USE OF FINE RICE BRAN (POLISHINGS) IN PIG DIETS

BY

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A THESIS SUBMITTED IN PARTIAL FULFILMENT OF THE DEGREE OF MASTER OF SCIENCE IN ANIMAL SCIENCE IN THE FACULTY OF VETERINARY MEDICINE UNIVERSITY OF NAIROBI.

SEPTEMBER, 1994.

ACKNOWLEDGEMENTS

I wish to express my gratitude to Prof B.N Mitaru for funding this work through the Alternative Feed Resources Project and for his invaluable advice all along. I would also like to thank him for providing my stipend from his research funds during the one year scholarship extension. To Prof M.M Wanyoike, thanks for the thorough critical appraisal of this work. Thanks also go to the University of Nairobi for awarding me a scholarship without which this work would have been impossible. I would like to register my appreciation to the Director, Kenya Agricultural Research Institute (KARI) for allowing me to use research facilities at Naivasha. To the staff working in the pig unit at Naivasha, thanks for providing a conducive working environment. I would particularly like to single out Mr Francis Mwaura, Mr John Osango and my assistant Ms Pamela Obare for their selfless devotion to this work. I am greatly indebted to the staff at the Animal Nutrition Lab, University of Nairobi for their assistance in the analysis of my samples. I would also like to thank my colleague and friend, Mr G.A. Olukoye for his encouragement and assistance in data analysis. Special thanks go to Dr R.G. Wahome, with whom I shared some very challenging experiences in Naivasha, for his encouragement and support at times when I might have given up. Lastly to my dear wife Chiru and daughter Njoki, thanks for your patience and understanding.

DEDICATION

This work is dedicated to my loving mother, Grace Njoki Kiigu.

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ABSTRACT

Experiments were carried out to determine the composition of the rice milling by-products produced in Kenya and the effect of including fine rice bran in the diets for growing-finishing pigs on growth performance, nutrient digestibilities and carcass quality.

Samples of rice milling by-products were analyzed for proximate and mineral composition. The by-products analyzed in the order of their recovery from the mills were: rice hulls (RH), coarse rice bran (CRB), fine rice bran (FRB), fine broken rice (FBR) and coarse broken rice (CBR). Moisture ranged from 9.58 (CRB) to 11.93% (CBR), crude protein from 3.08 (RH) to 10.80% (FRB), crude fibre from 1.39 (CBR) to 41.70% (RH), ether extract from 1.39 (RH) to 14.21% (FRB), ash from 1.10 (CBR) to 31.77% (RH) and nitrogen free extract (NFE) from 12.46 (RH) to 74.65% (CBR). Calcium ranged from 0.07 (CBR) to 0.14% (CRB), phosphorus from 0.63 (CRB) to 1.08% (CBR) and zinc from 9 (CBR) to 40 ppm (FBR). In general, it was observed that the higher the proportion of endosperm in the rice milling by-products, the higher the NFE and the lower the protein, fibre, fat and ash contents.

A feeding trial with 36 pigs (18 males and 18 females) on sorghum based diets containing 0, 10, 20, 30, 40 and 50% levels of fine rice bran was conducted. The results showed that inclusion of rice bran up to a level of 50% in diets for growing-finishing pigs had no significant effect ($p > 0.05$) on weight gains, feed conversion efficiencies, dressing-out percentage, carcass length and back fat measurements. However, boars had a significantly lower ($p < 0.05$) dressing-out percentage than gilts. The apparent digestibilities of dry matter, energy, protein and fat for growing pigs showed a significant linear increase ($p < 0.05$) as the level of rice bran in the diets increased.

The gross margin profit from pigs on diets containing 0, 10, 20, 30, 40 and 50% levels of fine rice bran was Ksh 731, 886, 940, 1038, 1129 and 1294 respectively. This indicates that fine rice can be used as a more economical substitute for sorghum in pig diets. It would however be important to determine pig performance at even higher levels of dietary rice bran.

1. INTRODUCTION.

The pig industry forms an important section of the livestock production enterprise in Kenya. The population of pigs has grown steadily over the last few years. The total number of pigs was estimated to have stood at 128,168 in 1990 (Ministry of livestock Development, 1990) up from 107,639 in 1989. The industry has however had its share of production constraints. These include the high cost of feeds, unavailability of feeds, poor extension services, lack of skilled labour in most piggeries, shortage of good proven breeding stock and poor pork popularization and marketing. The high cost of feeds is by far the single greatest constraint to pig production in Kenya today.

Pig feed currently takes about 60-80% of the total input costs in a pig enterprise (Gichohi, Mitaru, Munyua and Wahome, 1988). The underlying reason for this is that the raw materials (mainly grains and oil seed cakes) used in pig feed manufacturing are expensive. This underscores the need for seeking alternative feedstuffs that are both cheap and available. One such group of raw materials is the rice-milling by-products.

The main by-products from rice mills that are useful as animal feeds are rice bran, rice polishings and broken rice. The first two are usually not distinctly separated and are therefore simply referred to as rice bran. Rice in Kenya is mainly grown under irrigation. The 1988/89 rice crop yielded about 34,304 Metric tonnes of paddy (Central Bureau of Statistics, 1990). The crop should have yielded about 8,500 MT of the by-products, this being a significant amount when considered against the estimated pig feed production of about 21,481 tonnes (Ministry of Livestock Development, 1990).

Due to its relatively low cost, rice bran is being incorporated into pig feeds by some farmers and feed manufacturers in Kenya. The extent to which the rice bran can replace locally available grains without compromising pig performance, has not been determined locally. The objectives of this study therefore were:

i) To determine the chemical composition of the rice milling by-products available in Kenya.

ii) To determine the effect of substituting fine rice bran for sorghum in growing and finishing rations on pig performance and nutrient digestibilities.

2. LITERATURE REVIEW.

2.1 Rice and rice milling by-products

Rice is basically a semi-aquatic annual plant. The two cultivated species of rice are *Oryza sativa* L. and *O. glaberrima* Steud. Cultivars of these two can grow in a wide range of water-soil regimes, from a prolonged period of flooding in deep water to dry land on hilly slopes. Asia is the largest producer of rice. However other continents have shown a remarkable increase in production over the years.

The world rice paddy production in 1989 stood at about 506 million Metric Tons (MT) with Africa producing about 15% of this (FAO, 1990). Kenya's rice paddy production in the same year was about 50,000 MT. Though this represents only a small fraction of the total world rice production, it is nevertheless a reliable supply of grain for this country.

There are four main rice growing areas in Kenya all of which are irrigation schemes; Mwea, Ahero, West Kano and Bunyala. Mwea Irrigation Scheme yields about 78% of the rice paddy produced in Kenya (Table 1). At Mwea five varieties of rice are grown. These are BW 196, Basmati 217, Sindano, and two IR varieties. Rice paddy production will be boosted by a further 18,500 MT by 1996 when a

Table 1: Rice production in Irrigation schemes in Kenya: 1984-89.

Irrigation scheme	Paddy yields (mt)				
	1984/85	1985/86	1986/87	1987/88	1988/89
Mwea	27 553	26 407	25 236	27 163	27 555
Ahero	3 777	4 378	3 894	4 213	2 983
West Kano	2 059	2 650	2 319	1 728	2 387
Bunyala	1 094	1 259	1 209	1 379	1 379
TOTAL	34 483	34 694	39 658	34 483	34 304

Source: Central Bureau of Statistics, 1990.

new project, the Tana Delta Irrigation Project becomes fully operational.

The nature of by-products from rice mills depends mainly on the type of milling operation. Mechanised operations undertake de-hulling and whitening either in a single step or in several steps. Coarse bran is the main by-product in single step operations. Multi-step operations undertake shelling, whitening and polishing separately. During each of these stages certain by-products are recovered.

The coarse bran recovered from the shelling stage mainly consists of hull fragments, a small proportion of pericarp, some germ, rachilla and small fragments of the endosperm as well as dust and soil. This type of bran is of little nutritional value especially to non-ruminants. The bran resulting from whiteners consists mainly of fragments of the pericarp, the tegmen, aleurone layer and germ. Some hull particles may also be present. The rice polishings, resulting from the polishing of white rice consists of fine grain particles and small proportions of adulterants carried over from the previous stages.

The milling process at Mwea is a multi-stage operation. The by-products so far identified and recovered separately are rice hulls, coarse rice bran, fine rice bran, coarse broken rice and fine broken rice (locally known as"chicken feed"). The relative proportions of the various rice fractions are shown in Table 2. With the exception of rice hulls, all the others are used as animal feeds. Fine rice bran is the most widely used by-product and has therefore merited more attention in this study.

2.2 Chemical composition of rice bran and polish.

2.2.1 Proximate constituents.

The composition of bran varies over a wide range. Results published by Mahatab (1985) on the gross chemical composition of 21 samples of rice bran were as follows: moisture varied from 8.2 to 14.0 % , crude protein from 5.94 to 20.3 %, ether extract from 2.60 to 28.6%, crude fibre from 3.94 to 26.4 % , total ash from 7.57 to 26.8% and NFE from 34.5 to 60.2%.

The wide variation in chemical composition is attributed to factors associated with the rice grain itself (varietal and environmental) and the milling process (processing methods, machines and milling conditions). Mc Call, Jurgens, Hoffacir, Pons, Stark, Cucullu, Heinzelman, Cirino and Murray (1953) showed significant differences in bran composition of eight varieties of rice grown during three years at three locations and where milling was carefully controlled. Huller type mills produce bran that has lower protein and oil content and higher fibre and ash content than bran produced from cone type mills (Siriwardene, 1969). The friction type

Table 2: Relative proportions of by-products from the milling of paddy rice.

Fraction	Quantity (% of paddy rice)
Rice hulls	15
Coarse rice bran	10
Fine rice bran	10
Coarse broken rice	3
Fine broken rice (chicken feed)	2

Source: Mwea Rice Mills

whitening machines produce bran of higher fat content than the abrasion type (Barber and Benedito de Barber, 1980). The latter machines frequently scratch the grain, reaching into the deeper layers of the starchy endosperm.

The degree of milling affects the chemical composition of bran so that in a multi-step milling operation, the bran from the latter cones is higher in NFE and lower in protein, fat, fibre and ash (Primo *et al.*,1970). This may be due to the fact that kernel layers at various depths differ greatly in chemical composition.

2.2.2 Carbohydrates.

Commercial bran contains a substantial amount of starch mainly due to the endosperm present. The starch content increases from the first to the last whitening machines. Non-reducing sugars are more abundant than reducing sugars, the ratio being 3:1 to 4:1 (Pascual and Primo, 1955). Bran is rich in cellulose and hemicellulose with higher quantities of the former being reported in bran than in polish (Leoinzio, 1966). The same author reported higher lignin content in bran than in polish.

2.2.3 Oils.

Rice bran contains oils that are predominantly esters of the unsaturated fatty acids oleic and linoleic acids and the saturated fatty acid palmitic acid (Sarkar and Bhattacharyya, 1989; Choi and Park, 1983; Bhattacharyya A.C., Majumdar and Bhattacharyya D.K., 1985). Other fatty acids found in lesser amounts are myristic, palmitoleic, stearic, linoleic, and arachid acids. The variety of rice influences the amount of oils present (Izzo, Fasbrin and Lotti, 1972). The fatty acids linoleic and oleic are the major constituents of the phospholipids present in rice bran (Babkhodzheava, 1974). Rice bran oil may contain as much as 4.1% unsaponifiable matter which includes various sterols and γ-oryzol (Rukmini, 1988). Tocopherols, especially δ-tocopherol (vitamin E), form a substantial proportion of the unsaponifiable fractions of crude bran oil.

