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Effect of rice distillers' by-product on growth performance and digestibility of Moo Laat and Mong Cai pigs fed rice bran and water spinach

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Abstract

Two experiments were carried out at the Integrated Farming Demonstration Center of Champasack University, situated about 13 km from Pakse City, Pakse District, Champasack Province, Laos PDR.

The first experiment was on the effect of rice distillers' by-product on growth performance and digestibility of Moo Laat and Mong Cai pigs fed rice bran and water spinach. Sixteen growing female pigs (8 Moo Laat and 8 Mong Cai) with an initial weight of 11 to 13 and 25 to 26 kg, respectively, were allocated to a 2*2 factorial arrangement with four replications of four treatments in a Completely Randomized Design (CRD). The factors were: breed of pig and supplementation with or without rice distillers' by-product. The basal diet was a mixture of rice bran and fresh water spinach. The diets were offered in amounts based on an expected DM intake of 4 % of live weight. For the control diet (no distillers' byproduct) the water spinach comprised 30% of the diet DM. For the diets with rice distillers' by-product the proportions (% DM) were 70, 20 and 10 for rice bran, water spinach and rice distillers' byproduct, respectively.

Mong Cai pigs grew faster than Moo Laat pigs, but the latter tended to have better feed conversion. There was an interaction between breed and rice distillers' supplementation for both DM intake per unit LW and live weight gain. Supplementation increased the intake and growth rate in the Mong Cai pigs. During the first 6 weeks of the experiment the Moo Laat pigs fed the rice distillers' product grew more slowly than those not fed the supplement. During the final 6 weeks the response of the Moo Laat pigs was reversed, with higher gains observed for the pigs fed the supplement. Coefficients of digestibility determined by the insoluble ash method were not affected by supplementation with rice distillers' by-product but appeared to be higher for the Mong Cai compared with the Moo Laat.

The second experiment was on the effect of a supplement of water spinach on digestibility by growing Mong Cai pigs fed a basal diet of rice bran. Three Mong Cai gilts weighing from 67 to 70 kg were allocated at random to three treatments within a 3*3 Latin Square design with periods of 10 days (5 days for adaptation and 5 days for collection of data). The treatments were: RB: rice bran only; RBWS15: rice bran supplemented with 15% of water spinach; and RBWS30: rice bran supplemented with 30% of water spinach. Feeding level was 4% of live weight as dry matter (DM). The ratios of rice bran to water spinach were on a DM basis.

Intake of DM and apparent digestibility of DM and crude protein were increased when water spinach replaced up to 15% of the DM of the basal diet of rice bran. Using the "difference" method it was estimated that the coefficients of apparent digestibility of the DM and crude protein of the water spinach were 99 and 150%, implying that the effects of the water spinach on the digestibility of the mixed diet with rice bran were synergistic.

Key words: Acid insoluble ash, adaptation, forages, local breeds, foliages, local breeds, synergism

Table of contents

Abbreviations

ADG	Average daily gain
ADF	Acid detergent fiber
AIA	Acid insoluble ash
CRD	Completely Randomized Design
CP	Crude protein
CF	Crude fibre
DMI/LW	Dry matter intake/Live weight
DM	Dry matter
HCl	Hydrochloric acid
LW	Live weight
LWG	Live weight gain
MC	Mong Cai pig
MC-RW	Mong Cai fed rice bran and water spinach
MC-RWDB	Mong Cai fed rice bran and water spinach supplemented with rice distillers' by-product
ML	Moo Laat pig
ML-RW	Moo Laat fed rice bran and water spinach
ML-RWDB	Moo Laat fed rice bran and water spinach supplemented with rice distillers' by-product
N	Nitrogen
NDF	Nitrogen detergent fibre
No RDB	No rice distillers' by-product
OM	Organic matter
RDB	Rice distiller's by-product
RB	Rice bran
RBWS15	Rice bran with water spinach 15% of the diet DM
RBWS30	Rice bran with water spinach 30% of the diet DM
RDB	Rice distillers' by-product
RWS	Rice bran mix with water spinach
WS	Water spinach

1. Introduction

Farmers in Laos traditionally keep pigs of predominantly indigenous breeds in foraging systems. The number of pigs kept by a household varies between 1.4 and 3.7 animals, depending on the region (Knips 2004). There are several breeds of local pig called: Moo Chid, Moo Laat, Moo Daeng and Moo Nonghaet. They are slow growing with high fat content in the carcass. Mature body weight in sows ranges from 60 to 90 kg, except for the Moo Chid that is smaller. The litter size is usually small (7 to 8) and the farrowing interval about 1.5 litters per year. The native breeds are hardy, well adapted to a free-ranging system and can survive in a hot climate on low quality feed, and have a high resistance to diseases (Vongthilath and Blacksell 1999). A small number of farmers use exotic breeds or crossbreeds, but compared to local breeds they are considered to be less resistant in smallholder farming conditions and do not perform as well. The type of feed given depends on the farming system, the availability of labor and suitable natural vegetation. Feeds include rice bran, broken rice, banana pseudostem, taro, yams, maize, cassava, by-products (especially rice distillers' waste) and vegetation collected in fallow fields and forests (Stür Werner et al 2002)

Lon Mong Cai (Mong Cai pig) is an indigenous breed that originated from Quang Ninh province, in northern Vietnam. The breed is very well adapted to the harsh conditions in the region and is known for its early puberty, good litter size and maternal ability. The Mong Cai have been shown to perform better than Large White sows when the diet is based on forages (Nguyen Van Lai 1998 and Hoang Nghia Duyet et al 2006).

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. Thus Bounhong Norachack et al (2004) reported that N retention was two times higher when cassava leaves replaced stylosanthes.

2. Hypotheses

The hypotheses underlying the present study were that: (i) the growth performance of local Moo Laat pigs and Mong Cai pigs imported from Vietnam would be improved when rice distillers' by-product was added to a basal diet of rice bran and water spinach; (ii) the Mong Cai breed would have superior performance compared with the local Moo Laat breed; and (iii) a supplement of fresh water spinach will lead to improvements in the apparent digestibility of the basal diet of rice bran.

3. Objectives

- To evaluate the growth performance of local Moo Laat and Mong Cai pigs when fed rice distillers' by-product as a supplement to a basal diet of rice bran and water spinach
- To compare the local Moo Laat breed with the Mong Cai breed imported from Vietnam
- To evaluate the effect of the level of water spinach on intake and digestibility in growing Mong Cai pigs fed a low protein basal diet of rice bran.

4. General discussion

4.1 Local feed resources for pigs in Laos

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 remote upland areas, the collection of feed can take up as much as 2-3 hours per day in addition to its preparation and cooking. In some villages, cassava and maize are specially planted for pig feed and this reduces the labor needs (Stür Werner 2002). On the other hand, Phengsavanhanh et al (2006a) reported that Stylo 184, which was introduced as a broadly adapted forage legume for feeding to ruminants, could also be fed to pigs and poultry. Using Stylo as a supplement to traditional feeds has great potential, and they considered that for poor smallholder farmers in the uplands of Lao PD, Stylo could be a valuable supplement. The pigs liked to eat Stylo and it was found that they grew better with Stylo than with natural leaves and herbs, the gain in weight being 191 g/day and 95 g/day, respectively. Intake was better when the Stylo was fed sun-dried than fresh (Phengsavanhanh 2006b). Khoutsavang (2003) reported that the mixture of cassava foliages and fresh Stylo 184 fed together *ad libitum* improved the quality of the diet, resulting in higher intake and better growth rate and feed conversion, which led to improved economical efficiency, as well as making use of locally available, low cost resources.

4.2 Pig production in Laos

Pig production is an important livelihood activity of the small-holder farmer in Laos. Management is simple as the pigs are allowed to scavenge freely around the house and village. In some cases a supplement of cooked feed made from locally available resources is provided.

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).

Table 1: Trends in the number of animals in the Mekong region 1990 to 2000 and predicted for 2015.

		Stocks in 1,000 heads			
Country	**Year**	**Buffaloes**	**Cattle**	**Pigs**	**Chickens**
Cambodia	1990	736	2,181	1,515	8,163
	2000	694	2,993	1,934	15,249
	2015		4,088	2,788	26,785
Laos	1990	1,072	842	1,372	7,884
	2000	1,028	1,100	1,425	13,095
	2015		2,856	2,267	18,361
Thailand	1990	5,094	5,482	4,762	107,559
	2000	1,900	4,602	6,558	232,000
	2015		11,333	8,241	245,171
Vietnam	1990	2,854	3,117	12,261	75,200
	2000	2,897	4,128	20,194	137,300
	2015		8,040	24,296	230,665

Source: Knips Vivien 2004

4.3. Local pig breeds in Laos and Vietnam

The tropics present great opportunities for sustainable development thanks to the enormous cultural and biological riches of these regions. The rational exploitation of local feeds and local breeds of livestock will support much more sustainable production systems in the medium and long term. These have received insufficient attention in the past and have not been considered seriously because of the introduction of "exotic" systems based on high inputs, high technology and "breeds of high genetic merit". As a result, local breeds of pigs and cattle in many tropical countries have disappeared, or their population is decreasing drastically (Rodríguez and Preston 1997). Local breeds perform well in low-input systems, fulfilling multiple functions for small-holder households. They have lower performance than exotics, but require lower production inputs (Lemke et al 2005).

