of moderate quality (10.5% CP in DM) compared with that used by Nguyen Tuyet Giang et al (2010) in an experiment with ducks in An Giang (13.2% CP in DM). By contrast, the taro silage (CP 17.2% in DM) compared favourably with that prepared by Nguyen Tuyet Giang et al (2010) (18.7% in DM).

Table 2: Chemical characteristics of the diet ingredients

Ingredient	**Taro silage**	**Rice bran**
DM, %	29.5	87.3
As % in DM		
Organic matter	72.4	77.6
Crude protein	17.2	10.5

The Taro silage and rice bran as the basal diet were consumed completely; there were no residues of rice bran and taro silage on all treatments (Table 3). The daily DM intakes showed a curvilinear trend increasing as the proportion of taro silage was raised from 25 to 50% then declining (Figure 1; Figure 2). As a function of live weight the intakes were high (37 to 50 g DM/kg live weight).

Table 3: Mean values (individual treatments) for intake of DM, organic matter (OM) and crude protein (CP) of pigs fed taro silage or mixtures of taro silage (%TS in DM)) and rice bran

	TS25	TS50	TS75	TS100	SEM	Prob.
DM intake, g/day						
Taro silage	130	306	386	421	-	-
Rice bran	371	288	136	0.00	-	-
Total	501[b]	594[c]	522[bc]	421[a]	21.0	0.001
g/kg LW	43.6[b]	49.9[c]	43.1[b]	37.1[a]	1.58	0.001
OM intake, g/day						
Taro silage	94.9	224	280	306		
Rice bran	280	218	103	0.00		
Total	375[b]	442[c]	383[b]	306[a]	14.7	0.001
N intake, g/day						
Taro silage	2.86	6.89	8.65	9.20		
Rice bran	6.23	4.84	2.29	0.00		
Total	9.20[a]	11.7[b]	10.9[ab]	9.20[a]	0.5	0.001
CP in DM, %	11.5[a]	12.3[b]	13.1[c]	13.7[c]	0.32	0.001

[abc] *Means with different letters within the same row are different at P<0.05*

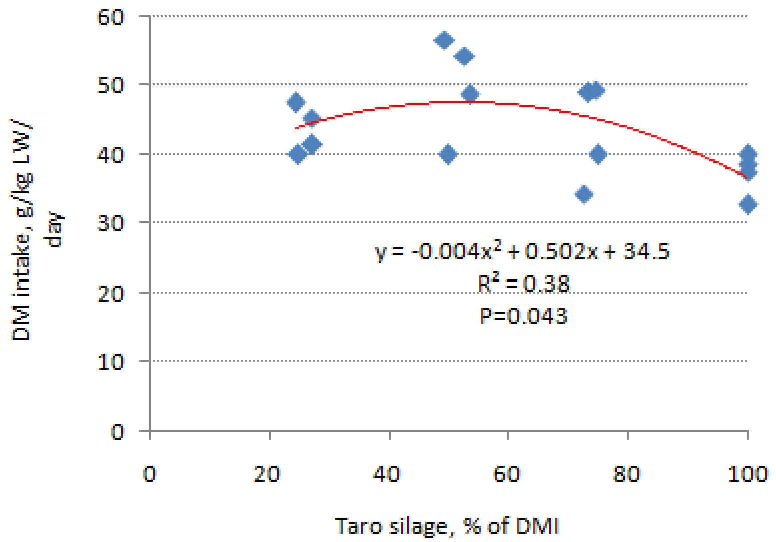


Figure 1. Relationship between proportion of taro silage in the diet and daily DM intake as function of live weight

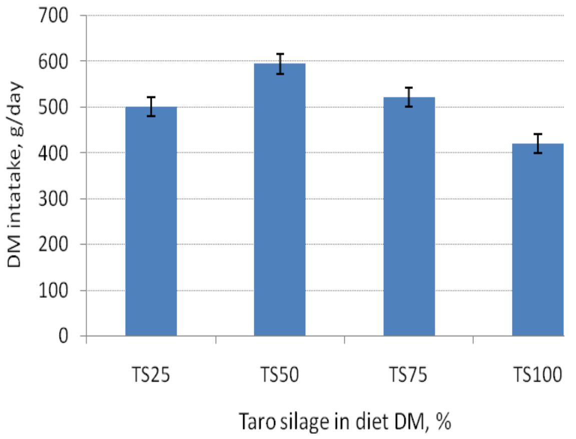


Figure 2: DM intake of pigs fed taro silage or mixtures taro silage and rice bran

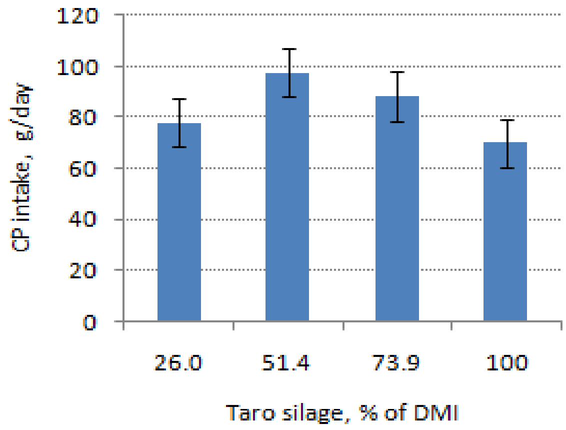


Figure 3: CP intake of pigs fed taro silage or mixtures of taro silage and rice bran

Coefficients of total tract apparent digestibility

The coefficients of apparent digestibility of DM, OM and CP were high on all treatments with highest values on Taro silage as the sole diet and lowest values on the 75% rice bran diet (Table 4). Compared to Chhay Ty et al (2010), apparent digestibility coefficients on the present study were higher for the diets containing Taro silage.