2.2.4 Protein.

Protein nitrogen forms the largest part of rice bran nitrogen. Non-protein nitrogen accounts for about 16% of the total nitrogen of rice bran and for about 11% of the rice polish nitrogen (Baldi, Fossati and Fontone, 1976). The major free amino acids in bran are glutamic acid (7-31%), alanine (11-16%), and serine (5-15%) (Ebisawa and Sugimura, 1956). Reported data for amino acid composition varies over a wide range. The main source of variation appears to result mainly from analytical procedure (Houston, Allis and Kohler, 1969). That no significant differences were noted among the deeper layers of the kernel suggests that the depth of milling does not influence the amino acid composition.

2.2.5 Minerals.

The degree of milling has an influence on the concentration of mineral elements in rice bran (Tanaka, Yoshida, Asada and Kasai, 1973). Some elements (Phosphorus, potassium and magnesium) increase initially and then decrease with deeper milling. Others (calcium, manganese and iron) exhibit an early sharp decrease.

Phosphorus is one of the major mineral constituents of bran. It occurs in phytic acid, nucleic acid, inorganic phosphate, carbohydrate and phosphatide, the major form being phytic acid (McCall *et al*, 1953). About 72.0 to 85.7% of the total phosphorus in bran is phytate phosphorus (Kirby and Nelson, 1988). Other common mineral elements are present in bran. However, cobalt, chromium, germanium, lead or vanadium have not been detected spectrochemically (McCall *et al.*,1953).

2.2.6 Vitamins.

Data reported for vitamin content of rice bran varies over a wide range. In general bran is rich in vitamins of the B group and tocopherols and is poor in vitamin A and C. Carangian and Sutaria (1970) reported that though trace amounts of ascorbic acid are present in fresh bran, total loss of the same occurs after one month storage at 27°C. The same workers also reported a total lack of vitamin D in rice bran. Although the vitamin content differs among rice varieties and to a lesser extent with location of growth the major causes of variation seems to be the analytical techniques employed and the differences in degree of milling.

2.2.7 Enzymes.

Although bran is rich in various enzyme systems, lipase has merited the most attention since it affects the keeping quality and the industrial use of the material. This enzyme is dormant in the intact grain but it becomes markedly active as soon the bran is removed from the rice grain (Barber and Benedito de Barber, 1980). The reason for this is that while lipase is localised in the testa-cross layer of the rice grains, its substrate, the oil, is located in the aleurone and sub-aleurone layers and germ. The two are brought together when bran is scoured during milling.

In general the germ and the outer layers of the caryopsis are the sites of higher enzymatic activity. Proteolytic activity was found to decrease in the order of germ, bran, de-germed brown rice and lastly polish (Barber, 1969). A protease inhibitor has been isolated from rice bran (Umechara, Kuruma and Takamori, 1983).

2.3 Use of rice bran and polish in non-ruminant diets.

Rice bran and polish show very wide variations in composition. Consequently, recommendations on the level of inclusion of these materials in pig diets are considerably varied.

Thrasher, Mullins and Scott (1966) have shown that the substitution of rice bran for maize in a maize soy-bean diet at two levels (20 and 30%) reduced pig gains by 5 and 8%, respectively, and significantly reduced feed efficiency, back fat thickness and carcass firmness. Tuah and Boateng (1982) fed pigs from 45 until 66 kg live weight on maize based finisher diets without or with rice bran replacing 20, 40 or 60% of the maize. They reported an increase in feed intake and a decrease in feed conversion efficiency as the level of rice bran in the diet increased. Carcass fat generally decreased with increasing levels of rice bran.

However, in contrast to the studies above, Campadal, Creswell, Wallace and Combs (1976) reported that for growing-finishing pigs, rice bran had approximately the same feeding value as maize if the level of substitution did not exceed 30% of the total ration. Young pigs on a maize-soybean diet but supplemented with rice bran fed at 0, 1 or 2% of body weight daily showed improved live weight gains although the digestion coefficients of dry matter, nitrogen and energy decreased linearly with increasing levels of rice bran (Robles and Ewan, 1982).

In some studies higher levels of rice bran have been reported to support pig performance to an extent comparable to that obtained when maize is used as the main energy source. A study done in

Hawaii showed that although small reductions in gains were observed when 60% maize in a maize-soybean meal diet was replaced with rice bran, significant reductions in gains were not noted until 80% of the maize was replaced (Brooks and Lumanta, 1975). Similarly, Chamorro and Maner (1973) reported no differences in gains, feed consumption and feed efficiency when rice bran substituted up to 45% of the maize and soybean meal in the diet. It is possible that the rice bran used in these two studies was very high in energy density and, by extension, quite low in fibre.

Rice bran has also been evaluated against other energy sources. Better performance was reported when a mixture of rice polish and molasses replaced maize than when rice polish alone replaced maize in grower-pig diets (Rao and Prasad, 1980). This suggests that molasses might be of higher feeding value than rice polish. It is also likely that the inclusion of molasses improved the palatability of the diets.

Pregnant gilts fed 35% maize in control diet, 30% rice polish plus 10% molasses or 30% tamarind seed plus 10% molasses showed no significant differences between groups in litter size at birth or at weaning, in lactation weight loss or in feed conversion efficiency (Reddy, Prasad and Murthy, 1981). Growing pigs on a fish meal-wheat bran-maize diet or either a molasses -tamarind seed mixture or a molasses -rice polish mixture replacing the maize in the first diet showed the lowest weight gains, the highest feed intake and the poorest feed/gain ratio in the group on the molasses-rice polish mixture (Reddy D.V, Prasad, Reddy B.S. and Charyulu, 1986). These results placed rice polishings lower in rank than tamarind seeds in terms of feeding value. Similarly, rice bran emerged as a more inferior substitute for sorghum in a study in which graded levels of fine rice bran replaced sorghum in pig diets (Ara, Owen and Buitrago, 1975).

Though for the most part reports on the performance of chicken on rice bran diets are inconsistent, the general conclusion is that incorporation of rice bran in chicken diets based on maize and soybean tends to lower the performance of the birds. Commercial White Leghorn pullets, given to appetite a diet with 81.5% rice bran from 20 weeks laid significantly fewer eggs than did pullets given a standard breeder diet (Piliang, Bird, Sunde and Pringle, 1982). Sinha, Rao, Sadagopan and Panda (1980) showed that rice polish had a lower ME value than maize and wheat but a higher one than pearl millet.

When Peking ducks were fed a meal containing yellow maize, sunflower meal, lucerne meal, maize germ, vitamins and minerals but with 0, 20, 40 and 60% non de-fatted rice bran, body weight did not differ significantly among groups though with increasing rice bran feed intake increased progressively and conversion became less efficient (Hertrampf, 1985). In comparison to chicken, ducks appears to have done better provided they could increase intake.

2.4 Factors limiting use of rice bran as feed.

2.4.1 High fibre content.

Rice bran is associated with a high fibre content which results from hull adulteration. In general, high fibre content in diets for non-ruminants tends to affect feed intake and efficiency of utilization. High dietary fibre is known to reduce the mean transit time in the gut, increase faecal water excretion (Cherbut, Barry, Wyers and Delort-Laval, 1988) and increase faecal nitrogen excretion (Morgan and Whittemore, 1988). This might be a consequence of the fact that an increase in dietary fibre tends to increase gut motility.

In an experiment in which growing-finishing pigs were fed diets containing 0, 10, 20, 30 or 40% ground hulls, it was demonstrated that though the level of hull adulteration did not affect the rate of gain, each increase in the level of hulls in the bran was accompanied by a linear increase in both daily feed intake and feed required per kilogram of gain (Chamorro and Maner, 1974). Incorporation of the hulls into the feed tended to lower the energy density of the feed. Further, the increasing fibre levels in the feed may have adversely affected digestion due to the corresponding reduction in the transit time of the digesta along the gut.

Pigs slaughtered following long term consumption of diets containing medium to high levels of rice bran have displayed some degree of inflammation of the gastro-intestinal mucosa (Arnott and Lim, 1966). Mucosa inflammation has been reported to be progressively more severe as the amount of bran was increased (Campadal *et al.*,1976). Both the fine particle size of the rice bran and the high level of coarse abrasive fibre (silica) have been suggested as causative factors.

2.4.2 Inconsistent composition

The wide variation of bran between lots is a disadvantage especially in advanced animal husbandry where balanced feedstuffs are used. Rice variety and location (Mcall, 1953), mill type (Siriwardene, 1969), whitener type (Barber and Benedito de Barber, 1980), degree of milling (Primo *et al.*,1970) and depth of milling are the main factors contributing to this wide variation. This means that for recommendations to be made on the level of use of a given batch of rice bran the above factors have to be taken into consideration. Difficulties would however arise in the case of batches of rice bran whose history is not clearly known.

2.4.3 Anti-nutritive factors

The presence of anti-nutritive factors has been reported in rice bran. These include trypsin inhibitor (Barber, Benedito de Barber, Floves and Montes, 1978), hemaglutinin (Benedito de Barber, 1978) and anti-thiamin factor (Chaudifuri, 1964). These may interfere with feed utilisation and efficiency. The fungi *Aspergillus* is often present in bran producing in some cases aflatoxins (Jayaraman and Kalyasundaram, 1990) which are highly potent mycotoxins.

A high proportion (72.0 to 85.7%) of total phosphorus in rice bran is found bound to phytic acid (Kirby and Nelson, 1988). Phytate phosphorus is poorly available to the pig. Corley *et al.* (1980) determined available phosphorus to be only 0.23% in rice fed to chicken on an *as is* basis and to be only 17.6% of the total phosphorus in the bran. Phytic acid or plant phytates also increases the dietary requirement for zinc (Oberleas *et al.*,1962; Oberleas, 1983) by binding it thereby making it less available.

2.4.4 Low calcium: phosphorus ratio

Rice bran is associated with a low calcium: phosphorus ratio. Rao and Reddy (1986) reported a calcium: phosphorus ratio of 1: 3.6. This compares unfavourably with the NRC (1988) requirements of between 1: 1 and 1.5: 1 in corn-soybean diets for pigs. Maury and Colin (1980) have shown that phosphorus and calcium are intimately linked and that a deficiency of these either singly or in combination leads to growth depression in pigs. The addition of calcium can balance out the low calcium: phosphorus ratio. However if calcium is included beyond the recommended level of 1% of the diet (NRC, 1988) the dietary requirement for zinc would also increase.

2.4.5 Rapid deteriorative changes.

Rice bran oil is composed mainly of the unsaturated fatty acids and can therefore easily undergo hydrolytic and oxidative deteriorative changes. Lipases promote the hydrolysis of the bran oil into glycerol and free fatty acids (De Rege, 1955). Peroxidases can cause oxidative spoilage of bran components (oil and tocopherols) at low moisture levels. These changes, besides altering the nutrient composition of the rice bran, also make the bran less palatable.

Rice bran is also very prone to attack by molds and other micro-organisms. Micro-organisms are present in populations exceeding several million micro-organisms per gram of the bran (Barber *et al.*,1978). Micro-organisms, besides changing directly the nutrient composition of bran, can produce enzymes such as lipase which may intensify hydrolytic changes of the bran oil. Others, such as Aspergillus flavus, produce mycotoxins which may adversely affect the health of animals feeding on such material.

2.5 Methods used to overcome the nutritional limitations of rice bran.

2.5.1 Stabilisation.

Bran stabilisation is done with the aim of removing or arresting the activity of enzymes, micro-organisms, insects, natural toxicant constituents, harmful contaminants and adulterants. Most of the processes involve moist or dry heat treatment. Less commonly used methods that are nonetheless effective in bran stabilisation include use of enzymes such as cellulase (Tangendjaja, Johnson and Noland, 1988 A), gamma radiation and storage under low temperature (Sayre, Earl, Kratzer and Saunders, 1987). These processes are probably too costly for commercial exploitation.

Use of dry heat and steam in stabilising bran has been reviewed by Barber and Benedito de Barber (1980). Dry heat does not inactivate lipases totally and therefore storage moisture levels of 3-6% are recommended to prevent a Free Fatty Acid (FFA) rise. Moist heating processes generally involve steaming the bran for 1-30 minutes, drying the product to 3-12% moisture content and then cooling.