4.3.1 Moo Laat pigs

In Lao PDR, farmers keep pigs more than other species of animal. Local pigs are the main stock to be raised and their feeds are derived from vegetables collected from the forest, root crops such as cassava, maize and wild root crops and household refuse. This practice is termed low input - low output. The main constraint is protein (Keo 2000).

Several native breeds are recognized, including ‘Moo Chid’, ‘Moo Laat’, ‘Moo Daeng’ and ‘Moo Nonghaet’. Most local pigs tend to have high fat content in the carcass, are black in colour and are swaybacked, as are most Asian breeds. They reach a mature weight of 60-100 kg. They are hardy and able to scavenge at least part of their feed requirements in free-range conditions. Growth rates tend to be slow in extensive management systems and animals may take 15 months to reach a weight of 40-50 kg (Kennard 1996). 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.

4.3.2 Mong Cai pigs

In Vietnam there are about 1 million Mong Cai sows, which is around 50% of the total sow population. The breed is particularly popular in the North and Central parts of the country, where it is used as parent stock for the production of crossbred fatteners. In the rural areas farmers often feed Mong Cai sows with low levels of protein based on locally produced feed resources, such as crop residues and agro-industrial by-products (Hoang Nghia Duyet et al 2000).

The Mong Cai breed has small to medium body size. The head is black with small and upright ears. Black patches are elsewhere on the body with a white band running from one side of the abdomen over the shoulder to the other side of the abdomen, making a white saddle over the middle of its concave back. High prolificacy, good adaptation to poor-quality feed and disease resistance are its favored characteristics. Gilts reach puberty at 2-3 months of age. Average litter size at birth is as high as 12. Pigs weigh 60 kg at 12 months of age, with back-fat thickness of 53-59 mm (Nguyen Ngoc Tuan and Tran Thi Dan 1995).

Lemke (2006) studied pigs in two villages with semi-intensive production conditions and a high rate of improved Mong Cai sows producing LW×MC offspring. The performance in the observed population was high (1.5 litters/year, with 8.4 piglets weaned, up to 93.0 kg weight of piglets weaned sow/year, and 177 g/day daily weight gain). Lower performance of 1.1 litters/year, 5.5 piglets weaned/litter, 30.9

kg piglets' weaned sow/year, and 85 g/day ADG were observed in indigenous Ban pigs in villages distant from towns managed under extensive conditions.

In the experiment reported in Paper I, the Mong Cai gilts grew faster than the Lao indigenous Moo Laat pigs, and appeared to digest better the basal diet of rice bran and water spinach. The Mong Cai also grew faster when the basal diet of rice bran and water spinach was supplemented with rice distillers' by-product. In contrast, the Moo Laat gilts appeared to require a considerable time (about 6 weeks) before they began to respond to the rice distillers' residue.

Dam Van Tien and Preston (2003) showed that weaned piglets exposed to an unfamiliar feed (duckweed) required a considerable time to adapt to the new feed, but this time was shortened when the mother sows were fed the "unfamiliar" feed during pregnancy (*in utero* adaptation), or in early lactation when the piglets could "learn from their mother". It is possible that a similar phenomenon might explain the long adaption period to rice distillers' by-product noted in the Mong Laat pigs.

4.4 Water spinach (Ipomoea aquatica)

Water spinach is easy to grow on soil or in water and responds dramatically to fertilization with organic manure, especially the effluent from biodigesters. Kean Sophea and Preston (2002) reported that the important feature of water spinach is its capacity yield high levels of biomass when fertilized with effluent from biodigesters charged with pig manure. The biomass yield was higher when water spinach was grown in soil rather than in water according to Ly Thi Luyen and Preston (2003). Le Thi Men and Preston (2005) have suggested that small-holder farmers should cultivate vegetables as supplements for pigs, using animal excreta effectively. San Thy and Preston (2001) also reported that the effluent from a biodigester loaded with pig manure was a good fertilizer for water spinach production, and improved soil productivity. Earthworm compost was superior to urea in promoting biomass growth and crude protein content of water spinach (Tran Hong Chat and Preston 2005).

Fresh biomass yields were higher (15 tonnes/ha/month) when water spinach was established from seed than from stem cuttings (9.18 tonnes/ha/month) (Ho Bunyeth and Preston 2004). The N content of the water spinach leaves increased from 3.08 to 5.56% in DM (from 19.3 to 34.8% crude protein) by application of 200 kg N/ha as biodigester effluent. Stems were much lower in N (1.2 to 2.0% in DM) and this index tended to decrease with increasing application of effluent N

4.4.1 Using Water spinach as a protein supplement in pig diets

Water spinach is traditionally consumed by people in SE Asia and appears to be devoid of non-nutritional elements. Harvesting this plant from lagoons fertilized with waste water from urban centres is an important source of income for poor people in Vietnam, Cambodia and Laos. In addition, water spinach can produce high yields of biomass rich in protein, which makes it a potentially valuable supplement for feeding pigs (Sorn Suheang et al 2003). Fresh chopped water spinach can replace 30% of the DM of concentrate diets for gestating sows and 15% of the diet of lactating sows of both local and exotic breeds according to Le Thi Men et al (2000) and Sivilai et al (2010). Hoang Nghia Duyet et al (2010) have shown that a mixture of foliages (sweet potato leaves, water spinach and cassava leaves) can replace 50% of a conventional protein supplement for both Mong Cai and Yorkshire sows without affecting piglet performance or sow reproduction. Water spinach can replace 20% of the crude protein in a concentrate for fattening pigs (Le Thi Men 2001). Higher levels of water spinach were used by Chhay Ty et al (2005), who reported that the growth and conversion rates were 50% better for the diets with water spinach alone, or as a mixture with fresh cassava leaves, compared with fresh cassava leaves alone. Growth rates and feed conversion tended to be better when mulberry leaves were mixed with the water spinach compared with mulberry leaves alone (Chiv Phiny et al 2008). Chhay Ty and Preston (2006) have shown that there is a synergistic effect on growth rate of pigs by replacing cassava leaves with water spinach, as the main protein source. The relative response to substituting cassava leaves with water spinach increased as the degree of replacement was increased (Chhay Ty et al 2006a and 2006b).

A similar synergistic effect was observed when water spinach was added to rice bran in the experiment reported in Paper II. The predicted (by the "difference" method) coefficients of apparent digestibility were 99 and 150% for the DM and crude protein in the water spinach, when this supplied 15% of the diet DM) implying that the effect of adding the water spinach to the rice bran was much greater than expected from the arithmetic average of the digestibility of the rice bran and the water spinach as separate feeds, even assuming the water spinach had been 90% digestible.

4.5 Rice distillers' by-product

Local alcohol can be made from sticky rice, maize, sweet potato, cassava and bananas. Most popular for pig feeding is rice distillers' residue. It should be mixed with other feeds such as rice bran and broken rice. Distillers' residues can be fed to fattening pigs. The following is an example of combining distillers' residues with energy-rich feeds: rice bran (2 kg), broken rice (1 kg) and distillers' residues (5-10 liters) (Oosterwijk and Vongthilath 2003).