Table4: Apparent digestibility of the diets fed to the pigs

	TS25	TS50	TS75	TS100	SEM	Prob.
Dry matter	85.2^{b}	88.1^{ab}	86.1^{b}	89.9^{a}	1.28	0.002
Organic matter	85.2^{b}	88.1^{ab}	85.9^{b}	89.8^{a}	1.32	0.007
Crude protein	80.9^{a}	86.3^{b}	82.1^{ab}	87.5^{b}	2.34	0.142

^{ab}Means within rows without common letters differ at $P<0.05$

Nitrogen balance

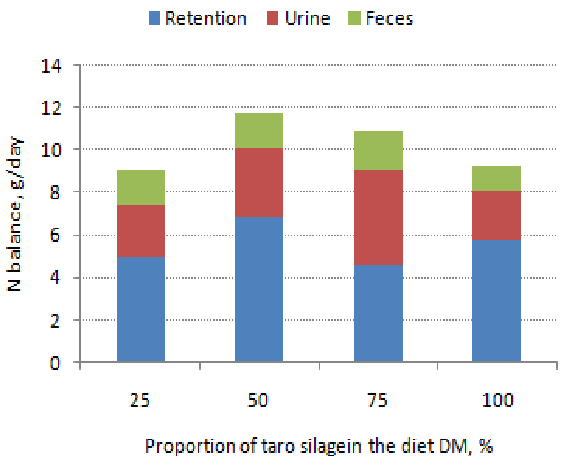
N intakes were higher with 50% taro silage in the diet than with 25 or 50% with intermediate values with 75% taro silage in the diet (Table 5). These intakes mostly reflected differences in DM intake which was highest on the TS50 diet. N retention followed the same trend with highest values for the TS50 diet. However, when N retention was corrected for differences in DM intake, the highest N retention was on the 100% taro silage diet with no differences among the diets that also contained rice bran (TS25, TS50 to TS75).

Table 5. Mean values for N balance in pigs fed taro silage or mixtures of taro silage and rice bran

	TS25	TS50	TS75	TS100	SEM	Prob.
N balance, g/day						
Intake	9.09^{a}	11.7^{b}	10.9^{ab}	9.20^{a}	0.54	0.001
Feces	1.70	1.68	1.86	1.16	0.21	0.106
Urine	2.50^{a}	3.18^{a}	4.55^{b}	2.27^{a}	0.32	0.001
N Retention						
g/day	8.30^{a}	10.8^{b}	8.71^{a}	7.76^{a}	0.52	0.01
g/day#	5.05^{a}	5.41^{a}	4.43^{a}	7.31^{b}	0.38	0.001
% of N digested	77.6^{ab}	77.1^{ab}	68.9^{a}	78.7^{b}	4.01	0.001
% of total N intake	53.3^{a}	56.8^{a}	49.7^{a}	62.0^{b}	3.54	0.001

^{ab} Means with different letters within the same row are different at $P<0.05$

 # Corrected by covariance for differences in DM intake



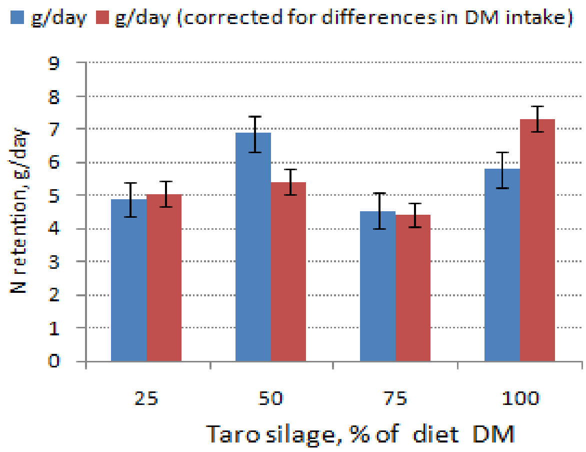
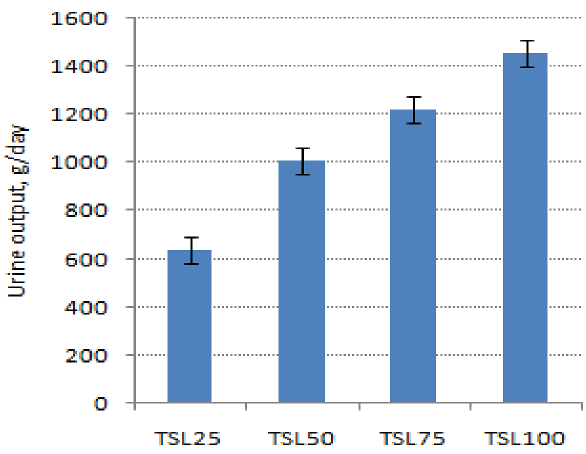


Figure 4: Trends in N balance with increasing proportions of taro silage in the diet of growing pigs

Figure 5: Comparison of N retention with and without correction for DM intake in pigs fed different ratios of rice bran and taro silage

Diuretic effect of Taro silage

The volume of urine excreted by the pigs increased (Figure 7) with a curvilinear tendency (Figure 8) as the intake of taro silage increased, being almost threefold greater on the 100% compared with the 25% taro silage diet. A diuretic effect in pigs due to feeding water spinach has been reported by Chhhay Ty and Preston (2006) and Nguyen Yuyet Giang (2009) but this appears to be the first observation of such an effect due to feeding taro silage.



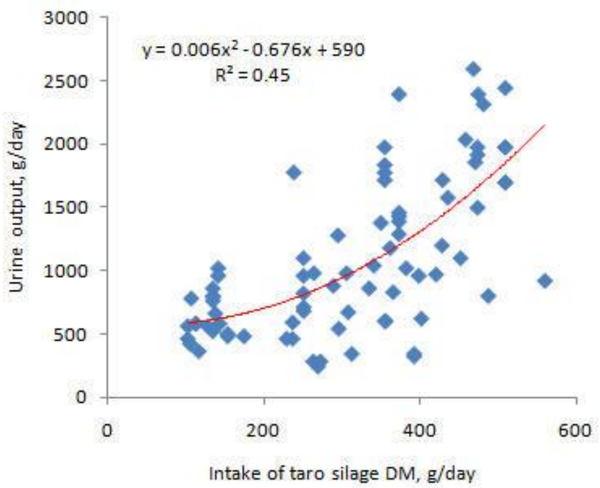


Figure 7. Mean values of urine excreted in pigs fed taro silage with rice bran.