Tangendjaja, Johnson and Noland (1988 B) demonstrated an improved feed conversion efficiency in pigs fed rice bran which had either undergone extrusion or to which hot water had been added. Sayre *et al.* (1987) also showed that chickens fed on diets containing rice bran that had been stabilised by extrusion cooking at 130°C gave significantly greater gains than those fed on raw rice bran diets. Eshwaraiah, Reddy and Rao (1988) reported that chickens fed on diets based on autoclaved rice polishings had similar weight gains and feed conversions as those on maize based diets. Other workers, however, could not show the beneficial effects of heat-stabilised rice bran on the performance of pigs (Chamorro, 1978) and chicken

(Serra, Johnson, Smith and Noland, 1983). The differences in reported work are probably a reflection of the variations in temperatures and methods used.

2.5.2 De-oiling.

Oil extraction is aimed at separating the oil from the rice bran, hence reducing rancidity development. It is done either by mechanical methods involving use of hydraulic presses and expellers or by n-hexane solvent extraction techniques.

Although de-oiled rice bran has a better keeping quality than raw bran, its energy density is lower since oil is a good source of energy. Virk, Lodhi and Ichponani (1980) reported that replacing equivalent weights of maize with de-oiled rice bran in broiler diets lowered the ME content, increased the crude fibre content and led to an increase in feed intake while depressing body weight gains. It appears that if the fibre level of the de-oiled bran could be lowered (by treating the bran with acid or alkali), its nutritive quality would be improved. Indeed Purusothaman, Agrawal and Sadagopan (1989) have shown that there are no differences in the performance of broiler chicken fed 0, 10, 15 or 20% acid (0.34 N HCl) treated rice bran.

2.5.3 Parboiling.

Parboiled rice bran is a by-product from the milling of parboiled rice. Parboiling is in itself a hydrothermal process in which the crystalline form of starch is changed into an amorphous one due to the irreversible swelling and fusion of starch (Luh and Mickus, 1980). This is accomplished by soaking, steaming, drying and milling. The resultant rice bran is higher in oil content than the raw bran (Siriwardene, 1969).

Wide differences in oil, fibre, ash and available carbohydrate content exist between parboiled, raw, stabilised and de-oiled rice bran (Zombade and Ichponani, 1981). These workers showed that ME values and body weight gains were lower for broiler chicks fed on parboiled and stabilised rice bran than those fed on unprocessed rice bran. As for Leghorn pullets, sexual maturity was delayed significantly when they were fed on diets containing 60% parboiled rice bran.

2.5.4 Pelleting rice bran diets.

Pelleting of rice bran containing diets has led to an improvement in pig performance. Angelova and Ilieva (1988) reported improved performance in pigs in terms of gains, feed utilisation, slaughter indices and chemical composition of meat when a pelleted mixture of rice husks, bran and commercial feed was used to make a mixed feed based on maize and barley. Pelleting seems to improve pig or chicken performance through increasing feed intake. The size of pellets also has an effect on feed intake. An increase in feed intake was noted when broiler chicks were switched from feeding on pellets that were 2-mm to those that were 3-mm in diameter (Prasad and Jensen, 1988).

2.5.5 Use of anti-oxidants in rice bran.

Rice bran contains peroxidases that can cause oxidative spoilage of bran components especially oils and tocopherols. Anti-oxidants have been used to control rancidity development in rice bran. Linderman, Brooks and Kornegay (1986) showed that furtherance of oxidative rancidity could be prevented by incorporating ethoxyquin into rice bran that had been stored for one year. Cabel and Waldroup (1989) used the Initial Peroxidase Value (IPV) and the 20-hour Active Oxygen Method (AOM) to assess the efficacy of ethoxyquin and EDTA as anti-oxidants. They were able to show that when ethoxyquin was used at the rate of 250 mg/kg, the IPV was reduced and that 1000 mg/kg EDTA reduced the 20-hour AOM value in fresh bran maintained at 35 and 38°C and 80 to 90% relative humidity for four weeks. When given to chicks at a level of 60% in the diet, rancid rice bran produced less growth than fresh rice bran or a stored sample in which rancidity was controlled by the addition of EDTA (Hussein and Kratzer, 1982).

2.5.6 Mineral supplementation.

Supplementation of calcium and zinc in diets containing rice bran is associated with an improvement in pig or poultry performance. Symptoms of zinc deficiency were noted in pigs fed on maize based diets in which the maize had been replaced with rice bran (Rao and Prasad, 1980). However when the experiment was repeated with a zinc supplementation of 100 mg/kg no such symptoms were seen. Maust, Pond and Scott (1972) showed that zinc supplementation restored the digestibility of components of a maize-soybean meal having 29% rice bran. Piliang, Bird, Sunde and Pringle (1982) reported that so long as zinc carbonate and limestone as sources of zinc and calcium respectively were added to rice bran diets, there was no difference in egg production between hens given bran containing diets and those on the control diet (a standard breeder diet) and that no feather defects were noted in chickens hatched from the eggs. Sayre, Earl, Kratzer and Saunders (1988) also showed that calcium supplementation of stabilised rice bran diets significantly increased weight gains and improved feed utilisation. These studies indicate the extent to which calcium and zinc are inter-related, with an excess of the former resulting in an increased dietary requirement of the latter.

3. STUDIES TO DETERMINE THE CHEMICAL COMPOSITION OF RICE MILLING BY-PRODUCTS AND THE EFFECT OF FEEDING GRADED LEVELS OF FINE RICE BRAN ON PIG PERFORMANCE.

3.1 EXPERIMENT 1: DETERMINATION OF THE CHEMICAL COMPOSITION OF RICE-MILLING BY-PRODUCTS.

3.1.1 Introduction.

Previous studies on the chemical composition of rice materials have revealed wide variations which have been attributed to factors associated with the grain itself (varietal and environmental) and the milling process (processing methods, machines and milling conditions). The range and type of by-products may also vary depending on the milling process employed. It was therefore found appropriate to determine the mineral and gross chemical composition of the various rice materials produced from Kenyan rice mills and wherever possible make comparisons on the basis of variety. Since about 78% of rice paddy is produced in the Mwea Irrigation and Settlement Scheme, this study dwelt solely on samples acquired from the Mwea Rice Mills.

3.1.2 Objective.

To determine the mineral and gross chemical composition of the rice milling by-products available in Kenya.

3.1.3 Materials and methods.

3.1.3.1 Rice materials sampled.

Samples of paddy rice and rice milling by-products were obtained from Mwea Rice Mills. At the Mwea Rice Mills, rice paddy is first dehulled leaving brown rice. The latter is then passed through cone shaped whiteners in which it is scoured in order to remove the kernel layers. Coarse rice bran is recovered as a by-product at this stage by means of a cyclone system that draws the bran upwards leaving the now whitened rice to proceed on to the polishers. In these the grains are rubbed further to remove any particles of grain dust or bran that may be attached on the surface. Fine rice bran is recovered at this stage as the by-product.

During the milling process some rice grains get broken. Small particles of broken rice grains are recovered mixed with particles of bran. This by-product is locally known as "chicken feed". Bigger particles of broken rice are lastly separated from intact grains by means of sieves. These are recovered as coarse broken rice.

The following samples were obtained for analysis:

a) Rice paddy (Basmati and BW 196 cultivars)

b) Coarse rice bran (Basmati and Sindano cultivars)

c)"Chicken feed" i.e fine broken rice (Sindano cultivar)

d) Fine rice bran i.e rice polishings (Basmati cultivar)

e) Coarse broken rice (Basmati and Sindano cultivars)

f) Rice hulls (not traced to any particular variety)

3.1.3.2 Laboratory analyses of rice paddy and by-products.

All samples were analyzed for proximate components and mineral (calcium, phosphorous and zinc) content in accordance with the official methods of A.O.A.C (1984). Calcium and zinc levels were determined by means of Model 2380 Perkin-Elmer atomic absorption spectrophotometer. Phosphorous was determined using a Model 24 Beckmann spectrophotometer.

3.1.3.3 Results and discussion.

Results of the proximate and mineral analysis are shown in Tables 3 and 4 respectively. There was apparently little difference in both proximate and mineral analysis results between the three rice varieties considered. A considerable difference however existed between the crude fibre levels of Basmati coarse bran (22.85%) and Sindano coarse bran (27.22%). McCall et al, (1953) has indeed

Table 3: Proximate analysis results for the rice materials[1]

Rice material	Moisture	Crude protein	Crude fibre	Ether extract	Ash	NFE
PADDY						
Basmati	11.82	6.79	11.06	4.49	6.44	63.89
BW196	11.41	5.95	11.60	4.48	5.55	61.01
Mean	11.62	6.35	11.33	4.49	6.00	62.45
COARSE BRAN						
Basmati	9.71	7.22	22.85	8.46	16.61	35.15
Sindano	9.44	8.97	27.22	7.44	14.54	32.39
Mean	9.58	8.10	25.04	7.95	15.58	33.77
FINE BRAN						
Basmati	10.72	10.80	8.18	14.21	8.08	48.01
FINE BROKEN						
Sindano	11.27	9.93	6.74	12.64	3.63	55.69
COARSE BROKEN						
Basmati	11.94	7.31	1.17	3.20	1.13	75.25
Sindano	11.92	7.52	1.60	3.85	1.07	74.04
Mean	11.93	7.42	1.39	3.53	1.10	74.65
HULLS[2]	9.60	3.08	41.70	1.39	31.77	12.46
Overall Mean	10.87	7.51	14.70	6.68	9.87	50.88
SD	1.04	2.28	13.40	4.38	9.83	20.91

[1]All values are percentages on 'as is' basis.

[2]Hulls could not be traced to any particular cultivar.

SD = Standard Deviation.

Table 4: Mineral analysis results for the rice material[1].

Rice material	Calcium %	Phosphorus %	Zinc ppm	Calcium: Phosphorus ratio
PADDY				
Basmati	0.088	0.325	13	1:3.7
BW 196	0.082	0.250	9	1:3.0
Mean	**0.085**	**0.288**	**11**	**1:3.4**
COARSE BRAN				
Basmati	0.130	0.556	32	1:4.3
Sindano	0.140	0.696	31	1:5.0
Mean	**0.135**	**0.626**	**31**	**1:4.6**
FINE BRAN				
Basmati	0.116	1.451	26	1:12.5
FINE BROKEN				
Sindano	0.081	0.749	40	1:9.2
COARSE BROKEN				
Basmati	0.073	1.144	11	1:15.7
Sindano	0.072	1.018	7	1:14.1
Mean	**0.073**	**1.081**	**9**	**1:14.8**
HULLS[2]	0.096	_	13	_
Overall mean	0.098	0.688	20	
SD	0.025	0.463	12	

[1]Results are on 'as is' basis.

[2]Phosphorus was not detected spectrochemically.

SD = Standard Deviation.

reported significant differences in bran composition of eight varieties of rice grown in different locations and subjected to the same milling conditions.

Differences in proximate and mineral composition existed among the different rice materials under study. Coarse broken rice had the highest moisture and nitrogen free extract (NFE) levels but had the lowest crude fibre, ash, calcium and zinc contents. Basmati fine rice bran had the highest crude protein, ether extract and phosphorus content. Rice hulls had the lowest protein and NFE levels but had the highest crude fibre and ash levels. Phosphorus was not detected in the rice hulls. Coarse rice bran had the highest calcium level compared to the other materials analyzed.

Proximate analysis results for fine rice bran and "chicken feed" (fine broken rice) showed very small differences except for ash whose content in fine rice bran was about two times higher than for"chicken feed". This is despite the fact that the two products were derived from two different rice varieties. However, the mineral analysis results were different with fine rice bran showing markedly higher values for calcium and phosphorus but a lower value for zinc content. The lowest calcium: phosphorus ratio was noted for coarse broken rice while the highest was in the case of rice paddy.