4.5.1 How to made Lao alcohol

The wine is made from sticky rice that is fermented with yeast, as shown below:

1. Weigh 25 kg of the sticky rice and then soak it with clean water for 1 night
2. After that take off the excess and steam for 1:30 hours
3. The total weight of the mixture is now about 36 kg and is then divided into 4 parts (9 kg/jar)
4. Water is added to clean the sticky rice and to reduce the temperature
5. The yeast (40 g/jar) is then added and mixed together with the sticky rice, and after that the mixture is returned to the jar which is then covered.
6. Wait for 3 days (72 h) and then add water (8 liters/jar) to the jar and ferment it for 4 more days (96h).
7. The final step is to distill the alcohol. The contents of the 4 jars are put into one large pot and boiled.
8. The final products are alcohol rich wine (19 – 21 liters of strength about 40 degrees) and rice distiller's residue (around 52 kg wet form)

Some of the steps in the process are shown below:

Photo 1: Steaming sticky rice

Photo 2: Washing

Photo 3: Putting the yeast in

Photo 4: Mixing it together

Photo 5: Putting in the jar

Photo 6: Fermenting

Photo 7: Boiling

Photo 8: Rice distillers' by-product

4.5.2 Chemical composition of the ingredients and the product

Table 2: Chemical composition of the ingredients, the fermented mixture and the residue

Ingredients	DM%	As % of DM		
		CP	**Ash**	**OM**
Sticky rice	82.3	5.8	0.4	99.6
Yeast	91.8	39.9	16.9	83.1
Rice fermented with yeast	29.9	24.1	0.68	99.3
Rice distillers' by-product	24.7	27.3	1.25	98.8

In the experiment reported in Paper I, there were positive responses in growth rate of Mong Cai gilts when rice distillers' by-product was added at the 10% level to the basal diet of rice bran and water spinach. This is in agreement with the report of Luu Huu Manh et al (2003). This positive effect was not initially evident in the indigenous Moo Laat gilts that grew more slowly on the distillers' by-product supplement during the first 6 weeks after first exposure to this feed. Subsequently, however, they compensated by growing faster with the distillers' supplement. The need for adaptation in the case of the Moo Laat may be because of lack of familiarity with this new feed by previous generations of this local breed. In contrast, in Vietnam (from where the Mong Cai gilts originated), it is common practice to feed the rice distillers' by-product to pigs and it has a well balanced array amino acids (Luu Huu Manh et al 2009).

Table 3: Crude protein (%, in DM) and amino acid composition (g/16 g N) of rice distillers' by-product

	Average	Minimum	Maximum	±SD	CV, %
Crude protein	23.1	16.7	32.5	4.59	25.5
Aspartic acid	8.92	6.82	15.97	2.4	13.33
Threonine	4.89	2.68	7.81	1.71	9.5
Serine	4.77	3.41	8.06	1.15	6.39
Glutamic acid	17.8	12.9	32.5	4.82	26.8
Proline	4.81	2.39	10.02	1.9	10.6
Glycine	4.86	3.51	9.57	1.62	9
Alanine	7.16	5.39	14.54	2.31	12.8
Cysteine	2.42	1.77	4.6	0.77	4.28
Valine	6.03	2.73	12.36	2.42	13.44
Methionine	2.05	1.24	3.99	0.78	4.33
Isoleucine	4.42	3.14	9.19	1.68	9.33
Leucine	7.98	4.19	15.82	2.94	16.33
Phenylalanine	5.32	4.19	9.57	1.46	8.11
Lysine	3.91	1.84	8.14	1.52	8.44
Arginine	5.59	3.96	10.02	1.71	9.5

Source: Luu Huu Manh et al 2009

4.6 Digestion and utilization of fibre by pigs

Fiber is an important component of all but a few feedstuffs used in the feeding of pigs. It is resistant to digestion by endogenous enzymes in the small intestine, thereby becoming the main substrate for bacterial fermentation in the large intestine and caecum (Knudsen 2009). Because of the physical properties of dietary fiber, it interacts both with the microflora and the mucosa at all sites in the gastrointestinal tract. In this way it has an important role in the complex interaction between the diet, the endogenous enzymes, the mucosa and the microflora, all of which are considered important in the assimilation of nutrients and are key components for optimal "*gut health*". Jérôme et al (2007) also commented on the role of dietary fiber as a possible means to reduce nitrogen losses in production units and to improve intestinal health and welfare of the pigs.

Various studies suggest that the pig can utilize fiber for growth, and up to 30% of its maintenance energy may be derived from volatile fatty acids produced in the large intestine and caecum (Roman et al 1987; Ogle 2006). It appears desirable that in the future, pig production should utilise at least a proportion of fibrous carbohydrate polymers (Leng 1991). On the other hand, fibrous feeds may have a potential role to play in the overall performance of breeding sows. The stress of 'hunger" associated with restricted feeding of high nutrient density feeds during gestation is lessened by feeding bulky (fibrous) feeds which are consumed more slowly (Zoiopoulos 2000). Increasing the fiber content in the diet affected the fecal digestibility of CP, ether extract, and energy (Wilfart et al 2007); however, ileal digestibility of amino acids was not affected according to Lenis et al (1996) and Sauer et al (1991).

5. Conclusions

- Indigenous pigs are suitable for the small-holder farmer as they are adapted to finding and consuming available feed resources in the farm environment.
- There are opportunities for using a wide range of forages as sources of protein to balance rice bran, which is the most commonly available feed resource in SE Asian countries

- The residues from artisan production and distilling of rice wine are valuable sources of high quality protein that are appropriate for supplementing feeds of lower nutritional density such as rice bran and forages.

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Effect of rice distillers' by-product on growth performance and digestibility of Moo Laat and Mong Cai pigs fed rice bran and water spinach

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Abstract

Sixteen growing female pigs (8 Moo Laat and 8 Mong Cai) with an initial weight of 11 to 13 and 25 to 26 kg, respectively, were allocated to a 2*2 factorial arrangement with four replications of four treatments in a Completely Randomized Design (CRD). The factors were: breed of pig and supplementation, with or without rice distillers' by-product. The basal diet was a mixture of rice bran and fresh water spinach. The diets were offered in amounts based on an expected DM intake of 4 % of live weight. For the control diet (no distillers' byproduct) the water spinach comprised 30% of the diet DM. For the diets with rice distillers' by-product the proportions (% DM) were 70, 20 and 10 for rice bran, water spinach and rice distillers' byproduct, respectively.

Mong Cai pigs grew faster than Moo Laat pigs but the latter tended to have better feed conversion. There was an interaction between breed and rice distillers' supplementation for DM intake per unit LW and live weight gain. Supplementation increased the intake and growth rate in the Mong Cai pigs. During the 6 weeks of the experiment the Moo Laat pigs fed the rice distillers' product grew more slowly than those not fed the supplement. During the final 6 weeks the response of the Moo Laat pigs was reversed with higher gains observed for the pigs fed the supplement. Coefficients of digestibility determined by the insoluble ash method were not affected by supplementation with rice distillers' by-product but appeared to be higher for the Mong Cai compared with the Moo Laat.

Key words: Acid insoluble ash, adaptation, forages, local breeds

1. Introduction

Farmers in Laos traditionally keep pigs of predominantly indigenous breeds in foraging systems. The number of pigs kept by a household varies between 1.4 and 3.7 animals, depending on the region

(Knips 2004). There are several breeds of local pig, called: Moo Chid, Moo Laat, Moo Daeng and Moo Nonghaet. They are slow growing with high fat content in the carcass. Mature body weight in sows ranges from 60 to 90 kg, except for the Moo Chid that is smaller. The litter size is usually small (7 to 8) and the farrowing interval about 1.5 litters per year. The native breeds are hardy, well adapted to a free-ranging system and can survive in a hot climate on low quality feed, and have a high resistance to diseases (Vongthilath and Blacksell 1999). A small number of farmers use exotic breeds or crossbreeds, but compared to local breeds they are considered to be less resistant in smallholder farming conditions and do not perform as well. The type of feed given depends on the farming system, the availability of labor and suitable natural vegetation. Feeds include rice bran, broken rice, banana pseudostem, taro, yams, maize, cassava, by-products (especially rice distillers' waste) and vegetation collected in fallow fields and forests (Stur Werner et al 2002).

Lon Mong Cai (Mong Cai pig) is an indigenous breed that originated from Quang Ninh province, in northern Vietnam. The breed is very well adapted to the harsh conditions in the region and is known for its early puberty, good litter size and maternal ability. The Mong Cai have been shown to perform better than Large White sows when the diet is based on forages (Nguyen Van Lai 1998 and Hoang Nghia Duyet et al 2006).

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. Thus Bounhong Norachack et al (2004) reported that N retention was two times higher when cassava leaves replaced stylosanthes.

Water spinach (*Ipomoea aquatica*) is a vegetable cultivated for food and also used as pig feed throughout Southeast Asia. The fresh leaves and stems of water spinach are rich in protein. They have been used successfully to replace part of the protein in diets based on rice by-products (Chhay Ty et al 2005; Chittavong Malavanh et al 2008a).

Another potential source of high quality protein in rural areas of Laos is the waste after distilling the alcohol derived by yeast fermentation of sticky rice. The waste is called "Khilao" and is used as a wet feed for pigs. Rice distillers' by-product or "hem" is traditionally used by farmers in Vietnam. Luu Huu Manh (2000) and Luu Huu Manh et al (2009) showed that the protein content ranged from 17 to 33% (mean of 23%) in dry matter (DM) and that it had a well-balanced array of amino acids. Luu Huu Manh et al (2003) reported that this product can replace completely the fish meal in growing and fattening pig diets with no loss of performance.