Figure 8. The relationship between intake of taro silage and the urine excreted in pigs fed Taro silage and rice bran.

Conclusions

- Diets with 50% of taro silage plus 50% rice bran (DM basis) supported higher rates of feed intake (49.9 g DM/kg LW/day) than diets with more or less taro silage.

- Apparent digestibility coefficients of DM, OM and crude protein were high and tended to increase as the proportion of taro silage in the diet was increased from 25 to 100% (from 85 to 89 for DM and OM and from 81 to 88% for crude protein).
- N retention was higher with 50% taro silage in the diet than with 25% or 50% with intermediate values for 75% taro silage. However, when N retention was corrected for differences in DM intake, the highest N retention was on the 100% taro silage diet with no differences among the diets that contained rice bran.
- Urine excretion was increased threefold by raising dietary taro silage intake from 25% to 100% of the diet.

Acknowledgements

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Apparent digestibility and N retention in growing pigs fed rice bran supplemented with different proportions of ensiled Taro foliage (*Colocacia esculenta*) and rice distillers' by-product

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Abstract

The Experiment was carried out in the area of Souphanouvong University (SU), the farm of faculty of agriculture (Animal science department), situated about 7 Km from Luang prabang City, Luang prabang province, Laos PDR.

Four crossbred castrated male pigs (Duroc x Large White), weighing on average 25 kg, were allotted at random to 4 diets within a 4*4 Latin square design, to study effects on digestibility and N retention of level of rice distillers' by-product (0, 10, 20, 30 % in DM) replacing ensiled Taro (leaves and stems) in a basal diet of rice bran.
Feed intake and N retention were increased, but apparent digestibility of DM and CP were reduced, as the rice distillers' by-product replaced taro silage. Daily retention of N and N retained as percent of N digested increased linearly with replacement of Taro silage by rice distiller's by-product and rice bran. It appears that the biological value of the distiller's by-product is superior to that of Taro silage.

Key words: *Biological value, feed intake, N retention, protein.*

Introduction

As the human population grows, there will be a need for more food to meet the increasing demand. The production of meat from non-ruminants (pigs and poultry) is increasing faster than from the ruminants because of the quick turnover of the capital and the ease to the market (Khien Borin et al 1996). Pigs are widely kept throughout the country of Laos, with 64 percent of all households involved in pig production. The number of pigs kept by smallholders varies between an average of 1.4 and 3.7 animals per household, depending on the region (Kaufmann et al 2003). In the Laos PDR, almost all farmers use agricultural by - product such as rice bran for feeding pigs but they cannot support full performance because of their poor nutritive value (ILRI 2002).

Taro (*Colocasia esculenta*) is known as a food crop which provides high yield of roots (or corms) and foliage. Its leaves are rich in protein and easy to ensile (Peng Buntha et al 2008). Taro is known in Khmer as 'Trao' and is planted as food supply for both human and animals. (Chhay Ty et al 2007). Forage which is receiving much attention recently as a feed for pigs is Taro (*Colocacia esculenta*). http://aggiehorticulture.tamu.edu/archives/parsons/vegetables/taro.html

Leaves from Taro are rich in vitamins and minerals. They are a good source of thiamin, riboflavin, iron, phosphorus and zinc, and a very good source of vitamin B6, vitamin C, niacin, potassium, copper and manganese. Oxalic acid may be present in the corm, however, and especially in the leaves (http://en.wikipedia.org/wiki/Taro). The leaves can be chopped and ensiled to considerably reduce undesirable substances in Taro, which thus becomes more palatable.

Recently, ensiling the Taro foliage is developed and has proved to be effective in reducing the oxalate content (Du Thanh Hang and Preston 2008). Initially molasses was used in the ensiling of Taro leaves (Malavanh et al 2006). However, the finding that the stem contained a high level of sugars led to the idea of ensiling the leaves and stem together (Rodríguez and Preston 2009), obviating the need for additional molasses.

"Khilao" or rice distillers' by-product is another potential source of high quality protein in rural areas of Laos, and is the waste after distilling the alcohol derived by yeast fermentation of sticky rice. The farmers use it as a wet feed for the pigs, it can be used as a mixture with other feeds such as rice bran and broken rice and can be fed to fattening pigs (Oosterwijk and Vongthilath 2003).

The farmers in Vietnam also use rice distillers' by-product or "hem" (Photo 1) as a traditional feed for pigs (Luu Huu Manh 2000). The report of Luu Huu Manh et al (2009) showed that the protein content ranged from 17 to 33% (mean of 23%) in dry matter and had a well-balanced array of amino acids. Luu Huu Manh et al (2003) reported that this product could replace completely the fish meal in growing and fattening pig diets with no loss of performance.

Photo 1. Rice distillers' by-product

The aim of this study therefore was to determine effects of inclusion of rice distillers' by-product into diets containing different proportions of taro silage and rice bran.

Material and methods

Location and duration

The experiment was carried out in Souphanouvong University, located in Donmai village, Luang Prabang district, Luang Prabang province about 17 Km from the City, from 3rd April 2011 to 12th May 2011.

Experimental design

Four treatments were compared in a 4*4 Latin Square arrangement with 4 pigs (Duroc x Large White), weighing on average 25 kg and 4 periods (Table 1). The treatments were:

RD0: Taro silage 59% (TS) supplement with rice bran (RB) 40% and minerals 1%.
RD10: Rice distillers' by-product (RD) 10% mixed with TS 39% , RB 50 % and minerals 1%.
RD20: RD 20% mixed with TS 24%, RB 55% and minerals 1%
RD30: RD 30% mixed with TS 10%, RB 59% and minerals 1%

Table1. Layout of the treatments.

Period	Pig1	Pig2	Pig3	Pig4
1	RD 0	RD10	RD20	RD 30
2	RD 30	RD 0	RD 10	RD 20
3	RD 20	RD 30	RD 0	RD 10
4	RD 10	RD 20	RD 30	RD 0

The duration of the experiment was 40 days with 4 periods each of 10 days, the first 5 days for adaptation then 5 days for collection (faeces and urine).