In general, by-products from the milling of rice paddy are recovered in the following order: rice hulls, coarse rice bran, fine rice bran, fine broken rice (chicken feed) and finally coarse broken rice. In this study, NFE tended to be higher in the latter fractions while protein, fibre, fat and ash tended to be lower This was in complete agreement with work done by Primo et al. (1970). This is probably due to the fact that the kernel layers at different depths of the grain differ in chemical composition with the deeper layers being poorer in protein, fibre, fat and ash but richer in NFE.

Phosphorus increased from undetectable amounts in the rice hulls to 1.45% in fine rice bran. It then decreased to 1.08% in the coarse broken rice . This agrees with work by Primo *et al* (1970) and Tanaka *et al* (1973) who reported that some elements, notably phosphorus, potassium and magnesium, increased initially only to decrease later with deeper milling.

Calcium, on the other hand, increased in the order -rice hulls to coarse rice bran but subsequently decreased in the order fine rice bran, fine broken rice and finally coarse broken rice. This is in partial agreement with work done by Tanaka, Yoshida, Asada and Kasai (1973) who otherwise reported an early sharp decrease in the concentration of calcium, manganese and iron as milling is taken deeper and deeper.

The materials under study cannot be used on their own in feeding growing to finishing pigs with satisfactory results. NRC (1988) tables for nutrient requirements of swines propose a protein level of about 16% for growing pigs and 13% for finishing pigs respectively. A digestible energy level of about 3400 kcal/kg feed is required while a calcium: phosphorus ratio of between 1.0 and 1.5 calcium to 1.0 total phosphorus is desired. Rice paddy, as was evaluated in this experiment, is too low in protein yet too high in fibre. The high fibre tends to lower the energy concentration in the material. Fine rice bran is low in fibre and high in protein. Thus, on the basis of these two nutrients, the material is more appropriate for pig feeding than the other by-products.

Fine broken rice is lower in fibre and protein than fine rice bran. Coarse broken rice is lower in fibre than all the other materials. Its protein content is also lower than for fine broken rice and fine rice bran. The high NFE content of coarse broken rice is indicative of high energy value. The high fibre, low protein, low NFE and high ash (resultant from high levels of silica) levels collectively disqualify rice hulls from being used as a feed for pigs.

The low calcium:phosphorus ratio in all the materials under study suggests a need for supplementation of calcium if the NRC (1988) recommended ratio of between 1:1 and 1.5:1 in pig diets is to be met. Fine rice bran, fine broken rice and to some extent coarse rice bran can be used in compounding pig diets if appropriate mineral supplementation is done. The energy requirements can be met by use of grains as the main sources of energy. The calcium-phosphorus imbalance can be corrected by addition of various calcium sources(such as calcium carbonate) to the pig rations.

3.2 EXPERIMENT 2: AN INVESTIGATION INTO THE EFFECT OF INCLUDING FINE RICE BRAN IN SORGHUM BASED DIETS ON THE GROWTH PERFORMANCE AND NUTRIENT DIGESTIBILITIES OF GROWING PIGS.

3.2.1 Introduction.

Results from previous work portrays fine rice bran as a material that can be used in compounding diets for pigs. Its protein and digestible energy values suggest a feedstuff that is comparable to cereal grains such as maize, wheat and sorghum. Fine rice bran is cheaper than these other energy sources. It was therefore found necessary to investigate the extent to which the level of fine rice bran in diets based on a locally available energy source (sorghum) would affect the digestibilities of various nutrients and the growth performance of pigs from weaning to the end of the growing phase.

3.2.2 Objectives.

1. To determine the effect of inclusion of fine rice bran at graded dietary levels on the performance of growing pigs.

2. To determine the effect of inclusion of fine rice bran at graded dietary levels on the nutrient digestibilities of growing pigs.

3.2.3 **Materials and methods.**

3.2.3.1 **Diets.**

Using data obtained from laboratory analysis of raw materials and from NRC (1988) tables for ingredient composition and nutrient requirements for swine, six grower diets were formulated. The diets were formulated to be isonitrogenous at 16% crude protein. The control diet contained no fine rice bran while the other five diets had rice bran replacing sorghum to make 10, 20, 30, 40 and 50% of the diets by weight. Mixing was done by means of a vertical batch mixer.

For the purpose of the digestibility trial, chromic oxide was incorporated in all diets as a marker at a rate of 0.25%. The level of other nutrient constituents was taken to be unchanged.

.2.3.2. **Experimental design.**

3 entire boars and 18 gilts were obtained from a commercial pig arm. The pigs were Large White x Landrace crosses. At the eginning of the experiment the animals were 60 days old and had an erage weight of 19.1 kg (SE = 0.27kg).

e pigs were housed in 6 separate pens each with a floor area of out 19.5 m^2. The walls and floors were made of concrete. Each pen had three discernible areas; a feeding area (demarcated into 6 separate sub-pens to accommodate individual feeding), a communal pig run (within which was the nipple drinker) and the resting or sleeping area which, unlike the other two, had a roof.

A completely randomised block design was adopted with three pens allocated to each of the two sexes. The pigs were then randomly allocated to the sub-pens where they remained for the whole experimental period. Randomisation into the diets was done separately for the two blocks. All in all, 3 boars and 3 gilts shared the same diet although they were held in separate pens.

Feeding was done both in the morning (8-9 a.m) and in the afternoon (4-5 p.m). The amount of feed offered was in accordance with the Agricultural Research Council's Feeding Scales for Pigs (1967) as shown in Appendix 1. Since the pigs were previously used to wet feed, dry feeding could not be adopted. The animals were offered wet (damp) feed.

The ration for a given pig was weighed and then transferred to a trough within the sub-pen to which the particular pig was allocated. An equal amount of water was then added to the feed and the two mixed thoroughly until no dry feed or "free" flowing water was discernible. The pigs were expected to completely finish the ration offered within the allocated one-hour feeding time. However in situations where a pig failed to finish off its ration the following formula was used to determine the feed intake:

$$\text{Feed intake(kg)} = \underset{\text{(on "as is" basis)}}{\text{Amount of dry feed offered}} - \frac{\text{Amount of Wet feed refused}}{2}$$

Feeding levels were updated every week to correspond to the new body weights of the pigs.

The same experimental design was retained for the digestibility trial. All the 36 pigs were used for a digestibility study during their 7th week in the experiment. This study took 7 days during which time the pigs were fed diets containing chromic oxide. As in the feeding trial, they were fed individually twice a day on predetermined amounts of feed based on their body weights as shown in Appendix 1.

3.2.3.3 Data collection.

Weekly live weight and feed intake values were obtained. Live weights were obtained by passing pigs over a weighing bridge suspended on a Salter Harris scale. Feed intakes were obtained as outlined in section 3.2.3.2.

For the purpose of the digestibility study, faecal samples were grabbed straight from the rectum by initiation of the defecation reflex twice every day (9 a.m.and 5.00 p.m) on day 6 and 7 of the test period. Feed samples containing the indicator were also obtained. The faecal samples were then dried in ovens set at 60°C. The four samples obtained from each animal were bulked and ground together. Analysis was then done for chromic oxide, crude protein, energy, crude fat, and dry matter in both feed and faecal samples. Proximate components were analyzed by AOAC (1980) methods while chromic oxide concentration in feed and faecal samples was determined using a modification of the method by Fenton and Fenton (1979). 1 g of faecal and 2 g of feed samples were digested in 15ml of a digestion mixture (10 mg sodium molybdate dissolved in a 150: 150: 200 mixture of distilled water, concentrated sulphuric acid and perchloric acid). In order to correct for the background chromic oxide in the samples, blanks were prepared by digesting feed and faecal samples containing no indicator along with those that contained the indicator. The end-point of digestion was a yellow colour. The digests were quantitatively transferred to 100 ml volumetric flasks with distilled water, made to volume and then allowed to settle overnight. The solutions were then carefully pipetted out and optical density measured in 1 cm cuvettes against blanks at 440 nm using a Beckmann Model 24 spectrophotometer. Graded levels of pure analytical grade chromic oxide were digested and subsequently subjected to the same procedure. From these a standard curve was prepared so that chromic oxide concentrations in diets and faeces could be read off.

Nutrient digestibilities were calculated using the following formula:

$$\text{Apparent digestibility \%} = 100 - \frac{(100 \times (\% \text{ IFd} \times \% \text{ NFc})}{(\% \text{ IFc} \times \% \text{ NFd})}$$

Where IFd= Indicator in feed.
IFc= Indicator in faeces.
NFd= Nutrient in feed.
NFc= Nutrient in faeces.

To convert digestible coefficient for energy (DCE) to digestible energy in kcal/kg from the gross energy (GE) in feed, the following formula was used:

DE (kcal/kg) = DCE% x GE (kcal/kg) in feed

3.2.3.4 Statistical analysis.

The data on daily weight gain, daily feed intake, feed:gain ratio, and the digestibilities of dry matter, crude protein, crude fat and energy was subjected to analysis of variance for a completely randomised design. Since a high correlation was noted between the time the pigs had taken on the experiment and the growth data, means were adjusted for days on experiment by regression analysis. Where significant differences were noted between means, the treatment sums of squares were partitioned into the polynomials while treatment means were compared by use of Least Square Means (Steel and Torrie, 1980).

3.2.4 Results.

3.2.4.1 Chemical analyses of the diets.

The pig grower rations were fairly isonitrogenous with the crude protein content ranging from 16.7 to 17.4 % of dry matter (Table 5). Table 6 shows the composition of diets used for the digestibility study. Gross energy (GE) values ranged from 4608.90 (diet 2) to 4977.60 kcal/kg (diet 6). The ash content increased progressively from 6.75% in the control diet to 9.25% in the diet containing the highest level of rice bran (diet 6). In contrast, the NFE decreased progressively from 59.39 in diet 1 to 50.23% in diet 6. Total phosphorus levels apparently increased with every increase in the level of fine rice bran. Non-phytate phosphorus increased slightly from 0.34 (diet 1) to 0.45% (diet 6). No trend was established in the variation of crude fibre as the dietary level of fine rice bran increased. Fibre varied within a narrow range (10.0 % in diet 2 to 11.4% in diet 4).

3.2.4.2 Growth performance.

The parameters evaluated were weight gain, feed intake and feed conversion efficiency. The results are shown in Table 7. The feed intakes were not significantly different between treatments ($p > 0.05$). However, gilts consumed more feed than boars though this was not significant ($p > 0.05$). The lowest daily feed intake was

Table 5: **Composition of pig grower rations used in the feeding trial.**

Ingredient	Diet number					
	1	2	3	4	5	6
Fine rice bran	0.00	10.00	20.00	30.00	40.00	50.00
Grain sorghum	61.52	52.80	44.21	35.58	26.96	18.34
Sunflower cake	33.38	32.10	30.69	29.32	27.94	26.56
Bone meal	2.00	2.00	2.00	2.00	2.00	2.00
Sodium chloride	0.50	0.50	0.50	0.50	0.50	0.50
Hcl-Lysine	0.10	0.10	0.10	0.10	0.10	0.10
Vit/min premix[a]	2.50	2.50	2.50	2.50	2.50	2.50
TOTAL	100.00	100.00	100.00	100.00	100.00	100.00
Chemical analyses (DM basis)[b]						
G.E (kcal/kg)	4653.30	4608.90	4795.90	4785.20	4705.80	4977.60
Crude protein %	17.37	16.96	16.76	17.05	16.75	16.70
Crude fibre %	10.64	10.17	9.97	11.24	11.43	10.87
Ash %	6.75	7.54	7.58	8.68	9.22	9.25
Ether extract %	5.85	6.84	8.49	10.46	11.30	12.95
NFE %	59.39	58.49	57.20	52.57	51.30	50.23
Calcium %	0.93	0.93	0.93	0.93	0.93	0.93
Phosphorus[c]:						
Total %	0.87	0.98	1.10	1.20	1.31	1.42
Non-Phytate %	0.34	0.36	0.38	0.40	0.43	0.45
Lysine %	0.84	0.84	0.84	0.85	0.85	0.86
Methionine %	0.70	0.70	0.68	0.67	0.66	0.65

[a]The vitamin/ mineral premix supplied the following per kg of diet: Vitamins: A, 6000 iu; D3, 800 iu; E, 20 iu; K3, 2 mg; B1, 1 mg; Nicotinic acid, 15 mg; Pantothenic acid, 7 mg; B6, 1 mg; B12, 0.01 mg; Folic acid, 0.1 mg; Choline chloride, 150 mg.
Minerals: Mn, 24 mg; Fe, 96 mg; zn, 84 mg; Cu, 15 mg; Co, 0.20 mg; I, 0.8 mg; Se, 0.06 mg.