2. Materials and methods

2.1 Location

The experiment was carried out at the Integrated Farming Demonstration Center of Champasack University, situated about 13 km from Pakse City, Pakse District, Champasack Province, Laos PDR. The temperature in the area averages 27^0C (range 22 to 32). The experiment began on 14 September and finished on 14 December 2009.

2.2 Experimental design

Four treatments were compared in a 2*2 factorial, Completely Randomized Design (CRD) (Table 1). The factors were:

- **Breed:** Moo Laat or Mong Cai (Photos 1 and 2)
- **Diet:** With or without rice distillers' by-product

Photo 1: Moo Laat female

Photo 2: Mong Cai female

Table 1: Experiment layout.

Pen No.	1	2	3	4	5	6	7	8
Treatment	MC-RW	ML-RWDB	MC-RWDB	MC-RW	MC-RWDB	ML-RW	ML-RWDB	MC-RWDB
Pen No.	9	10	11	12	13	14	15	16
Treatment	ML-RW	MC-RW	ML-RWDB	ML-RW	MC-RW	ML-RW	ML-RWDB	MC-RWDB

The individual treatments were:

- **ML-RW:** Moo Laat fed rice bran and water spinach
- **MC-RW**: Mong Cai fed rice bran and water spinach
- **ML-RWDB:** Moo Laat fed rice bran, water spinach and rice distillers' by-product
- **MC-RWDB**: Mong Cai fed with rice bran, water spinach and rice distillers' by-product

2.3 Animals and management

The local pigs (Moo Laat) were bought from the market in Pakse district with initial weights ranging from 11 to 13 kg. The Mong Cai pigs were imported from the Government pig farm in Hue province, Vietnam, with initial weights ranging from 25 to 26 kg. Both breeds were the same age (1 year), and the pigs were housed in individual pens (2*2 m) with concrete floors and provided with feeders, and automatic water drinkers. The pigs were vaccinated against salmonella disease and de-wormed with Ivermectin before the start of the experiment.

2.4 Feeds and feeding

The diets (Table 2) were formulated to contain 11% crude protein in the diet DM. They were supplemented with a mineral-vitamin premix (Table 3). The diets were offered in amounts based on an expected DM intake of 4 % of live weight. For the control diets (no distillers' byproduct) the water spinach was given at 30% of the diet DM. For the diets with rice distillers' by-product the proportions (% DM) were 70, 20 and 10 for rice bran, water spinach and rice distillers' by-product, respectively.

Table 2: Amounts of feed (fresh basis) offered daily, according to LW

		Diet RW, kg/d		Diet RWDB, kg/d		
LW kg	DM, kg/day	Rice bran	Water spinach	Rice bran	Water spinach	Rice distillers' byproduct
15	0.6	0.47	2.25	0.47	1.5	0.75
20	0.8	0.62	3	0.62	2	1
25	1	0.78	3.75	0.78	2.5	1.25
30	1.2	0.93	4.5	0.93	3	1.5
35	1.4	1.09	5.25	1.09	3.5	1.75
40	1.6	1.24	6	1.24	4	2
45	1.8	1.4	6.75	1.40	4.5	2.25

Table 3: Composition of the vitamin - mineral premix supplied (in 1 kg)

	Amount	Unit
Vitamin A	500	IU
Vitamin D3	150	IU
Vitamin B2	0.25	mg
Vitamin E	0.4	mg
Folic acid	0.165	mg
Mineral premix		
Ca	378160	mg
P	8400	mg
Iron	3410	mg
Cobalt	88.4	mg
Manganese	1280	mg
Iodine	76.1	mg
Potassium	23.6	mg
Zn	4344	mg
Mg	244	mg
Copper	550	mg
Other	200	mg

The rice bran (Photo 3) and water spinach (Photo 4) were bought in the market. The distillers' waste (Photo 5) was purchased every three days directly from farmer households. The water spinach was chopped into small pieces (0.5 cm) and then all the diet ingredients were mixed together before feeding the pigs, which was done in two meals per day at 07.00 and 16.00 hours.

Photo 3: Rice bran

Photo 4: Water spinach

Photo 5: Rice distillers' by-product

2.5 Measurements

2.5.1 Growth and feed conversion

The pigs were weighed every 2 weeks during the experiment, which lasted 84 days. Live weight gains were calculated from the linear regression of live weight (Y) on days in the experiment (X). Feeds offered and residues were recorded daily. Samples of feeds and residues were taken weekly and stored at -16 °C until analysis.

2.5.2 Apparent digestibility

The acid-insoluble ash (AIA) method was used (Van Keulen and Young 1977). Samples of feed and feces were taken over 5 consecutive days. Samples of feces were collected from the floor of the pens 3 to 4 hours after the first feed in the morning and stored at -18°C. This procedure was repeated for 5 days, after which the samples were bulked according to individual animals. Feed samples were taken over the same time period.

2.6 Chemical analysis

Samples of feeds and refusals were analyzed for dry matter (DM) by micro-wave radiation (Undersander et al 1993), and nitrogen (N), crude fibre (CF) and ash following AOAC (1990) procedures.

The samples taken during the digestibility trial were analysed for acid-insoluble ash (AIA) according to the method of Van Keulen and Young (1977). Samples (5g) were ashed for 4-6 hours in a muffle furnace at 450°C. The ash was transferred to a 600 ml beaker and extracted with 100 ml of a solution of HCl (178 ml concentrated HCl and 1 litre of water) after boiling for 5 minutes. The suspension was then filtered and the solid residue transferred to filter paper and ashed again at 450°C for 6h. Acid insoluble ash (AIA %) was calculated as:

- **% AIA** = [initial weight of ash-final weight of ash]/initial weight*100

Calculations of apparent digestibility were made as follows:

- **Digestibility of DM** = 100-[(100*%AIA in feed)/%AIA in feces]

- **Digestibility of nutrients** = 100- [[(%AIA feed) x % concentration of nutrient] x 100%]/ %AIA Feces x % concentration of nutrient

2.7 Statistical analysis

The data were analyzed using the General Linear Model (GLM) in the Analysis of variance (ANOVA) program of the Minitab software (version 13.1. The sources of variation in the model were: breed, diet, interaction breed*diet and error.

3. Results and discussion

3.1 Chemical composition of diets

The rice bran was of low quality (only 7.3% CP in DM); the CP in the water spinach was also low compared to other published data (e.g.: 23%, 26%, 27%, 29% and 32% CP in DM) (Le Thi Men et al 2005, Chiv Phiny 2008, Le Thi Men et al 2000, Thim Sokha et al 2008 and Chhay Ty and Preston 2006, respectively). The average CP in the rice distillers' by-product was a little higher than the average (23% in DM) of the samples reported by Luu Huu Manh et al (2009) in Vietnam.

Table 4: Average chemical composition of ingredients (% dry basis, except for DM which is on fresh basis)

Ingredient	DM	CP	CF	Ash
Water spinach	8.8	15.8	12.4	10.1
Rice bran	88.2	7.3	20.4	10.7
Rice distillers' by-product	14.6	28.2	2.3	1.97
Salt	96.2			
Premix	98.2			

Table 5: Formulation of diets, % of DM

Ingredient	RW	RWDB
Rice bran	70	70
Water spinach	30	20
Rice distiller's by-product	0	10
Total	100	100
% Crude protein	10	11

RW = Rice bran and water spinach; RWDB = Rice bran and water spinach with rice distiller's by-product

3.2 Feed intake, growth rate and feed conversion

There was an interaction between breed and rice distillers' supplementation for both DM intake per unit LW and live weight gain (Table 6, Figures 1 and 2). Supplementation increased the intake and growth rate in the Mong Cai pigs but decreased the weight gain and had no effect on DM intake in the Moo Laat pigs.

The Mong Cai pigs were superior to the Moo Laat in live weight gain (Table 7). In contrast, feed conversion was better for the Moo Laat. The differences in growth rate between the breeds were not due to the differences in initial live weight as there was no relationship between initial live weight and subsequent growth rate in either breed (Figures 3 and 4).