The composition of the diets is in Table 2.

Table 2. Composition of the diets (DM basis)

Ingredient	RD0	RD10	RD20	RD30	%CP in DM
Rice distillers' by-product	0	10	20	30	24.9
Taro silage	59	39	24	10	15.6
Rice bran	40	50	55	59	7
Mineral	1	1	1	1	-
Total	100	100	100	100	-
Estimated CP in DM	12	12.1	12.6	13.2	-

Animals and housing

The pigs were individually housed in cages made of wood, designed to separate faeces and urine (Photo 2). The floor area was 60*70 cm^2.


Photo 2: Metabolism cages made from wood

Feeds and feeding

The Taro (leaves and stems) were collected in the vicinity of Souphanouvong University where it was growing wild (Photo 3). The rice bran was bought from a rice mill in Luang Prabang city and rice distillers' by-product was bought from farmers in Donmai village.

Photo 3. Taro (*Colocaciaesculenta)* growing wild in Luang Prabang

The leaves and stems were chopped into small pieces (2-3 cm length) (Photo 4) and exposed to sunlight for 6 hours to reduce the moisture to about 75%, prior to packing tightly into 50 litre plastic bags where it was stored for 14 days before being fed to the pigs (Photo 5). The feeds were given two times per day at 6:30 AM and 5:30 PM, the amount being based on an offer level of 40-50 g DM/kg live weight. All ingredients were mixed and fed together; water was supplied *ad libitum* through nipple drinkers.

Photo 4: Taro (Leaves + stems) being chopped

Photo 5: Ensiled taro foliage (Leaves and stems)

Measurements and data collection

The pigs were weighed in the morning before starting each period. Feed offered was recorded and refusals collected daily. The refusals were stored in a refrigerator (4 °C) until the end of each collection period when they were mixed and sub-samples taken for analysis of DM, ash and N. Faeces and urine were collected daily. Each day 20 ml of 15 % H_2SO_4 were added to the urine container to maintain the pH of the urine below 4.0. All the faeces were stored in the refrigerator until the end of the collection period when they were mixed and a sub-sample taken for analysis of DM, ash and N. A sub-sample of urine was taken daily and stored in the refrigerator until the end of the collection period when the samples were mixed and a sub-sample taken for analysis for N.

Chemical analysis

Samples of feeds offered and refused and faeces were analysed for DM, ash and N using the procedures of AOAC (1990). Urine was analysed for N (AOAC 1990).

Statistical analysis

The data were analyzed using the general linear model (GLM) option of the ANOVA program in the MINITAB software (Minitab 2000). Sources of variation were pigs, periods, treatments and error.

Results and discussion

Chemical composition of feed

The content of crude protein in the rice bran was very low indicating that the quality of the bran was low with probably a high percentage of husks (Table 3). The crude protein in the rice distillers' by-product was in the range reported by Manh et al (2009).

Table 3: Chemical characteristics of the diet ingredients

		As % of DM	
Ingredients	**Dry matter**	**Organic matter**	**Crude protein**
Taro silage	27.1	93.2	15.6
Rice bran	89.47	88.5	7
Rice distillers' waste	7.8	98.6	24.9
Premix	98.4	-	-
Salt	97.6	-	-

Feed intake

The mixed diets were consumed completely. The daily DM intake as g/kg live weight increased to a maximum with 23% of the diet DM as rice distillers' by-product (Table 4; Figure 1). On all treatments the intake levels were high.

Table 4: Mean values (individual treatments) for intakes of DM, organic matter (OM) and crude protein (CP) by pigs fed increasing levels of rice distillers' by-product (as a supplement to taro silage and rice bran

	RD0	RD10	RD20	RD30	SEM	Prob.
DM intake, g/day						
Taro silage	745	508	314	131	-	-
Rice bran	534	684	756	802	-	-
Rice distillers' by-product	0	156	312	465	-	-
Total	1279^{b}	1348^{ab}	1382^{ab}	1398^{a}	31.5	0.048
g/kg LW	39.9^{b}	43.2^{ab}	46.3^{a}	45.8^{a}	1.08	0.013
OM intake, g/day						
Taro silage	696	479	295	123	-	-
Rice bran	472	605	668	709		
Rice distillers' by-product	0	154	308	460	-	-
Total	1168^{b}	1237^{ab}	1271^{a}	1292^{a}	27.58	0.013
N intake, g/day						
Taro silage	21.4	14.6	9.1	3.7	-	-
Rice bran	5.9	7.6	8.4	8.9	-	-
Rice distillers' by-product	0	6.4	12.8	19.1	-	-
Total	27.3^{b}	28.6^{b}	30.3^{ab}	31.8^{a}	0.81	0.001
CP in DM, %	13.3^{b}	13.2^{b}	13.7^{ab}	14.2^{a}	0.16	<0.001

^{ac} *Means without common superscript differ at P<0.05*

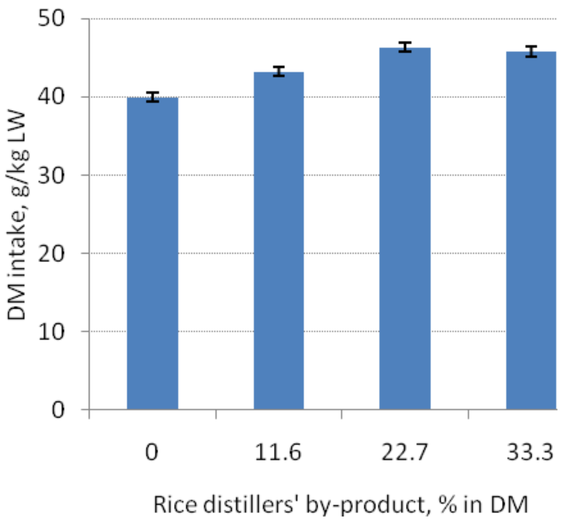


Figure 1: DM intake of pigs fed taro silage and rice bran, or mixtures of the two, with rice distillers' by-product