[b]Values for calcium, phosphorous, lysine and methionine were determined by calculation.

[c]In order to calculate non-phytate phosphorus the following bioavailability levels (adapted from Pond and Maner, 1984) were assumed:

Fine rice bran	18%
Sorghum	12%
Sunflower	18%
Bone meal	100%

Table 6: **Composition of diets used in the digestibility trial.**

Ingredient	Diet number					
	1	2	3	4	5	6
Fine rice bran	0.00	10.00	20.00	30.00	40.00	50.00
Grain sorghum	61.27	52.55	43.96	35.33	26.71	18.09
Sunflower cake	33.38	32.10	30.69	29.32	27.94	26.56
Bone meal	2.50	2.50	2.50	2.50	2.50	2.50
Sodium chloride	0.50	0.50	0.50	0.50	0.50	0.50
Lysine-HCL	0.10	0.10	0.10	0.10	0.10	0.10
Chromic oxide	0.25	0.25	0.25	0.25	0.25	0.25
Vit/min premix[a]	2.50	2.50	2.50	2.50	2.50	2.50
TOTAL	100.00	100.00	100.00	100.00	100.00	100.00
Chemical analyses (DM basis)						
GE (kcal/kg)	4653.30	4608.90	4795.90	4785.20	4705.80	4977.60
Crude protein %	17.37	16.96	16.76	17.05	16.75	16.70
Crude fibre %	10.64	10.17	9.97	11.24	11.43	10.87
Ash %	6.75	7.54	7.58	8.68	9.22	9.25
Ether extract %	5.85	6.84	8.49	10.46	11.30	12.95
NFE %	59.39	58.49	57.20	52.57	51.30	50.23
Chromic oxide %	0.25	0.27	0.26	0.26	0.26	0.25

[a] Composition of premix as in Table 4.

recorded for pigs on the 40% fine rice bran diet while the highest was for those on the 10% fine rice bran diet. The lowest feed intake for male pigs was for those on 40% fine rice bran while the highest was for those on 10% fine rice bran diet. Female pigs recorded the lowest intake on 30% fine rice bran and the highest for those raised on 10% fine rice bran diet. The overall mean daily feed intake was 1537 g/ day.

The mean daily weight gain was 366 g. Males gained 368 g against 363 g for females. This difference was not significant ($p > 0.05$). There was a non-significant decrease in daily gains as the level of dietary rice bran increased. The highest daily gain was for pigs on diet 1 (377 g) while the lowest was for those on diet 6 (354 g).

Boars had a better feed conversion efficiency (FCE) than gilts though the difference was not significant. The best conversion ratio for males was 3.88 (diet 5) while that for females was 4.15 (diet 1). The poorest ratio for males was 4.52 (diet 6) while that for females was 4.48 (diet 2). The mean feed: gain ratio was 4.21. Analysis of covariance between daily weight gain and daily feed intake was not significant. Consequently, adjustment of gains and FCE for feed intake had little effect on the treatment means.

Table 7: Effect of fine rice bran on the growth performance of growing pigs

Criteria[a]	Sex[b]	N	Level of fine rice bran (%)							
			0	10	20	30	40	50	Mean	SE
Feed intake,	M	3	1527	1567	1523	1530	1412	1556	1519	
g/ day	F	3	1566	1595	1551	1527	1562	1531	1555	
	Mean	6	1546	1581	1537	1529	1487	1544	1537	8.17
Weight gain,	M	3	376	377	378	369	364	344	368	
g/ day	F	3	377	356	367	354	361	363	363	
	Mean	6	377	367	373	361	362	354	366	2.58
Feed: gain	M	3	4.06	4.16	4.03	4.15	3.88	4.52	4.13	
	F	3	4.15	4.48	4.23	4.31	4.33	4.22	4.29	
	Mean	6	4.11	4.32	4.13	4.23	4.11	4.37	4.21	0.04

[a]No significant differences ($p > 0.05$) between treatment means for the parameters under study.

[b]No significant ($p > 0.05$) sex effect

SE = Standard Error.

3.2.4.3 Digestibility trial.

The apparent digestibilities of dry matter, crude fat, crude protein and gross energy were considered. Results are shown in Table 8. The apparent dry matter digestibility showed a significant linear increase ($p < 0.05$) as the level of fine rice bran in the diet increased from 0 to 50% in diet 6. However, the highest digestibility value was 61.81% for pigs on 40% fine rice bran while the lowest was 55.00% for those on 20% fine rice bran. The differences between the digestibilities for corresponding diets for males and females were not significant ($p > 0.05$). The mean apparent dry matter digestibility was 58.29%.

The mean digestible energy (DE) value was 2976 kcal/ kg DM. There was a significant linear effect ($p <0.05$) of the rice bran content on the DE. An increase in the dietary levels of rice bran resulted in an increase in DE. Diet 2 had the lowest DE (2839 kcal/ kg DM) while diet 6 had the highest (3272 kcal/ kg DM). There was no significant difference ($p > 0.05$) between sexes. The apparent digestibility of crude fat showed a highly significant linear increase ($p < 0.001$) as the level of fine rice bran in the diets increased. Pigs on 40% fine rice bran registered the highest digestibility value while those on 10% fine rice bran had the lowest. The mean crude fat digestibility was 57.36%.

Table 8: Effect of level of fine rice bran on the apparent digestibilities of nutrients for growing pigs.

Criteria	Sex	N[1]	Level of fine rice bran (%) 0	10	20	30	40	50	Mean	SE
Dry matter	M	3	58.60	56.23	52.88	58.54	61.25	60.11	57.99	
(%)	F	3	58.32	55.77	57.12	56.68	62.37	61.30	58.59	
Mean[a]		6	58.46	56.15	55.00	57.61	61.81	60.71	58.29	0.41
Crude fat	M	3	41.05	47.65	56.57	69.72	72.96	63.07	58.50	
(%)	F	3	39.40	34.70	59.05	65.73	75.73	62.63	56.21	
Mean[b]		6	40.23	41.18	57.81	67.73	74.35	62.85	57.36	1.71
Crude pro-	M	3	50.16	43.84	44.55	57.07	62.55	60.44	53.07	
tein (%)	F	3	44.24	41.70	53.26	52.15	62.82	61.78	52.49	
Mean[a]		6	47.20	42.77	48.91	54.61	62.68	61.11	52.78	0.64
Energy	M	3	2868	2819	2743	2993	3011	3300	2956	
(kcal/kg)	F	3	2816	2859	3033	3005	3025	3244	2997	
Mean[a]		6	2842	2839	2888	2999	3018	3272	2976	27.47

[1] N = 2 for the results of males on diets containing 30% fine rice bran.
[a] Significant linear effect ($p < 0.05$).
[b] Significant linear effect ($p < 0.001$)
SE = Standard Error.

The digestibilities of crude protein followed a trend similar to those of dry matter, energy and crude fat. A significant linear increase ($p < 0.05$) of the crude protein digestibility with an increase in the level of fine rice bran was noted. The highest value attained was 62.68% (diet 5) while the lowest was 42.77% (diet 2). The mean crude protein digestibility was 52.78%.

3.2.5 Discussion.

While formulating the diets, the dietary fibre level had been intended to be at most 5%. The determined fibre levels in the diets were however higher. This was due to the use of the high fibre sunflower seed cake as the protein source. Since fine rice bran with a crude fibre content of 8.2% was replacing sorghum, an ingredient with a lower crude fibre content of 4.3%, diets were expected to have progressively higher levels of crude fibre as the dietary levels of fine rice bran increased. However, on analysis it was noted that all diets had almost similar levels of crude fibre. This was brought about by the fact that the level of sunflower seed cake, whose crude fibre content was 21.2%, also decreased progressively as the level of fine rice bran in the diets increased. An increase in the fibre contributed by the fine rice bran occurring simultaneously with a decrease in the fibre contributed by the sunflower seed cake resulted in diets of almost similar fibre levels.

The high ash content in the high fine rice bran diets resulted from the high levels of silica and phosphorous in rice bran. The phosphorous content of fine rice bran was 1.5% against 0.3% for sorghum and 1% for sunflower seed cake. The decrease in the content of the NFE as the levels of fine rice bran in the diets increased was probably due to the fact that bran had a lower content of NFE than sorghum.

In general, the daily weight gains and feed conversion efficiencies were poor compared to the NRC (1988) values. A growing pig is expected to gain between 500 and 700 g/ day and should give a feed/ gain ratio of between 2.0 and 2.9. The poor performance recorded in the present study may have resulted from, among other things, the restricted mode of feeding and the high fibre levels (10.0 to 11.4%) in the diets. NRC (1988) recommends a dietary fibre level of not more than 5%. The daily nutrient intake as well as nutrient density were therefore quite low. This meant that the pigs did not have enough nutrients to adequately satisfy their maintenance and growth requirements.

The generally low digestibility coefficients recorded in this study further confirm the poor feeding value of the diets. In comparison to the NRC (1988) DE value of about 3390 kcal DE/ kg, the mean value reported for the experimental diets of 2976 kcal/ kg was low. The low values are a reflection of the high fibre levels in all the diets. A negative correlation has been reported between the fibre content and the digestible energy in pig diets (Batterham, Lewis, Lowe and Mcmillan, 1980) and between fibre and both dry matter and protein digestibilities in rat diets (Mitaru and Blair, 1984).

Lack of significant differences in weight gains among diets differs from results obtained by Ara, Owen and Buitrago (1975) who noted a linear decrease in daily gains and efficiency of feed utilisation in pigs fed graded levels of rice bran as a substitute for sorghum. The quality of both rice bran and sorghum may have played a major role in determining the performance of the pigs.

The digestibility of fat increased linearly with the increase in fine rice bran content in the diet. This appeared to correspond to the increasing levels of crude fat in the diets. This supports the observations made by Just, Andersen and Jargensen (1981) who reported that the apparent digestibility of crude fat and fatty acids increased as the dietary crude fat increased. Further, these workers established that more unsaturated than saturated fatty acids were digested. Rice bran contains oils that are mostly esters of the unsaturated fatty acids, oleic and linoleic acids (Sarkar and Bhattarcharyya, 1989). Higher crude fat digestibility may therefore be expected at high dietary levels of rice bran.

The linear increase in the digestibility of crude protein and energy can be explained in terms of the relative amounts of rice bran, sorghum and sunflower seed cake. As observed above an increase in the level of rice bran in the diets led to an increase in crude fat digestibility. In addition since fat is a good source of energy, the increase in crude fat digestibility may have led to a corresponding increase in energy digestibility. Since fine rice bran was mainly replacing sorghum, a grain that contains tannins, it is expected that the dietary levels of tannins decreased as the content of rice bran in the diets increased. Tannins depress the digestibilities of energy and protein in swine (Cousins, Tanksley, Knabe and Zebrowska, 1981). This may further explain the higher crude protein and energy digestibilities at higher levels of fine rice bran.