Table 6: Mean values for change in live weight, feed intake and conversion for Mong Cai and Moo Laat pigs supplemented or not with rice distillers' by-product (RDB)

Item	MC+RW	MC+RWDB	ML+RW	ML+RWDB	SE	Prob.
Number of pigs	4	4	4	4		
Live weight (kg)						
Initial	25.5	24.9	13.3	11.1	2.77	
Final	44.0	49.0	26.5	23.3	1.81	0.04
Daily gain (g)	239[b]	294[a]	189[c]	139[d]	16	0.002
DMI, g/day	1237	1429	722	584	46.42	0.004
DMI/LW (g/kg)	32.6[b]	35.7[a]	31.4[b]	31.4[b]	0.47	0.001
DM feed conversion	5.40[a]	5.23[a]	3.92[b]	3.65[b]	0.31	0.003

[a, b, c ,d] *Mean values within rows with different superscript are different at P<0.05*

Table 7: Mean values (main effects) for change in live weight, feed intake and conversion for Mong Cai and Moo Laat pigs supplemented or not with rice distillers' by-product (RDB)

	MC	ML	Prob.	No RDB	RDB	Prob.	SEM
Live weight, (kg)							
Initial	25.2	12.2	0.001	19.4	18.0	0.19	0.7
Final	45.5	24.9	0.001	35.3	36.1	0.64	1.28
Daily gain (g)	266	164	0.001	214	216	0.91	15.34
DMI (g/day)	1333	653	0.001	979	1006	0.57	32.82
DMI/kg LW	34.1	31.4	0.001	32.0	33.6	0.001	0.34
DM feed conversion	5.31	3.78	0.001	4.65	4.44	0.49	0.31

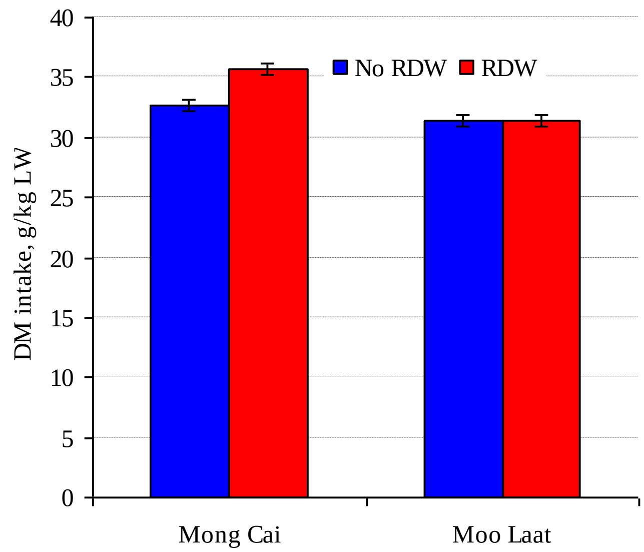

Figure 1: Contrasting effect of the rice distillers' by-product on feed intake in Mong Cai and Moo Laat pigs

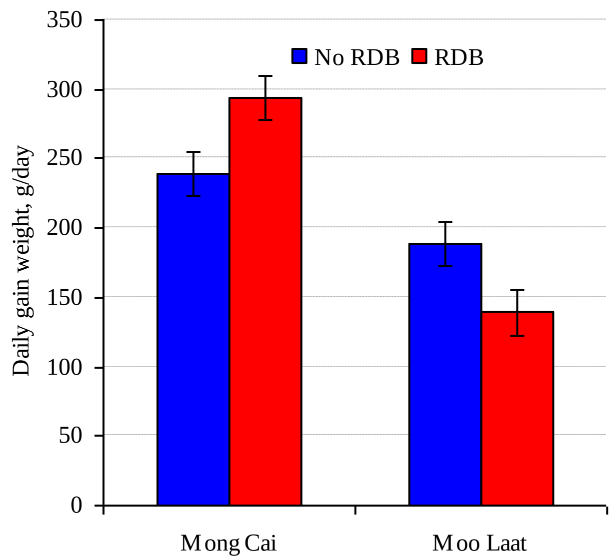

Figure 2: Contrasting effect of the rice distillers' by-product on growth rate of Mong Cai and Moo Laat pigs

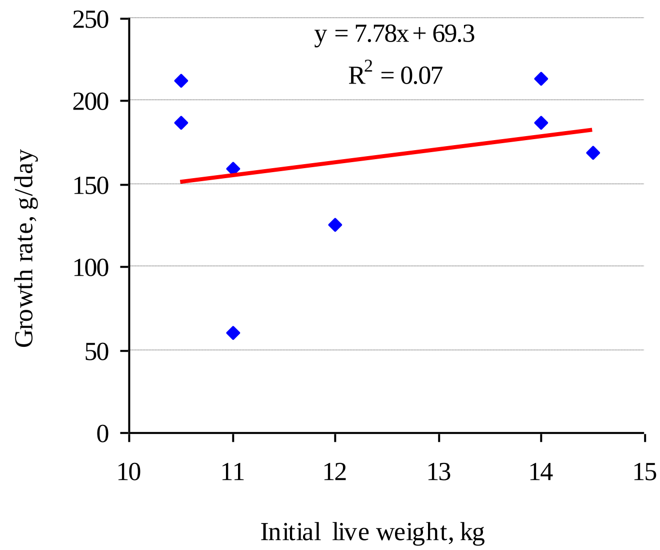

Figure 3: Relationship between growth rate and live weight gain in Moo Laat females fed rice bran and water spinach supplemented with rice distillers' by-product

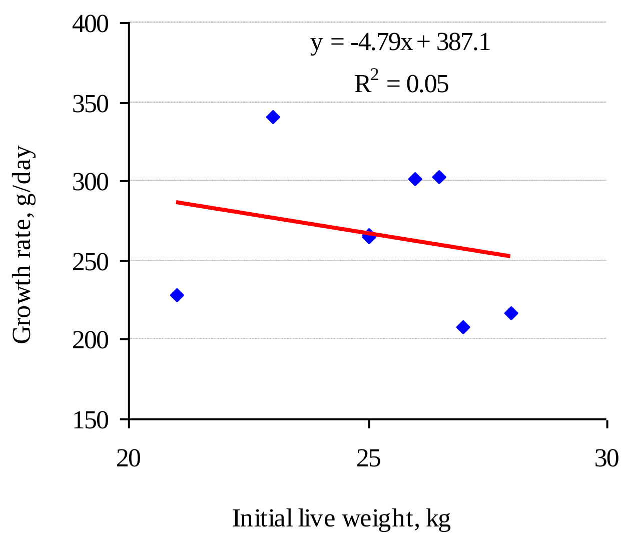

Figure 4: Relationship between initial live weight and live weight gain in Mong Cai females fed rice bran and water spinach supplemented with rice distillers' by-product

3.3 Apparent total tract digestibility

The results of the estimation of apparent digestibility by the acid insoluble ash method (Tables 9 and 10) appeared to show major advantages to the Mong Cai breed over the Moo Laat. It is not possible to explain the reason for such a difference, which needs to be confirmed or disproved in a subsequent experiment. Supplementation with rice distillers' by-product did not affect the coefficients of digestibility. The coefficients for DM and OM were lower than those (81.1% for DM and 84% for OM) reported by Chittavong et al (2008b) for Mong Cai gilts. In contrast for crude protein the coefficient of apparent digestibility was higher in our study than the value (59%) recorded by these authors. The methods used were similar (Acid Insoluble Ash in each case) but Chittavong et al (2008b) fed diets in which the energy component was a mixture of ensiled cassava root and broken rice, ingredients with negligible fiber content as compared with the rice bran used in the present study.

Table 8: Chemical composition of the feeds and feces for Mong Cai and Moo Laat pigs in the study on AIA measurement of digestibility

	Mong Cai		**Moo Laat**		
	No RDB	**RDB**	**No RDB**	**RDB**	**SEM**
AIA, %					
Feed	8.0	7.1	8.0	7.1	0.51
Feces	14.4	14.0	13.1	12.0	0.62
DM %					
Feed	22.1	21.9	24.3	22.7	0.66
Feces	37.6	38.3	34.0	32.3	1.59
OM % in DM					
Feed	84.9	87.1	86.5	85.7	1.05
Feces	79.0	79.2	79.6	81.1	0.59
Crude protein % in DM					
Feed	10.3	10.8	10.2	11.0	0.31
Feces	2.7	2.8	3.1	4.2	0.16

Table 9: Mean values (main effects) for apparent digestibility # of DM, OM and crude protein in Mong Cai and Moo Laat pigs with and without a supplement of rice distillers' byproduct

	Breed			**Supplement**		**SEM**	**Prob.**
	Mong Cai	**Moo Laat**	**Prob.**	**No RWDB**	**RWDB**		
DM	46.3	39.4	0.033	41.1	44.6	2.75	0.24
OM	50.6	43.3	0.034	45.5	48.4	0.86	0.34
Crude protein	86.0	79.4	0.001	83.4	82.0	2.20	0.27

 # Determined by Acid Insoluble Ash method

Table 10: Mean values for apparent digestibility # of DM, OM and crude protein in two breeds of pigs with (RDB) and without (NRDB) a supplement of rice distillers' byproduct

	Mong Cai		Moo Laat		SEM	Prob.
	NRDB	RDB	No RWDB	RWDB		
DM	43.7	49.0	38.4	40.3	2.75	0.05
OM	47.6	53.6	43.3	43.3	2.88	0.03
Crude protein	85.5	86.6	81.3	77.5	1.13	0.06

 # Determined by Acid Insoluble Ash method

The interaction between breed and supplementation in DM intake (per unit LW) and growth rate is not easy to explain. Supplementation increased feed intake and growth rate in Mong Cai but had no effect on intake yet decreased growth rate in the Moo Laat. There were indications from the growth curves (Figure 5), that in the case of the Moo Laat, those fed the rice distillers' by-product took a long time to adapt to this supplement. During the last part of the trial they appeared to be growing faster than those not supplemented.