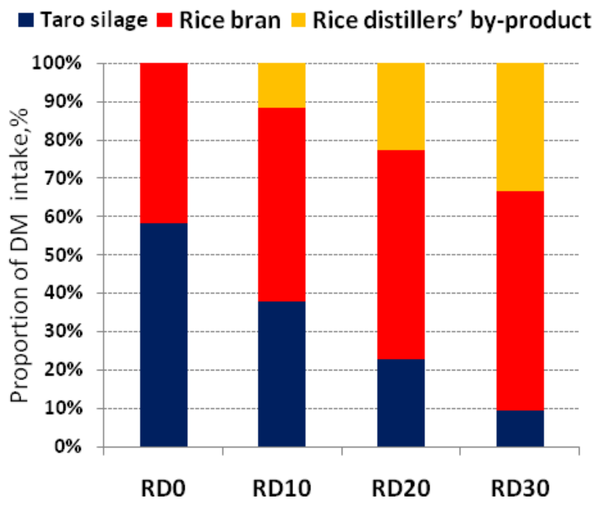


Figure 2: Proportion of DM intake of dietary ingredients in pigs fed taro silage and rice bran, or mixtures of the two, with rice distillers' by-product

Apparent digestibility coefficients

The apparent digestibility of DM, OM and CP decreased with increasing levels of rice distillers' by-product in the diet (Table 5; Figure 3). As the increase in rice distillers' by-product was associated with an increase in per cent of rice bran in the diet (Table 2), the resultant increase in fibre (higher in rice bran than in Taro silage) could explain the decrease in apparent digestibility (Kass et al 1980).

Table 5: Apparent digestibility of the diets fed to the pigs

	RD0	RD10	RD20	RD30	SEM	Prob.
Dry matter	72.9^{a}	65.5^{b}	67.2^{ab}	64.8^{ab}	2.43	0.049
Organic matter	71.7	64.3	66.2	63.9	2.43	0.100
Crude protein	78.6^{b}	68.3^{a}	73.8^{ab}	75.6^{ab}	2.2	0.012

[ab]Means within rows without common letters differ at P<0.05

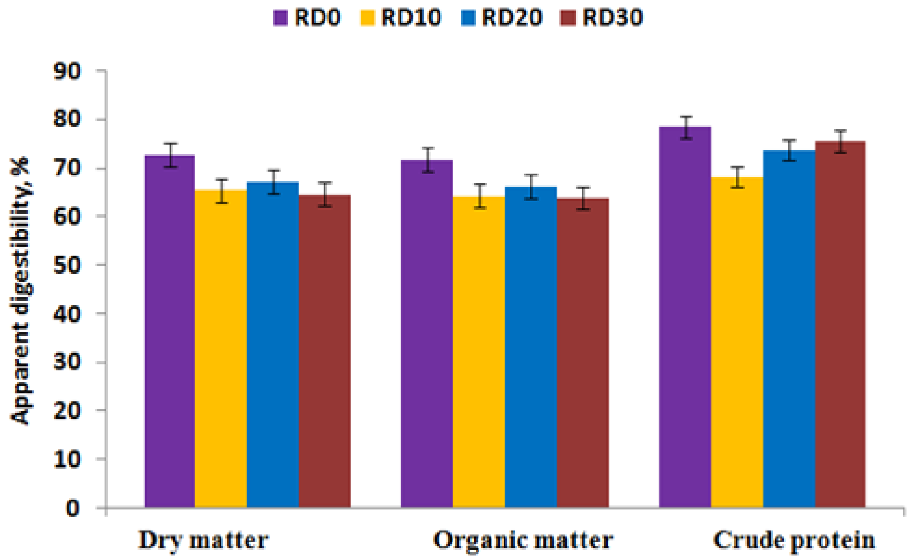


Figure 3: Mean values for digestibility of DM, OM and crude protein in pigs fed taro silage and rice bran, or mixtures of the two, with rice distillers' by-product.

Nitrogen balance

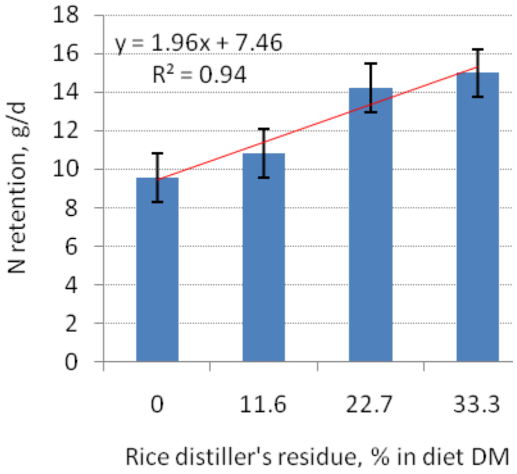
N intake and N retention increased on the diets with increasing level of rice distiller's by-product replacing taro silage (Table 6; Figure 4). Part of the increase in N retention was apparently due to the increased N intake, in turn the result of increased DM intake caused by replacement of Taro silage with rice distillers' by-product. Correcting the N retention data for differences in N intake decreased the effect of the level of rice distillers' by-product (P=0.26). The same trend was observed for N retained as per cent of N digested. The improvement in N retention with increasing levels of rice distillers' by-product replacing taro silage contrasts with the observed decrease in apparent N digestibility. The implication from these results is that the biological value of the rice distiller's by-product is higher than that of ensiled taro leaves and stems and that this effects more than counteracted the decrease in N digestibility.