The current study showed that despite a linear increase in the nutrient digestibilities as the level of fine rice bran increased, no corresponding improvement in weight gains was noted. Indeed, to the contrary, weight gains tended to decrease with an increase in the level of dietary rice bran. Certain factors tended to counteract the benefits that may have been gained from an improvement in nutrient digestibilities. It is likely that increments in dietary levels of fine rice bran resulted in imbalances or deficiencies of certain minerals. An increase in dietary rice bran was accompanied with a concomitant increase in phytic acid. Phytic acid had the effect of binding both phosphorus and zinc hence making them less available. Although non-phytate phosphorus increased slightly with increments in dietary rice bran, zinc availability is likely to have been considerably lowered by the high levels of phytic acid. Oberleas *et al* (1962) showed that the addition of phytic acid to a diet based on animal protein produced symptoms of parakeratosis and growth depression typical of plant protein diets. These workers were also able to show that zinc supplementation completely counteracted the effect of phytic acid. Although no symptoms of zinc deficiency were noted in the current experiment, an impediment in zinc availability is likely to have adversely affected the growth of the pigs to the extent that any anticipated improvements in growth performance at higher levels of dietary fine rice bran were not discernible.

3.3 EXPERIMENT 3: AN INVESTIGATION INTO THE EFFECT OF INCLUDING FINE RICE BRAN IN SORGHUM BASED DIETS ON THE GROWTH PERFORMANCE AND CARCASS QUALITY OF FINISHING PIGS.

3.3.1 Introduction.

Results from the previous experiment indicate that there are no significant differences in weight gain and feed: gain ratios between pigs fed diets containing varying levels of fine rice bran. This was so despite a linear increase in most digestion coefficients. On the basis of this information a follow-up on the trends in growth performance during the finishing phase was found necessary. The overall effect of feeding pigs on graded levels of fine rice bran on carcass quality was also assessed.

3.3.2 objectives.

1. To determine the effect of feeding fine rice bran on the growth performance of finishing pigs.

2. To determine the effect of feeding fine rice bran on the carcass quality of finishing pigs.

3.3.3 Materials and methods.

3.3.3.1 Diets

The materials used in the grower diets were again used for the finisher diets. However the formulation was changed in order to have diets that were lower in protein content. The diets were formulated to be isonitrogenous at 13% crude protein. Like in the case of the grower diets, six diets were formulated to have fine rice bran contributing 0, 10 ,20, 30, 40 and 50% of the diets by weight.

3.3.3.2 Experimental design.

The experimental design adopted for the grower phase of the feeding trial was retained for the finishing phase. A pig that was previously on a grower diet containing a certain level of fine rice bran continued on a finisher diet containing the same level of fine rice bran when it reached a live weight of about 60 kg. When a pig attained a weight that was short of 60 kg by a margin that was equal to or less than its previous weekly weight gain, it was immediately put on the corresponding finisher diet. The method and time of feeding was as described for the grower phase in section 3.2.3.2 above.

3.3.3.3 Slaughter of pigs.

When the pigs reached a live weight of about 90 kg, they were taken for slaughter. On the day of slaughter, the animals were put off feed, weighed and transported to a commercial slaughterhouse. The animals were subjected to a standard ethical slaughter process for pigs which involved stunning, bleeding, scalding, evisceration and carcass splitting in that order. The carcasses were split along a caudo-dorsal plane through the vertebral column.

3.3.3.4 Data collection.

Data on live weight gains, feed intake and feed conversion efficiency was obtained as described in section 3.2.3.3. Feed samples obtained from several batches of the diets were subjected to routine proximate analysis.

For carcass evaluation the following measurements were considered:

1. **Warm dressed weight:** Weight of the carcass about one hour after bleeding.
2. **Percent warm dressed weight:** Warm dressed weight as a percentage of the live weight of the animal at slaughter.
3. **Rump back fat thickness:** Depth of the mid-line back fat at the rump anterior to the *m. gluteus medius*.
4. **Mid-back back fat thickness:** Depth of the mid-line back fat at the mid-back between the 7th and 8th vertebrae forward of

the sacrum.

5. **Shoulder back fat thickness:** Depth of the mid-line back fat at the shoulder at the level of the first rib.
6. **Average back fat thickness:** Mean of the depths of back fat at the rump, mid-back and shoulder.
7. **Carcass length:** Length of the interval between the anterior edge of the symphysis pubis to the recess of the 1st rib.

3.3.3.5 Statistical analysis.

Statistical analysis of data on daily weight gain, daily feed intake, feed to gain ratio, warm dressed weight percent, carcass length and average back fat thickness was done as described in section 3.2.3.4. The effect of slaughter weight on gains, intakes, and carcass measurements was removed by regression analysis.

3.3.4 Results.

3.3.4.1 Chemical analyses of the diets.

The crude protein content in the diets ranged from 13.28% in diet 6 to 14.12% in diet 3 on a DM basis (Table 9). Crude fibre ranged from 7.68% (diet 2) to 10.28% (diet 6) while ether extract generally increased from 4.84% (diet 1) to 9.61% (diet 5). Ash content was highest in diet 5 (9.46%) and lowest in diet 1 (5.63%).

Table 9: Composition of pig finisher rations used in the feeding trial.

Ingredients	Diet number					
	1	2	3	4	5	6
Fine rice bran	0.00	10.00	20.00	30.00	40.00	50.00
Grain sorghum	75.18	66.46	57.68	49.22	40.59	31.97
Sunfl.s.cake	20.05	18.77	17.55	16.01	14.64	13.26
Bone meal	2.15	2.15	2.15	2.15	2.15	2.15
Sodium Chloride	0.05	0.05	0.05	0.05	0.05	0.05
Hcl-Lysine	0.07	0.07	0.07	0.07	0.07	0.07
Vit/Min premix[a]	2.50	2.50	2.50	2.50	2.50	2.50
TOTAL	**100.00**	**100.00**	**100.00**	**100.00**	**100.00**	**100.00**
Chemical analyses (DM basis)[b]						
G.E (Kcal/kg)	4558.30	4490.60	4596.50	4377.90	4595.20	4657.20
Crude protein %	13.57	13.32	14.12	14.08	14.00	13.28
Crude fibre %	7.84	7.68	9.43	8.72	8.91	10.28
Ether extract %	4.84	5.76	7.43	6.99	9.61	9.31
Ash %	5.63	6.57	7.07	8.04	9.46	8.36
N.F.E %	68.12	66.67	61.95	62.17	58.02	58.77
Calcium %	0.78	0.78	0.78	0.78	0.78	0.78
Phosphorous:[c]						
Total %	0.80	0.91	1.02	1.13	1.24	1.35
Non-phytate %	0.34	0.36	0.38	0.40	0.43	0.45
Lysine %	0.60	0.61	0.62	0.62	0.63	0.64
Methionine %	0.53	0.52	0.51	0.50	0.49	0.48

[a]Composition of vitamin/mineral premix as for the grower rations.
[b]Values for calcium, phosphorous, lysine and methionine were determined by calculation.
[c]Non-phytate phosphorus was calculated as explained in Table 5.

NFE content approximately followed a decreasing trend from 68.12 in diet 1 to 58.77% in diet 6. Gross energy ranged from 4377.90 (diet 3) to 4657.20 (diet 6). Calculated total phosphorus content increased from 0.80 (diet 1) to 1.35% (diet 6) while non-phytate phosphorus increased marginally from 0.34 (diet 1) to 0.45% (diet 6).

3.3.4.2 Growth performance.

The parameters evaluated were weight gain, feed intake and feed efficiency. The results are shown in Table 10. No significant differences ($p > 0.05$) among diets were noted in weight gain and feed conversion efficiency. Feed intakes were significantly different ($p < 0.05$) across dietary treatments with pigs on the 20% fine rice bran diets having the lowest and those on diet 6 having the highest. Pigs on diet 6 had the highest weight gain (582 g/day) while those on diet 3 had the lowest (528 g/day). The highest feed: gain ratio was 4.84 for animals on diet 4 while the lowest was 4.44 for those on diet 3. Males had a lower feed: gain ratio than females though this was not significant ($p > 0.05$).

3.3.4.3 Carcass data.

Table 11 shows carcass analysis data. Adjustment of the parameters for slaughter weight had little effect on the values due to low correlations between the relevant factors. Males had significantly

Table 10: Effect of fine rice bran on the growth performance of finishing pigs.

Criteria	Sex	N	Level of fine rice bran							
			0	10	20	30	40	50	Mean	SE
Feed intake	M	3	2533	2499	2318	2617	2347	2708	2504	
g/ day	F	3	2374	2722	2360	2633	2511	2513	2519	
Mean										
		6	2454bc	2610ab	2339c	2625a	2429c	2611ab	2512	22.98
Weight gain	M	3	536	557	529	536	523	590	545	
g/day	F	3	516	558	526	549	533	574	543	
Mean[1]										
		6	526	558	528	543	528	582	544	10.26
Feed:gain	M	3	4.73	4.49	4.38	4.88	4.48	4.59	4.59	
ratio	F	3	4.60	4.88	4.49	4.80	4.71	4.38	4.64	
Mean[1]										
		6	4.67	4.69	4.44	4.84	4.60	4.49	4.62	0.07

a,b,c Means bearing different letters in a row are significantly different ($p < 0.05$).

[1]Means are not significantly different ($p > 0.05$).

SE = Standard Error.

Table 11: Effect of fine rice bran on the carcass quality of pigs fed on it during the growing and finishing phases.

Criteria	Sex	N	Level of rice bran in the diets (%) 0	10	20	30	40	50	Mean	SE
Time(days) to slaughter										
	M	3	169	163	196	174	177	191	178	
	F	3	169	187	159	159	159	169	167	
	Mean	6	169	175	177	166	168	180	173	3.3
Slaughter weight (kg)[1]										
	M	3	93.7	93.8	93.0	94.2	92.3	97.8	94.1	
	F	3	93.2	97.5	91.5	94.2	92.0	93.8	93.7	
	Mean	6	93.5	95.7	92.3	94.2	92.2	95.8	93.9	0.6
Dressed weight (%)[2]										
	M	3	77.0	78.0	77.2	78.4	75.8	76.1	77.1	
	F	3	79.2	79.6	77.3	77.8	77.3	79.0	78.4	
	Mean	6	78.1	78.8	77.3	78.1	76.5	77.6	77.7*	0.3
Carcass length (cm)[2]										
	M	3	78.0	79.0	73.0	78.7	76.3	79.7	77.5	
	F	3	76.3	76.0	77.0	75.7	76.0	75.3	76.1	
	Mean	6	77.2	77.5	75.0	77.2	76.2	77.5	76.8	0.4
Rump back-fat (cm)										
	M	3	2.03	1.53	1.73	2.00	1.63	2.02	1.82	
	F	3	2.05	2.20	1.77	2.17	2.13	2.57	2.14	
	Mean	6	2.04	1.87	1.80	2.09	1.88	2.30	1.98	0.08
Shoulder back-fat (cm)										
	M	3	4.43	3.23	3.57	4.13	3.83	4.17	3.89	
	F	3	4.15	4.03	3.47	4.00	3.97	4.47	4.02	
	Mean	6	4.29	3.63	3.52	4.07	3.90	4.32	3.96	0.10
Mid-back back-fat (cm)										
	M	3	2.03	1.88	1.77	1.83	1.52	1.77	1.80	
	F	3	2.07	2.23	1.50	2.23	2.10	2.27	2.07	
	Mean	6	2.05	2.06	1.64	2.03	1.72	2.02	1.92	0.08
Average back-fat (cm)[2]										
	M	3	2.83	2.21	2.36	2.65	2.33	2.65	2.51	
	F	3	2.76	2.82	2.25	2.80	2.73	3.10	2.74	
	Mean	6	2.79	2.52	2.31	2.73	2.53	2.88	2.63	0.06

[1]The following non-significant ($p > 0.05$) correlations were noted:
Between slaughter weight and average back fat = 0.26
Between slaughter weight and carcass length = 0.18
Between slaughter weight and dressed wt. % = 0.06

[2]Non-significant differences ($p > 0.05$) between treatment means.