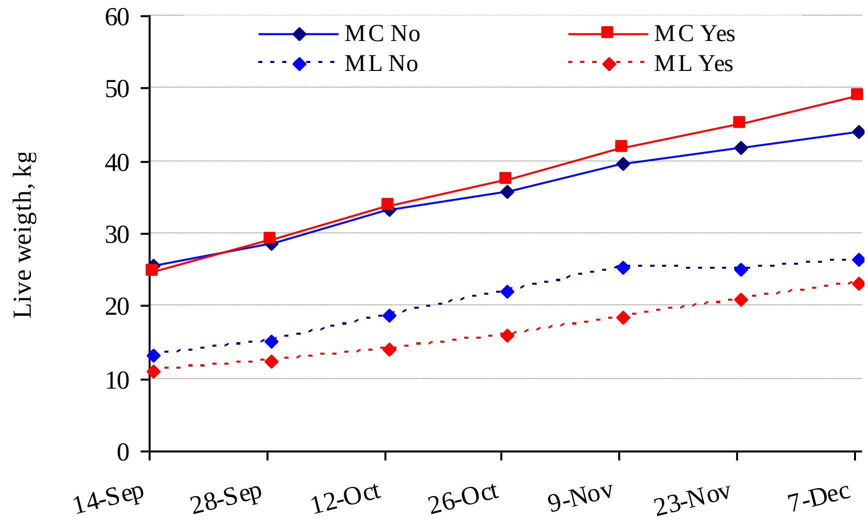

Figure 5: Growth curves of Mong Cai and Moo Laat pigs fed rice bran and water spinach supplemented with (yes) or without (no) rice distillers' by-product

Analyzing the growth rates and DM intakes (as g/kg LW) separately for the periods 0-6 weeks and 7-12 weeks (Tables 11 and 12), shows clearly that:

1. During each of the successive periods of 6 weeks, the Mong Cai fed the rice distillers' by-product had higher DM intakes (P = 0.15 and 0.001 for the successive periods) and faster growth than their control mates not fed the supplement (Tables 11 and 12; Figures 6 to 9).
2. During the first 6 weeks, the Moo Laat fed the rice distillers' by-product had the same DM intake but grew more slowly than their control mates not fed the supplement (Table 11; Figures 6 and 8). In contrast, during the final 6 weeks (Table 12; Figures 7 and 9), the Moo Laat fed the rice distillers' by-product had the same DM intake but grew at a faster rate than their control mates not fed the supplement.

Table 11: Mean values (0-6 weeks of experiment) for live weight gain and DM intake of Mong Cai and Moo Laat pigs with and without a supplement of rice distillers' by-product

	MC+RW	MC+RWDB	ML+RW	ML+RWDB	SE	Prob.
ADG	253^{b}	304^{a}	213^{b}	113^{c}	23	0.001
DMI/LW	33.2	35.9	32.3	32.6	1.16	0.15

Table 12: Mean values (7 to 12 weeks of experiment) for live weight gain and DM intake of Mong Cai and Moo Laat pigs with and without a supplement of rice distillers' by-product

	MC+RW	MC+RWDB	ML+RW	ML+RWDB	SE	Prob.
ADG	153^{b}	254^{a}	62.5^{c}	174^{b}	27.6	0.04
DMI/LW	32.1^{b}	35.5^{a}	30.9^{b}	30.8^{b}	0.465	0.001

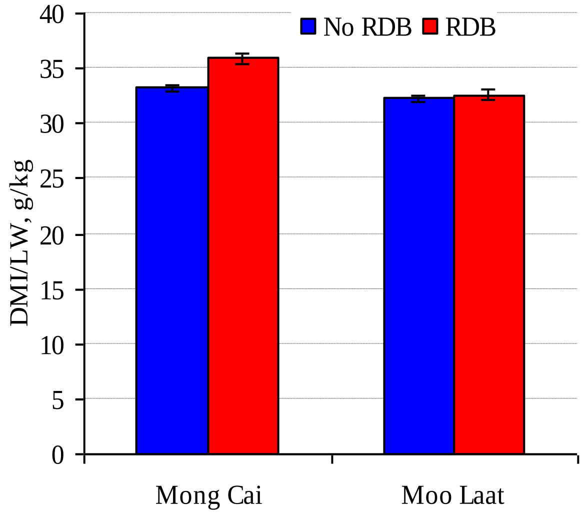

Figure 6. Effect of supplementation with rice distillers' by-product on DM intake of Mong Cai and Moo Laat pigs fed a basal diet of rice bran and water spinach (0-6 weeks)

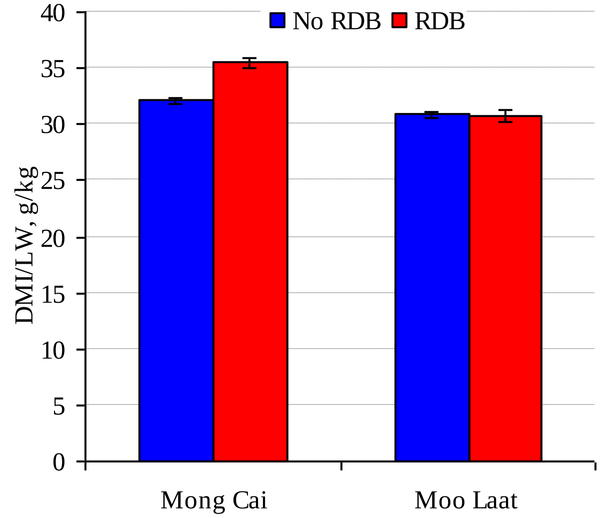

Figure 7. Effect of supplementation with rice distillers' by-product on DM intake of Mong Cai and Moo Laat pigs fed a basal diet of rice bran and water spinach (7-12 weeks)

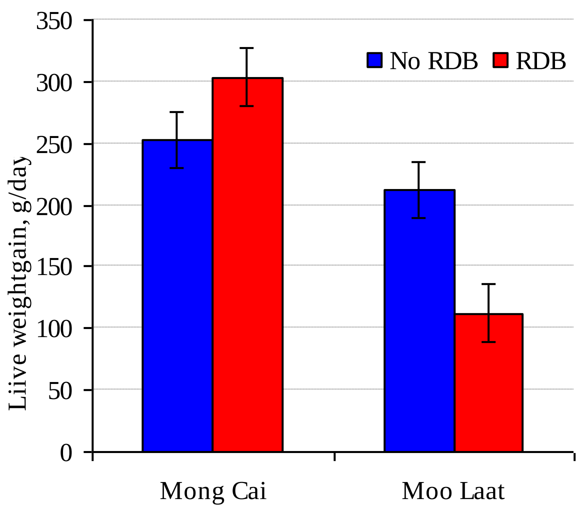

Figure 8. Effect of supplementation with rice distillers' by-product on live weight gain of Mong Cai and Moo Laat pigs fed a basal diet of rice bran and water spinach (0-6 weeks)

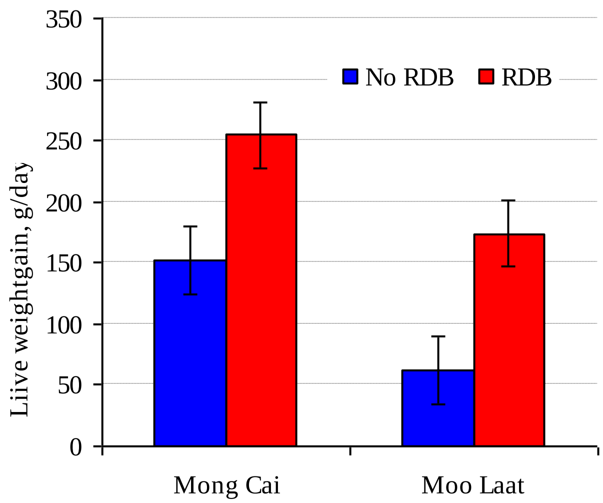

Figure 9. Effect of supplementation with rice distillers' by-product on live weight gain of Mong Cai and Moo Laat pigs fed a basal diet of rice bran and water spinach (7-12 weeks)

The reasons for the apparent need for adaptation of the Moo Laat pigs to the rice distillers' by-product do not appear to be due to the introduction of a new feed (the rice distillers' by-product) as DM intakes expressed as a function of live weight were not depressed by feeding the by-product; however, neither were they increased, which is in contrast with the response of the Mong Cai that responded with increased intakes due to the supplement.