Table 6. Mean values for N balance in pigs fed taro silage or mixtures of taro silage and rice bran or mixed of the two with rice distillers' by-product

	RD0	RD10	RD20	RD30	SEM	Prob.
N balance, g/day						
Intake	27.3^{b}	28.6^{b}	30.3^{a}	31.8^{a}	0.8	0.001
Faeces	5.70^{ab}	8.43^{a}	7.62^{ab}	7.51^{ab}	0.56	0.008
Urine	12.09	9.39	8.47	9.30	1.11	0.123
N Retention						
g/day	9.6^{b}	10.8^{ab}	14.2^{a}	15.0^{a}	1.28	0.009
g/day#	10.8	11.3	13.7	13.7	1.26	0.26
Retention, % (intake)	35.8	33.8	44.8	47.6	3.9	0.039
% of N digested	44.2	44.4	58.5	62.8	5.2	0.049
% of N digested#	45.2	49.0	58.9	59.8	6.9	0.49

^{ab} *Means with different letters within the same row are different at P<0.05*

 # Corrected for differences in N intake



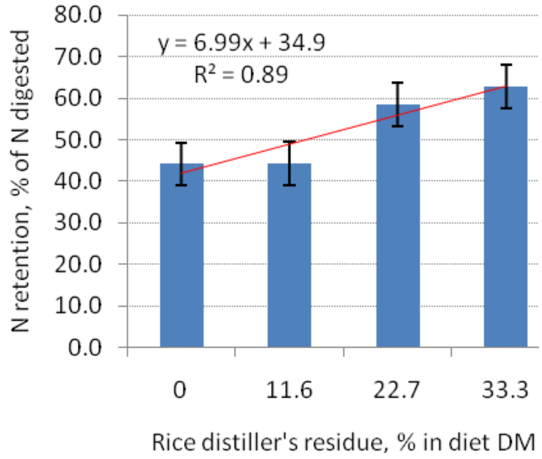


Figure 4. N retained in pigs fed increasing levels of rice distillers' by-product replacing taro silage

Figure 5. N retained as per cent of N digested in pigs fed increasing levels of rice distillers' by-product replacing taro silage

Conclusions

- Increasing the proportion of rice distiller's by-product in a basal diet of rice bran and taro silage (leaves and stems), led to an increase in feed intake of growing pigs
- Apparent digestibility of DM and CP tended to be lower, but N retention was increased.

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Effect of rice distillers' by-product on feed intake and growth performance of crossbred pigs fed mixtures of ensiled taro (*Colocacia esculenta*) leaves and stems and rice bran

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Abstract

A growth trial was conducted with 16 cross-bred pigs (Duroc x Large White) with average 23.4 kg mean initial live weight in a Randomized Complete Block Design (RCBD), with four replications of four treatments. The treatments were rice distillers' by-product (RD) at 0, 10, 20 and 30 percent of the diet DM replacing taro leaf-stem silage in a basal diet of rice bran.

There were positive curvilinear responses in live weight gain and feed conversion when rice distillers' by-product partially replaced taro leaf-stem silage in a basal diet of rice bran fed to growing pigs. It appears that part of the benefits from the rice distillers' by-product arises from the superior biological value of the protein compared with that in the taro silage. Another possibility is a probiotic effect arising from the residual yeast in the rice distillers' by-product. It is concluded that either the biological value of the protein in rice distiller's by-product is superior to that in taro silage, or that the rice distiller's by-product provides other nutrients or compounds (eg: probiotics) that promote better growth rate and feed conversion, or a combination of both factors.

Key words: *Feed conversion ratio, live weight gain, growth curves.*

Introduction

The livestock sub-sector in Lao PDR plays an important role in generating cash income for smallholder farmers. In particular poultry and pig production can be further developed in rural areas to increase the daily protein intake of the people and to generate cash income for the households (Horne et al 2000). Pigs are normally raised in a free-range system, and supplemented by rice bran and other household waste products. In remote villages, pigs are raised in traditional ways with pigs being allowed to scavenge for feed during the day and receiving additional cooked feed, such as cassava roots, maize and green feeds collected from forest margins, in the evenings. In these systems, pigs face feed shortages, both in terms of quantity and quality, with protein being particularly limiting. The lack of protein in traditional diets negatively affects the growth of pigs, with the average daily weight gain being no more than 100 g per day (Thorne 2005).

Leaves from Taro (*Colocasia esculenta* (L.) Schott), Giant taro (*Alocasia macrorrhiza*), and New Cocoyam (*Xanthosoma sagittifolium*) are traditionally used in pig diets by small-scale farmers in many tropical countries. Many studies report the nutritive value of Taro and that the plants can be used for feeding animals (Chhay Ty 2007; Pheng Buntha 2006; Giang 2010; Malavanh 2008). Taro is a tropical food crop with high potential because of the high yield of the roots (or corms) and foliage. The leaves are rich in protein and easy to ensile, which has been shown to reduce markedly the concentrations of calcium oxalate (Du Thanh Hang et al 2009). In the research by Pheng Bunta et al (2007), it was shown that taro leaf silage could replace up to 70-75% of the fish meal protein, with higher feed intakes and N retention than with 100% of the protein from fish meal.

Rice distillers' by-product is the residue from production of alcohol made from sticky rice, maize, sweet potato, cassava and bananas (Oosterwijk and Vongthilath 2003). Studies in Vietnam by Luu Huu Manh et al (2000) and Luu Huu Manh et al (2009) reported a mean protein content of 23% high quality protein in the DM. These authors suggested that this by-product was appropriate for supplementing feeds of lower nutritional density such as rice bran and forages. More recently, Lochana et al (2010) in a study in Lao PDR, reported the feeding of rice distillers' by-product with a mean crude protein content of 28% in DM basis.

The aim of the experiment reported in this paper was to determine average daily gain and feed conversion ratio in growing pigs fed rice distillers' by-product as partial replacement of ensiled taro foliage in a basal diet of rice bran.

Materials and methods

Location and climate of the study area

The experiment was carried out from April 3 to June 25, 2011 at the Faculty of Agriculture and Forestry, Souphanouvong University (SU), situated about 7 km from Luang Prabang city, Lao PDR. The mean daily temperature in the area at the time of the experiment was 27 ^{o}C (range 22-32 ^{o}C).

Animals and management

Sixteen crossbred pig (Duroc x Large White) with a mean body weight of 23.4 kg were bought from a pig farm in Vientiane city. They were vaccinated against swine fever and were treated against round worms with Ivermectin before starting the experiment.

The pigs were housed in individual pens (1 m x 1.2 m) made of wood with concrete floor and feeding troughs to allow recording of offered feed and to collect refused feed. The pigs had free access to water through nipple feeders.