*Dressed weight % for gilts significantly higher ($p < 0.05$) than for boars.

SE = Standard error of the mean.

lower ($p < 0.05$) percent warm dressed weight than females. They also had slightly longer carcasses but less back fat thickness than females though the differences were not significant ($p > 0.05$). There were no significant differences in carcass measurements considered across diets. In general, there was a linear decrease in percent warm dressed weight as the level of fine rice bran increased. The mean percent dressed weight was 77.73 while the mean carcass length was 76.8 cm with pigs on diet 3 having the shortest carcasses (75.1 cm) and those on diet 2 and 6 having the longest (77.5 cm). Back fat thickness at the shoulder, rump and mid-back was 3.96, 1.99 and 2.63 cm respectively while the overall average back fat thickness for the three points was 2.63 cm. Average back fat values ranged from 2.31 cm (diet 3) to 2.88 cm (diet 6).

3.3.5 Discussion.

The increase in crude fibre content as the level of fine rice bran increased suggests that the latter contributed significantly to the fibre level of the diets. The increasing levels of ether extract and ash can similarly be explained. The generally increasing fibre content as the levels of fine rice bran in the diets increased was expected to have had a bearing on the trend of weight gains and feed conversion efficiencies of the pigs. Weight gain was expected to decrease as the conversions became poorer. That this was not the case suggests that the pigs were able to tolerate the fibre. Indeed, the best weight gain was for pigs on the highest dietary level of fine rice bran. This is probably due to the fact that during this phase of growth, the pigs have an enhanced ability to digest fibre. Lack of response to increasing fibre levels has also been reported by Chamorro and Maner (1974) who noted lack of any significant differences in weight gains of pigs fed graded levels of ground rice hulls up to an inclusion rate of 40% of the diet by weight.

The daily gains and feed conversion efficiencies were on the whole poor. A mean daily gain and feed conversion efficiency of 544 g and 4.62 for this experiment compared unfavourably to 800 g and 3.75 respectively recommended by the NRC (1988) for finishing pigs of between 60 and 100 kg live weight. While the low weight gains may have been a consequence of the restricted mode of feeding, the poor conversions suggested that the feed was of low feeding value.

The carcass analysis data is actually a reflection of the performance of the pigs both in the growing and finishing phases. The significantly lower warm dressed weight percent in males compared to females agrees with results obtained by Yen, Wang and Yu, (1990). These results suggests that for the males the contribution of visceral organs to the live weight is higher than for the females. A decreasing linear relationship between dressed weight percent and levels of fine rice bran has also been reported by Tuah and Boateng (1983). That carcasses for boars were longer than those for gilts is more of a sex-related characteristic than it is diet related. Boars tend to have longer carcasses than barrows (Ingemar, Kerstin and Birgitta, 1975) which in turn have shorter carcasses than gilts (Christian, Stock and Carlson, 1980). Perhaps the fact that boars have a higher bone and meat percent (Yen, *et al.*, 1990) may partly explain why their carcasses are longer since these two carcass components greatly determine the morphological dimensions of an animal.

The positive correlation between carcass length and weight at slaughter suggests that one factor increases with an increase in the other. This is supported by Ingemar *et al.* (1975) who established that higher slaughter weights resulted in an increase in the length of the carcass by about 5-7 cm/ 20 kg increase in live weight. Christian *et al.* (1980) compared carcasses of pigs slaughtered at a live weight of 113.5 kg and those slaughtered at 98.5 kg and noted that carcasses for the heavier slaughter weight group were longer.

The correlation coefficient of 0.26 between the average back fat thickness and slaughter weight shows the importance of correcting for the latter. Ingemar *et al.* (1975) also showed that the heavier the pigs at slaughter, the higher the back-fat thickness, with the greatest increase occurring in the interval 90-110 kg. This work was also corroborated by Christian *et al.* (1980) who reported higher back fat values in pigs slaughtered at heavier weights. That boars have lower back fat values than gilts has also been shown by Giles, Murison and Wilson (1981).

Back fat thickness is an indication of the nutritional status of the pig at slaughter and by extension, of the feeding value of the diets under study. Fat deposition suggests that the energy the animal is obtaining from feed is in excess of maintenance and growth requirements. Animals with a high positive energy balance are likely to deposit more fat in their tissues. This is best illustrated by Giles *et al.* (1981). A comparison was made between pigs fed at four feeding levels per day : To appetite, ARC* DE intake, 87.5% ARC DE intake and 75% ARC DE intake. When this last level of feeding was compared to the ARC DE intake a decrease in the shoulder maximum back fat, mid-back and loin back fat thickness by 6.8 mm (14.4%), 4.2 mm (16.8%) and 4.1 mm (17.5%) respectively was noted. Tuah and Boateng (1983) reported that carcass fat generally decreased with increasing levels of rice bran. Animals in the present study however did not show significant differences in back fat thickness, neither was there any clear trend relating back fat thickness to the dietary level of fine rice bran. This indicates lack of any significant differences between the diets under study in the amount of that portion of dietary energy that was converted to fat.

* ARC = Agricultural Research Council.

4. GENERAL DISCUSSION.

The aim of this chapter is to summarise and tie up the results of the three experiments while attempting to evaluate the economics of feeding the diets under study.

When due consideration was given to proximate and mineral composition, fine rice bran and to some extent coarse rice bran emerged as suitable ingredients for compounding pig diets. Fine rice bran was particularly appropriate for pig diets due to its relatively low cost, high protein and high energy content. However it had a fibre level that surpasses that of grains, a low calcium: phosphorus ratio and lastly a high oil content that may lower its keeping quality.

The growth performance of pigs was not significantly affected by dietary fine rice bran during both the grower and finisher phases. However there were indications that the diets went down better with the finisher than the grower pigs. While weight gains for grower pigs tended to decrease as the dietary level of fine rice bran increased, the same was not observed for finishers. Indeed, although no trend was observed in the weight gains for the finishers, pigs on the highest dietary level of fine rice bran gave the best gains. Indeed, weight gains were expected to decrease during the finishing phase in response to the increasing levels of fibre with every increment in dietary fine rice bran. Again, the poorest feed:gain ratio for grower pigs was for those on the highest dietary level of fine rice bran. The situation was notably different during the finishing phase since pigs on the highest dietary level of rice bran registered a feed:gain ratio that was well below the mean for the six treatments.

Lack of any significant difference in weight gain and feed conversion efficiency between treatments in both the growing and finishing phases of the pigs meant that substitution of fine rice bran for sorghum did not affect the feeding value of the diets. This was so despite the fact that the apparent digestibilities of dry matter, energy, crude protein and crude fat improved as the levels of rice bran in the diets increased. It is likely that the advantage gained from an improvement in nutrient digestibilities was not large enough to have a discernible corresponding bearing on the growth performance of the pigs. Of no less importance was the fact that as the level of fine rice bran in the diets increased, the proportion of dietary phytate increased. This may have had the effect of binding dietary zinc making it less available to the pigs and thereby compromising their growth performance.

Nonetheless, better profit margins, calculated as shown in Table 12, were realised for pigs on higher levels of fine rice bran (Table 12). Diet 1 (0% rice bran) gave the lowest margin (Ksh 731) while diet 6 (50% rice bran) had the highest (Ksh 1294). Fine rice bran can therefore be recommended as a substitute for sorghum in rations for pigs especially those in their finishing phase.

The author feels that there is need for further work to be done before recommendations on the level of inclusion of fine rice bran are made. First, the fine rice bran produced from our mills does not undergo further processing such as stabilisation and de-oiling. Consequently it is quite prone to undergoing certain deteriorative changes especially during storage. Rancidity is likely to develop while attack of the material by molds is possible. It would therefore be worthwhile to investigate the extent to which these changes occur over time and their effect on the growth performance of pigs. An investigation should also be carried out to determine the performance of pigs offered diets containing fine rice bran but in which adequate supplementation of minerals such as zinc has been done.

Table 12: Gross margins per pig at slaughter (at an age of 233 days).

Particulars	Dietary treatment					
	1	2	3	4	5	6
Slaughter weight(kg)	98	100	98	99	98	101
Warm dressed wt.(kg)	76	79	75	77	75	78
Sale price @ kshs.40 per kg dressed wt(S).	3040	3160	3000	3080	3000	3120
Feed consumed in the experiment (kg)	346	363	335	359	339	359
Cost of feed ksh/kg	4.36	4.06	3.76	3.46	3.16	2.86
Cost of feed consumed, ksh (F)	1509	1474	1260	1242	1071	1026
Cost of 60 days old piglets, ksh(P)	800	800	800	800	800	800
GROSS MARGIN,ksh(S-F-P)	731	886	940	1038	1129	1294

5. CONCLUSION.

1. There was little difference in the gross chemical and mineral (calcium, phosphorous and zinc) composition between corresponding rice-milling by-products derived from three cultivars-Basmati, Sindano and BW 196. Sindano coarse bran however had about 19% more crude fibre than the one from Basmati.

2. The higher the proportion of endosperm relative to that of bran in the rice milling by-products, the higher the nitrogen free extract, the lower the protein, fibre, fat and ash and the lower the calcium: phosphorous ratio.

4. The apparent digestibilities of dry matter, energy, protein and fat for growing pigs increased linearly as the level of rice bran in the sorghum based diets increased.

5. Use of fine rice bran up to a level of 50% in sorghum based diets for growing-finishing pigs had no significant effect across dietary treatments on weight gains, feed conversion efficiencies, dressing-out percentage, carcass length and back fat measurements. However, boars had a significantly lower dressing-out percentage than gilts.

8. Fine rice bran can be used as a more economical substitute for sorghum especially in finishing pig diets.

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APPENDICES:

Appendix 1

Feeding scales adopted in feeding the experimental pigs[1].

Live weight (kg)	Feed/ day (kg)	Live weight (kg)	Feed/ day (kg)
15.0 - 15.5	0.85	54.0 - 55.0	2.35
16.0 - 17.0	0.90	55.5 - 56.5	2.35
17.5 - 18.5	0.95	57.0 - 58.0	2.40
19.0 - 20.0	1.00	58.5 - 59.5	2.45
20.5 - 21.5	1.05	60.0 - 61.0	2.50
22.0 - 23.0	1.10	61.5 - 62.5	2.50
23.5 - 24.5	1.15	63.0 - 64.0	2.55
25.0 - 26.0	1.20	64.5 - 65.5	2.65
26.5 - 27.5	1.30	66.0 - 67.0	2.70
28.0 - 29.0	1.35	67.5 - 68.5	2.70
29.5 - 30.5	1.45	69.0 - 70.0	2.75
31.0 - 32.0	1.50	70.5 - 71.5	2.75
32.5 - 33.5	1.55	72.0 - 73.0	2.80
34.0 - 35.0	1.65	73.5 - 74.5	2.80
35.5 - 36.5	1.70	75.0 - 76.0	2.85
37.0 - 38.5	1.75	76.5 - 77.5	2.90
39.0 - 40.0	1.85	78.0 - 79.0	2.95
40.5 - 41.5	1.90	79.5 - 80.5	3.00
42.0 - 43.0	1.95	81.0 - 82.0	3.05
43.5 - 44.5	2.00	82.5 - 83.5	3.05
45.0 - 46.0	2.05	84.0 - 85.0	3.10
46.5 - 47.5	2.10	85.5 - 86.5	3.10
48.0 - 49.0	2.15	87.0 - 88.0	3.15
49.5 - 50.5	2.20	88.5 - 89.5	3.15
51.0 - 52.0	2.25	90.0 - Slaughter	3.20
52.5 - 53.5	2.30		

[1] Agriculture Research Council (1967).

Appendix 2

Composition of ingredients used in the experimental diets.