The better feed conversion of the Moo Laat pigs compared to the Mong Cai was also unexpected as they grew more slowly, which normally would negatively influence the conversion rate. The smaller size, and hence reduced maintenance requirement, would appear to be the reason for the good feed conversion of the Moo Laat breed. From observation it also appeared that the Moo Laat was laying down less fat than the Mong Cai, another factor that would have benefited the feed conversion rate.

4. Conclusions

- Supplementation of a basal diet of rice bran and water spinach with rice distillers' by-product increased the feed intake and growth rate of Mong Cai pigs but decreased the weight gain and had no effect on DM intake in Moo Laat pigs.
- The Mong Cai pigs grew faster than the Moo Laat pigs, but the latter had the better feed conversion
- The coefficients of digestibility as measured by the Acid Insoluble Ash method were not affected by supplementation with rice distillers' by-product, but appeared to be higher for the Mong Cai compared with the Moo Laat.

5. Acknowledgements

We would like to acknowledge the support of the Swedish International Development Agency (Sida) in funding this experiment as part of the MSc program in the regional MEKARN project. We also thank the students of the Faculty of Agriculture of Champasack University for their help in the management and feeding of the animals.

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Effect of a supplement of water spinach on digestibility by growing Mong Cai pigs fed a basal diet of rice bran

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Abstract

Three Mong Cai gilts weighing from 67 to 70 kg were allocated at random to three treatments within a 3*3 Latin Square design with periods of 10 days (5 days for adaptation and 5 days for collection of data). The treatments were: RB: rice bran only; RBWS15 rice bran supplemented with 15% of water spinach; and RBWS30 rice bran supplemented with 30% of water spinach. Feeding level was 4% of live weight as dry matter (DM). The ratios of rice bran to water spinach were on a DM basis.

Intake of DM and apparent digestibility of DM and crude protein were increased when water spinach replaced up to 15% of the DM of the basal diet of rice bran. Using the "difference" method it was estimated that the coefficients of apparent digestibility of the DM and crude protein of the water spinach were 99 and 150%, implying that the effects of the water spinach on the digestibility of the mixed diet with rice bran were synergistic.

Key words: Acid insoluble ash, foliages, local breeds, synergism

1. Introduction

The use of green foliage from vegetables (e.g.: water spinach), forage trees (mulberry) and crop plants (cassava and sweet potato) is a recent development that aims to reduce the costs of pig production by making greater use of locally available, protein-rich, feed resources to replace the expensive, usually imported, soybean and fish meals (Preston 2006). The disadvantage of these feeds for pigs is the associated high content of fibrous cell wall constituents that generally results in increased rate of flow of digesta through the gut, and reduced ileal and total tract nutrient digestibility (Ogle 2006), especially the protein fraction (Rodríguez et al 2009; Chhhay Ty et al 2005a).

The lowest cost and most widely available energy feed in Laos, as in most of SE Asia, is rice bran. The fibre content of rice bran in Laos is relatively high as usually it contains variable amounts of the husk fraction. In this case the role of vegetative protein sources is not only to provide protein, but in many cases will result in a lowering of the overall level of the fibrous cell wall fraction, as happens if water spinach, mulberry leaves or taro foliage (leaf + stem) are the supplementary sources of protein (Table 1).

Table 1: Chemical composition of feed ingredients (% DM basis except for DM which is on fresh basis) (From Chhay Ty et al 2010)

	DM	OM	CP	ADF	NDF
Taro foliage silage	11.8	86.1	16.3	39.1	43.8
Mulberry leaf silage	24.5	87.7	19.7	35.5	41.3
Rice bran	91.0	87.9	9.50	46.2	64.3

In a companion experiment water spinach was used as the main source of supplementary protein for Mong Cai and Moo Laat pigs fed a basal diet of rice bran (Taysayavong Lotchana and Preston 2010). The present study aimed to investigate the effect of the water spinach supplement on the digestibility of the basal diet of rice bran.

2. Materials and methods

2.1 Location

The experiment was carried out at the Integrated Farming Demonstration Center of Champasack University, situated about 13 km from Pakse City, Pakse District, Champasack Province, Laos PDR. The temperature in the area averages 27^{0}C (range 22 to 32). The experiment was started on 20th January and ended on 20th February 2010.

2.2 Experimental design

The experiment was a 3*3 Latin Square design arrangement of three dietary treatments applied to three Mong Cai gilts (Table 2):

- **RB :** Rice bran
- **RBW15:** Rice bran with water spinach 15% of the diet DM
- **RBW30:** Rice bran with water spinach 30% of the diet DM

The Mong Cai gilts weighed from 67 to 70 kg. They were housed in individual pens during the 30 days trial. Each experiment period consisted of 10 days; 5 days to adapt to the diets followed by another 5 days for collection of feces and feed refusals.

Table 2: Experiment layout

Periods/pig	1	2	3
1	RB	RBWS15	RBWS30
2	RBWS15	RBWS30	RB
3	RBWS30	RB	RBWS15

2.3 Animals and management

The three Mong Cai gilts (Photo1) were housed in individual pens with concrete floors. Each pen was 2*2 m and was provided with feeders and automatic water drinkers. The pigs were vaccinated against salmonella disease and de-wormed with Ivermectin prior to beginning the study.

Photo 1: Mong Cai female

2.4 Feeds and feeding

The amounts of feed offered daily were based on a predicted DM intake of 4% of live weight (Table 3). The rice bran (photo 2) and water spinach (photo 3) were bought in the market every day (Photos 2 and 3).

Table 3: Amounts of feeds offered (kg/day, fresh basis)

		RB	RBWS15		RBWS30	
LW, kg	**DMI kg**	**RB**	**RB**	**WS**	**RB**	**WS**
55	2.2	2.46	2.09	4.46	1.72	8.92
60	2.4	2.68	2.28	4.86	1.88	9.73
65	2.6	2.91	2.47	5.27	2.04	10.54
70	2.8	3.13	2.66	5.68	2.19	11.35
75	3	3.36	2.85	6.08	2.35	12.16

The water spinach was chopped into small pieces (0.5 cm) and then all the diet ingredients were mixed together before feeding the pigs, which was done in two meals per day at 7.00 hours and 16.00 hours.

Photo 2: Rice bran

Photo 3: Water spinach

2.5 Data collection

Feed and feces samples were taken over 5 consecutive days. Samples of feces were collected from the floor of the pens 3-4 hours after the first feed in the morning and stored at -18°C. Care was taken to collect the sample from within the deposited feces, avoiding contact directly with the pen floor. The procedure was repeated for 5 days, after which the samples were bulked according to individual animals. Feed samples were taken over the same time period.

2.6 Chemical analyses

Feed and feces samples were analysed for acid insoluble ash (AIA) according to the method of Van Keulen and Young (1977), for DM by micro-wave radiation (Undersander et al 1993) and N, CF and ash according to AOAC (1990).

Samples for AIA determination (5g) were ashed for 4-6 hours in a muffle furnace at 450°C. The ash was transferred to a 600 ml beaker and extracted with 100 ml of a solution of HCl (178 ml concentrated HCl and 1 litre of water) and boiled for 5 minutes. The suspension was then filtered and the solid residue transferred to filter paper and ashed again at 450°C for 6h. Acid insoluble ash (AIA %) was calculated as:

- **% AIA** = [initial weight of ash-final weight of ash]/initial weight*100

Calculations of apparent digestibility were made as follows:

- **Digestibility of DM** = 100-[(100*%AIA in feed)/%AIA in feces]

- **Digestibility of nutrients** = 100- [[(%AIA feed) * % concentration of nutrient in feed]* 100%]/(%AIA Feces)*(% concentration of nutrient in feces)

2.7 Statistical analysis

The data were analyzed using the General Linear Models procedure of ANOVA in the Minitab (2000) software (version 13.1). Sources of variation were: diets, animals, periods and error.

3. Results and discussion

3.1 Chemical composition of the diets

The water spinach had 30% less crude fiber than the rice bran and almost twice as much crude protein content (Table 4). As a result, the crude protein level in the diets increased with the level of water spinach (Table 5).