Photo 1. Pigs individual pens made from wood with concrete floor

Photo 2. Pigs in individual pens, each with One feeder and one drinking nipple

Experimental design, treatments and management

Four treatments (Table 1) replicated 4 times were compared in a Randomized Complete Block Design (RCBD) as follows:

RD0 : Rice bran (RB) 40% and minerals 1% with ensiled taro foliage 59% (TS)
RD10: RB 50 % and minerals 1% with TS 39% and rice distillers' by-product (RD) 10%
RD20: RB 55% and minerals 1% with TS 24% and RB 55%
RD30: RB 59% and minerals 1% with TS 10% and RD 30%

Table 1. Composition of the diets (DM basis)

Ingredient	RD0	RD10	RD20	RD30	%CP in DM
Rice distillers' by-product	0	10	20	30	24.9
Taro silage	59	39	24	10	15.6
Rice bran	40	50	55	59	7
Mineral	1	1	1	1	
CP in DM, %	12.0	12.1	12.6	13.2	

Feeds and feeding

The taro leaves and stems were collected in the vicinity of Souphanouvong University where it was growing naturally. The rice bran was bought from a rice mill in Luang Prabang city. Rice distillers' by-product was bought from farmers in Donmai village.

The taro leaves and stems were chopped into small pieces (2-3 cm length) and exposed to sunlight for 6 hours to reduce the moisture to about 75%, prior to packing tightly into 50 litre plastic bags where it was stored for 14 days before being fed to the pigs. The feeds were given two times per day at 6:30 AM and 5:30 PM, the amount being based on an offer level of 40-50 g DM/kg live weight. All ingredients were mixed and fed together.

Data collection

The animals were weighed in the morning before feeding, at the beginning of the trial and every 14 days. Live weight gain was determined from the linear regression of live weight on days in the experiment. Samples of feed offered and refused were collected daily, weighed, and sub-samples stored at 4°C before being analyzed for DM, N and ash.

Chemical analysis

Chemical analysis of the feed ingredients and refusals were undertaken following the methods of AOAC (1990) for ash and N. The DM content was determined using the microwave method of Undersander et al (1993). All the analyses were conducted in duplicate.

Statistical analysis

The data for feed intake, feed conversion and growth rate were compared by using the general linear model (GLM) option in the ANOVA program of the Minitab software (Minitab 2000). The Tukey pair-wise comparisons were used to determine the differences between treatments with confidence level 95.0%.

Results and discussion

DM intake as a proportion of live weight increased slightly with 10% supplementation with rice distillers' by-product (RD) but with no further increase at higher levels. Increased in the diets up to the level of rice distillers' by-product 20% (Table 2; Figure 1). Intake of crude protein (CP) and crude fibre (CF), as proportions of the diet DM, increased linearly with the proportion of rice distillers' by-product in the diet.

Table 2. Mean values of feed intake of pigs fed taro silage and rice bran mixed with or without rice distillers' by-product

	RD0	RD10	RD20	RD30	SEM	Prob.
DM intake, g/day						
Taro silage	803	531	354	156		
Rice bran	542	682	813	842		
Rice distillers' by-product	0	143	310	448		
Total	1345[a]	1356[a]	1447[b]	1445[b]	20.9	<0.001
g DM/kg LW	40.3[a]	41.6[b]	41.0[ab]	40.7[a]	0.16	<0.001
CP intake, g/day						
Taro silage	122	81	54	23		
Rice bran	39	50	59	61		
Rice distillers' by-product	0	35	75	109		
Total CP intake	161[b]	165[b]	188[a]	193[a]	2.38	<0.000
CP / DM, g/kg	121[d]	123[c]	129[b]	136[a]	0.45	<0.001
Crude fiber intake, g/day						
Taro silage	205	136	90	40		
Rice bran	112	141	168	174		
Rice distillers' by-product	0	3	7	11		
Total CF intake	318[c]	280[b]	266[b]	225[a]	4.18	<0.001
Intake CF, g/kg LW	9.6[d]	8.4[c]	7.5[b]	6.2[a]	0.032	<0.001

[abcd] Mean values within rows with different superscript letters are different at P< 0.05

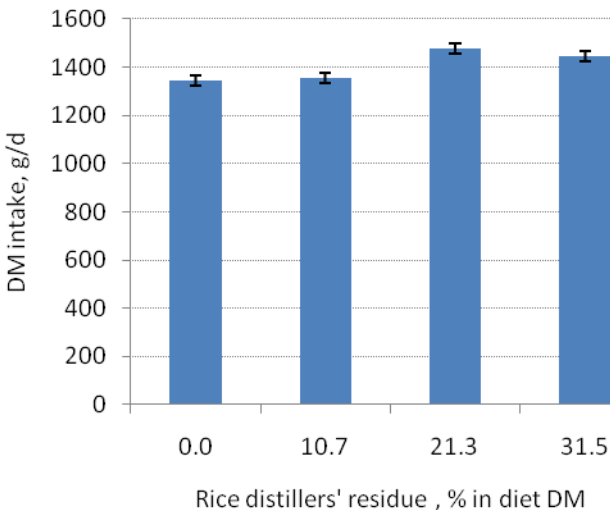

Figure 1. DM intake of pigs fed different proportions of rice distillers' by-product with taro silage and rice bran

Growth rate and feed conversion

The growth rate of the pigs was uniform on all treatments (Figure 2), with a positive curvilinear response to the proportion of rice distillers' by-product in the diet (Table 3; Figure 3). The DM feed conversion followed a similar curvilinear trend with improvements in feed conversion as the proportion of rice distillers' by-product in the diet was increased (Figure 4). There was a close relationship between live weight gain and DM feed conversion (Figure 5).