Feed ingredient	Composition (% Dry Matter)						
	CP	CF	EE	Ash	Ca	P	Lys
Fine rice bran	12.0	9.2	15.9	9.1	0.1	1.6	0.6
Grain sorghum	9.5	4.9	4.5	2.3	-	0.4	0.2
Sunflower s. cake	32.9	25.8	11.4	7.1	0.4	1.1	1.4
Bone meal	-	-	-	82.0	25.5	13.0	-
Sodium chloride	-	-	-	96.6	-	-	-
Lysine	-	-	-	-	-	-	99.0

CP = Crude protein
CF = Crude fibre
Ca = Calcium
EE = Ether extract
Lys = lysine
P = Phosphorous

Appendix 3: ANOVA for digestibility data (least square analysis)

A1. Effect of fine rice bran on dry matter digestibility.

ANOVA

Source	D.F	Sums of squares	Mean square	Calculated F	Probability	Signif. ($p<0.05$)
Sex	1	0.827	0.827	0.544	0.4683	ns
Treatment	5	191.470	38.294	6.564	0.0006	*
Linear	1	78.138	78.138	13.394	0.0013	*
Quad.	1	46.756	46.756	8.015	0.0095	*
Cubic	1	47.873	47.873	8.206	0.0088	*
Quard.	1	18.703	18.703	3.206	0.0868	ns
Quin.	1	0.000	0.000	0.000	0.9966	ns
Treat x Sex	5	29.805	5.961	1.022	0.4279	ns
Error	23	134.179	5.834			
Total	34	356.281				

Mean = 58.443% Error SD = 2.415% CV = 4.13% R^2 = 0.612

A2: Effect of fine rice bran on crude protein digestibility

ANOVA.

Source	D.F	Sum of squares	Mean square	Calculated F	Probability	Signif. (P=0.05)
Sex	1	1.726	1.726	0.123	0.7294	ns
Treatment	5	1882.920	376.584	26.743	0.0000	**
Linear	1	1547.564	1547.564	109.901	0.0000	**
Quad	1	30.793	30.793	2.187	0.1528	ns
Cubic	1	286.374	286.374	20.337	0.0002	*
Quard.	1	0.486	0.486	0.034	0.8543	ns
Quin.	1	17.704	17.704	1.257	0.2737	ns
Treat x Sex	5	184.465	36.893	2.620	0.0513	ns
Error	23	323.874	14.081			
Total	34	2392.985				

Mean = 53.120% Error SD = 3.753% CV = 7.06% R^2 = 0.863

A3: **Effect of fine rice bran on crude fat digestibility.**

ANOVA

Source	D.F	Sum of square	Mean square	Calculated F	Probability	Signif. ($p < 0.05$)
Sex	1	45.572	45.572	0.451	0.5087	ns
Treatment	5	5890.721	1178.144	11.649	0.0000	**
Linear	1	4261.260	4261.260	42.135	0.0000	**
Quadr.	1	732.601	732.601	7.244	0.0130	*
Cubic	1	845.225	845.225	8.357	0.0082	*
Quard.	1	9.602	9.602	0.095	0.7608	ns
Quint.	1	42.033	42.033	0.416	0.5255	ns
Trt x Sex	5	246.011	49.202	0.487	0.7828	ns
Error	23	2326.078	101.134			
Total		8488.382				

Mean = 57.375% Error SD = 10.057% CV = 17.53% R^2 = 0.727

A4: **Effect of fine rice bran on energy digestibility.**

ANOVA.

Source	D.F	Sum of squares	Mean square	Calculated F	Probability	Signif (p<0.05)
Sex	1	14634.3	14634.3	0.561	0.4614	ns
Treatment	5	3831256.4	766251.3	29.374	0.0000	**
Linear	1	1892136.2	1892136.2	72.535	0.0000	**
Quadr.	1	257943.8	257943.8	9.888	0.0045	*
Cubic	1	574204.9	574204.9	22.012	0.0001	*
Quard.	1	971151.6	971151.6	37.229	0.0000	**
Quint.	1	135819.9	135819.9	5.207	0.0321	*
Trt x Sex	5	103533.6	20706.7	0.794	0.5652	ns
Error	23	599974.1	26085.8			
Total	34	4552172.3				

Mean = 2896.029 kcal/kg Error SD = 161.511 kcal/kg CV = 5.62%
R^2 = 0.868

Appendix 4: ANOVA for data on the performance of growing pigs (least square analysis).

B1: Effect of fine rice bran on the daily weight gains of growing pigs.

ANOVA

Source	D.F	Sum of squares	Mean squares	Calculated F	Probability	Signif. (p=0.05)
Sex	1	0.000127	0.000127	0.529	0.4745	ns
Treatment	5	0.002033	0.000407	1.698	0.1752	ns
Sex x Trt	5	0.001192	0.000238	0.996	0.4423	ns
Regress(TOE)	1	0.025575	0.025575	106.767	0.0000	**
Error	23	0.005509	0.000240			
Total	35	0.034436				

Mean = 0.365 kg/day Error SD = 0.016 kg/day CV = 4.23% R^2 = 0.895
TOE = Time On Experiment

B2: Effect of fine rice bran on the daily feed intake of growing pigs.

ANOVA

Source	D.F.	Sum of squares	Mean squares	Calculated F	Probability	Signif. (p=0.05)
Sex	1	0.004618	0.004618	1.923	0.1788	ns
Treatment	5	0.026565	0.005313	2.212	0.0878	ns
Sex x Trt.	5	0.009980	0.001996	0.831	0.5409	ns
Regress TOE	1	0.029771	0.029771	12.396	0.0018	*
Error	23	0.055240	0.002402			
Total	35	0.126174				

Mean = 1.537 kg/day Error SD = 0.049 kg/day CV = 3.19%
R^2 = 0.610
TOE = Time On Experiment

B3: Effect of fine rice bran on feed conversion efficiency of growing pigs.

ANOVA

Source	D.F.	Sum of Squares	Mean squares	Calc. F		Table F.	
Sex	1	0.062951	0.062951	1.315	<	4.28	ns
Treatment	5	0.583198	0.116640	2.437	<	2.64	ns
Sex x Trt.	5	0.420209	0.084042	1.756	<	2.64	ns
Regress. (TOE)	1	2.127568	2.127568	44.446	>	0.00	**
Error	23	1.100966	0.047868				
Total	35	4.294892					

Mean = 4.245 Error SD = 0.219 CV = 5.15% R^2 = 0.823
TOE = Time On Experiment

Appendix 5

Time taken by growing pigs to reach a liveweight of 60 kg.

Treatment (% Rice bran)		Time (days) Boars	Gilts
0		119	112
		112	105
		91	105
	Mean	107	107
10		105	105
		112	119
		98	119
	Mean	105	114
20		154	112
		112	105
		133	105
	Mean	133	107
30		91	98
		119	91
		112	98
	Mean	107	96
40		91	98
		119	98
		112	105
	Mean	107	100
50		98	126
		133	91
		126	112
	Mean	119	110

Appendix 6: ANOVA for data on the performance of finishing pigs (least square analysis).

C1: Effect of fine rice bran on daily weight gain of finishing pigs.

ANOVA

Source	D.F.	Sum of Squares	Mean squares	Calc. F	Probability	Signif. (p=0.05)
Sex	1	0.000003	0.000003	0.001	0.9770	ns
Treatment	5	0.014407	0.002881	0.761	0.5873	ns
Sex x Trt.	5	0.001340	0.000268	0.071	0.9960	ns
Regress(DIE)	1	0.071139	0.071139	18.781	0.0002	**
Error	23	0.087121	0.003788			
Total	35	0.174010				

Mean = 0.544 kg/day Error SD = 0.062 kg/day CV = 11.31%
R^2 = 0.576

C2: Effect of fine rice bran on the daily feed intake of finishing pigs.

ANOVA

Source	D.F	Sum of Squares	Mean squares	Calc. F	Probability	Signif. (p=0.05)
Sex	1	0.003213	0.003213	0.169	0.6847	ns
Treatment	5	0.397789	0.079558	4.186	0.0075	ns
Linear	1	0.015590	0.015590	0.820	0.3745	ns
quadr.	1	0.010083	0.010083	0.531	0.4737	ns
Cubic	1	0.029026	0.029026	1.527	0.2290	ns
Quard.	1	0.000657	0.000657	0.035	0.8542	ns
Quint.	1	0.342434	0.342434	18.019	0.0003	**
Sex x Trt	5	0.200361	0.040072	2.109	0.1008	ns
Regress(TOE)	1	0.601560	0.601560	31.654	0.0000	**
Error	23	0.437093				
Total	35	1.640016				

Mean = 2.511 kg/day Error SD = 0.138 kg/day CV = 5.49% R^2 = 0.729

C3: Effect of fine rice bran on the feed conversion efficiency of finishing pigs.

ANOVA

Source	D.F.	Sum of squares	Mean squares	Calc. F	Proba-bility	Signif (p=0.05)
Sex	1	0.011554	0.011554	0.064	0.8027	ns
Treatment	5	0.571670	0.114334	0.632	0.6769	ns
Sex x Trt	5	0.305308	0.061062	0.338	0.8847	ns
Regress (TOE)	1	0.956730	0.956730	5.292	0.308	*
Error		4.157839	0.180776			
Total	35	2.003101				

Mean = 4.670 Error SD = 0.425 CV = 9.11% R^2 =0.413

Appendix 7:ANOVA for data on slaughter indices (least square analysis)

D1: Effect of fine rice bran on back fat thickness.

ANOVA.

Source	D.F	Sum of Squares	Mean squares	Calc. F	Probability	Signif (p=0.05)
Sex	1	0.544563	0.544563	3.534	0.0728	ns
Treatment	5	1.103568	0.220714	1.432	0.2502	ns
Sex x Trt	5	0.603106	0.120621	0.783	0.5724	ns
Regress(TTS)	1	0.173189	0.173189	1.124	0.3001	ns
Error	23	3.543857	0.154081			
Total	35	5.968283				

Mean = 2.62461 cm Error SD = 0.39253 cm CV = 14.96% R^2 = 0.432
TTS = Time To Slaughter

D2: Effect of fine rice bran on carcass length.

ANOVA

Source	D.F	Sum of squares	Mean squares	Calc. F	Probability	Sinif (p=0.05)
Sex	1	16.638934	16.638934	2.878	0.1033	ns
Treatment	5	21.841715	4.368343	0.756	0.5908	ns
Sex x Trt	5	66.594479	13.318896	2.304	0.0778	ns
Regress(TTS)	1	1.016605	1.016605	0.176	0.6789	ns
Error	23	132.983395	5.581887			
Total	35	239.075118				

Mean = 76.75000 cm Error SD = 2.40456 cm CV = 3.13 R^2 = 0.461
TTS = Time To Slaughter

D3: Effect of fine rice bran on dressed weight %.

ANOVA

Source	D.F	Sum of squares	Mean squres	Calc. F	Probability	Signif (p=0.05)
Sex	1	14.845732	14.845732	6.384	0.0189	*
Treatment	5	17.756740	3.551348	1.527	0.2204	ns
Sex x Trt	5	11.989873	2.397975	1.031	0.4229	ns
Regress(TTS)	1	0.002016	0.002016	0.001	0.9768	ns
Error	23	53.488966	2.325607			
Total	35	98.081513				

Mean = 77.73344% Error SD = 1.52499% CV = 1.96 R^2 = 0.466
TTS = Time To Slaughter

Appendix 8: Time taken by finishing pigs between the end of the growing phase and slaughter.

Treatment (% rice bran)		Time (days) Boars	Gilts
0		65	72
		56	63
		63	49
	Mean	**61**	**61**
10		63	63
		56	91
		56	65
	Mean	**58**	**73**
20		56	56
		56	49
		77	49
	Mean	**63**	**51**
30		63	56
		65	63
		72	70
	Mean	**67**	**63**
40		63	56
		91	56
		63	63
	Mean	**72**	**58**
50		56	58
		77	63
		84	56
	Mean	**72**	**59**