Table 4: Chemical composition of ingredients (% dry basis)

	DM	CP	CF	Ash
Water spinach	7.4	15.01	14.4	10.07
Rice bran	89.4	8	20.4	15.45
Salt	96.2			
Premix	98.2			

Table 5: Formulation of diets, % of DM

	RB	RBWS 15	RBWS30
Rice bran	100	85	70
water spinach	0	15	30
Total	100	100	100
% Crude protein	8	9.05	10.01

3.2 Feed intake

The DM intake of the diet increased linearly with the increase in the level of water spinach (Table 6; Figure 1). DM intake as a function of live weight was closely related with daily intake of crude protein (Figure 2).

Table 6: Mean values for feed intake of the pigs

Item	RB	RBWS15	RBWS30	SEM	Prob.
Number of pigs	3	3	3		
DMI, g/day	2011[c]	2396[b]	2737[a]	76.30	0.002
CP, g/day	169[c]	220[b]	272[a]	7.84	0.001
CP, g/kg DM	84.0[c]	91.8[b]	99.4[a]	1.0	0.001
DMI, g/kg LW/day	28.5[c]	36.2[b]	41.1[a]	1.26	0.001

[a, b, c] *Mean values within rows with different superscript are different at $P<0.05$*

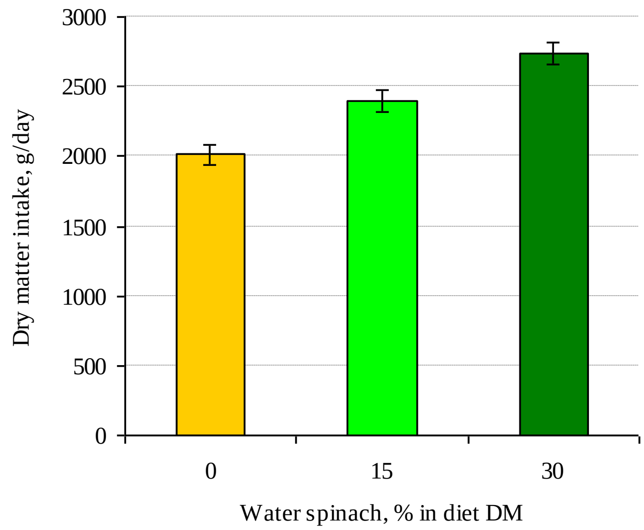

Figure 1: Effect of level of water spinach on feed intake of growing Mong Cai pigs fed a basal diet of rice bran

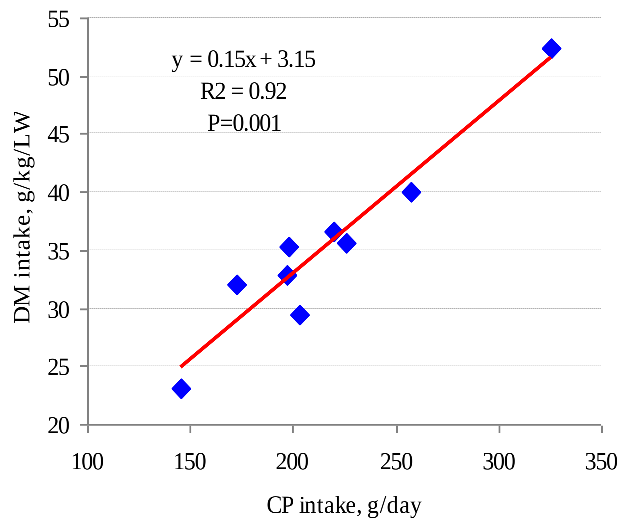

Figure 2: Relationship between crude protein intake and DM intake in growing Mong Cai pigs fed rice bran and increasing levels of water spinach

3.3 Apparent total tract digestibility

The coefficients of apparent digestibility of DM and CP increased as the level of water spinach in the diet was increased (Table 7; Figures 3 and 4). The effect of the water spinach at the 15% level appeared to be synergistic. The "difference" method of assessing the digestibility of a supplement assumes that the digestibility coefficients of the basal diet and the supplement are additive.

$Dig_{WS} = (Dig_{RBWS15} – Dig_{RB}*0.85)/0.15$, where 0.15 is the proportion of water spinach in the diet DM and 0.85 is proportion of rice bran).

Table 7: Apparent digestibility coefficients in MC gilts fed diets with different proportions of rice bran and water spinach

	RB	RBWS15	RBWS30	SE	Prob.
Apparent digestibility, %					
DM	51.0[b]	58.2[a]	58.6[a]	0.83	0.001
CP	59.7[c]	73.2[b]	78.0[a]	1.12	0.001

[a, ,b, c] *Mean values within rows with different superscript are different at P<0.05*

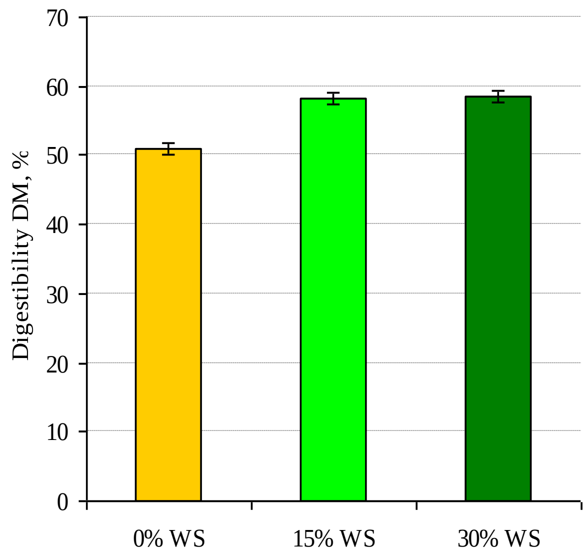

Figure 3: Effect of level of water spinach on apparent digestibility of DM in growing Mong Cai pigs

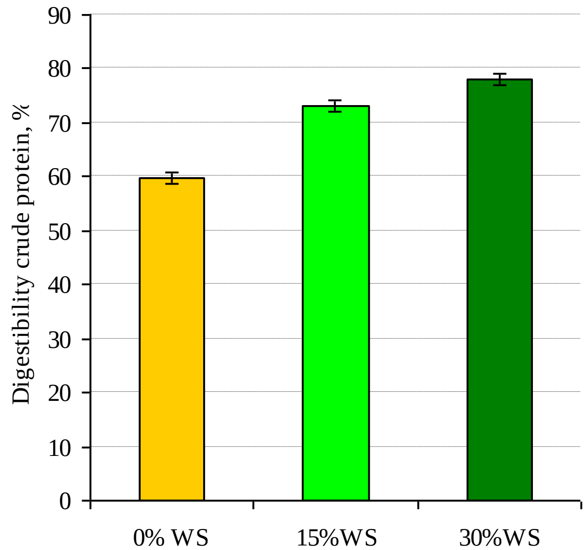

Figure 4: Effect of level of water spinach on apparent digestibility of crude protein in growing Mong Cai pigs

When this formula was applied to the observed digestibility coefficients of the RB and RBWS15 diets, the results were: 99 and 150% for the apparent digestibility of the DM and crude protein in the water spinach. Clearly, in this case the effects of the two components of the diet were not additive, especially in the case of the crude protein, and there was a synergistic impact of the water spinach on the nutritive value of the combined rice bran-water spinach diet.

A similar synergism was reported by Chhay Ty et al (2005b) when they replaced 50% of fresh cassava leaves with fresh water spinach in a basal diet of broken rice for growing pigs. Growth rate on the combined forage supplements was greater, and feed conversion better, than the average of the cassava and water spinach diets fed separately. Similarly, combinations of ensiled mulberry leaves and taro foliage (leaf plus stem), as supplements to rice bran, supported higher coefficients of digestibility of DM, CP, NDF and ADF, than would have been predicted from the arithmetic average of the diets with supplements (Chhay Ty et al 2010).

4. Conclusions

It is concluded that:

- The DM intakes, and the apparent digestibility of DM and crude protein by Mong Cai gilts, were increased when water spinach replaced up to 30% of the DM of the basal diet of rice bran.
- The coefficients of apparent digestibility of the DM and crude protein of the water spinach, estimated by the "difference" method, were 99 and 150%, implying that the effects of the water spinach on the digestibility of the mixed diet with rice bran were synergistic.

5. Acknowledgements

We would like to thank the Swedish International Development Agency (Sida) for funding this experiment a part of the MSc program through the MEKARN regional project. We also wish to thank the students from the Faculty of Agriculture of Champasack University for their assistance in ‘the care and feeding of the animals.

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