Table 3. Effect of rice distillers' by-product replacing taro silage on growth rate, feed intake and feed conversion of pigs fed a basal diet of rice bran

	RD0	RD10	RD20	RD30	SEM	Prob.
Live weight, kg						
Initial	24.2	23.4	24.1	22.1	1.52	0.75
Final	47.1[b]	48.8[ab]	54.5[ab]	58[a]	2.2	0.020
ADG, g/day	288[b]	295[b]	374[a]	451[a]	32	0.011
Feed intake, kg/day	1.35[b]	1.36[b]	1.48[a]	1.45[a]	20.9	<0.001
FCR, kg DM/kg LWG	4.9	4.81	4.02	3.22	0.505	0.135
Back fat, cm	2.41	2.73	3.24	3.12	0.306	0.360

[a,b] *Mean values within rows with different superscript letters are significantly different (P<0.05)*

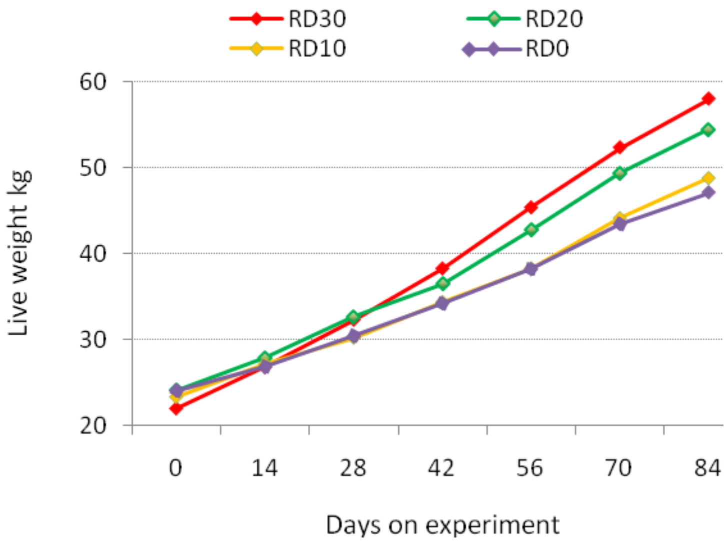

Figure 2. Growth curves of pigs fed increasing proportions of rice distillers' by-product replacing taro silage in a basal diet of rice bran

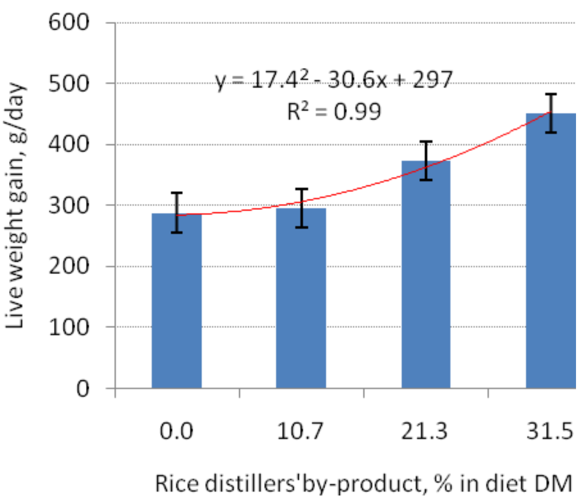

Figure 3. Growth rate of pigs fed increasing proportions of rice distillers' by-product replacing taro silage in a basal diet of rice bran

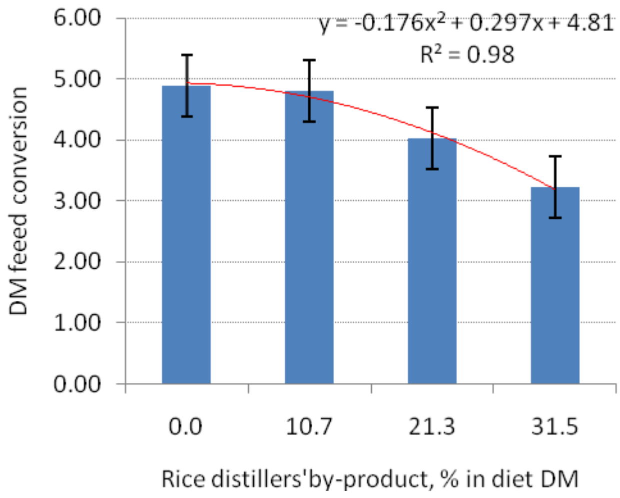

Figure 4. DM feed conversion of pigs fed increasing proportions of rice distillers' by-product replacing taro silage in a basal diet of rice bran

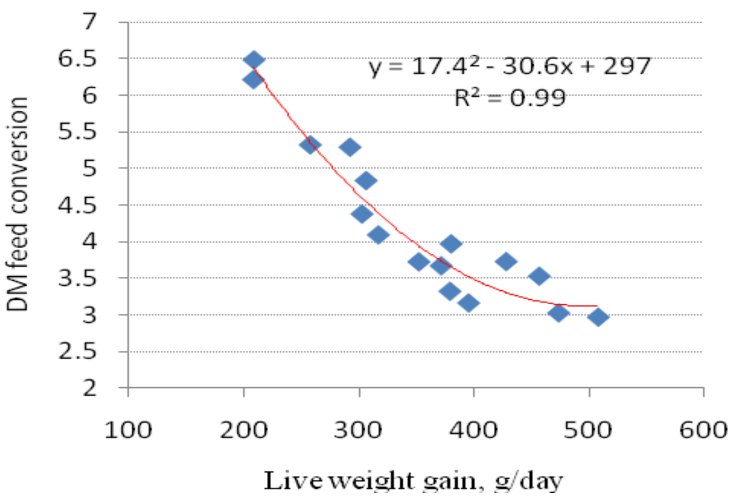

Figure 5. Relationship between live weight gain and feed conversion ratio of growing pigs fed increasing proportions of rice distillers' by-product replacing taro silage in a basal diet of rice bran

It is difficult to explain the 50% increase in growth rate and 36% improvement in feed conversion in response to the replacement by rice distillers' by-product by of some 80% of the dietary protein originally provided by the taro silage. Part of the improvement could be the result of the superior biological value of the protein in the rice distillers' by-product (Paper 2). The other possibility could be the provision of vitamins of the B-complex from the residual yeast in the rice distillers' by-product or perhaps more likely a probiotic effect also arising from the yeast in the rice distillers' by-product (Majdoub-Mathlouthi et al 2011; Marin Cárdenas et al 2007; Selmi et al 2010).

Conclusions

- There were positive curvilinear responses in live weight gain and feed conversion when rice distillers' by-product partially replaced taro leaf-stem silage in a basal of rice bran fed to growing pigs.

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