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THE EFFECTS OF VARIOUS HEATING METHODS UPON
THE CHEMICAL CHARACTERIZATION OF RICE
BY-PRODUCTS AND THEIR FEEDING VALUES
FOR POULTRY AND SWINE

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By

Maheshwar Sapkota

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ABSTRACT

THE EFFECTS OF VARIOUS HEATING METHODS UPON THE CHEMICAL CHARACTERIZATION OF RICE BY-PRODUCTS AND THEIR FEEDING VALUES FOR POULTRY AND SWINE

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Two practical systems of heating rice mill feed, dry and wet, were developed. The heat treated and untreated materials were chemically characterized and biologically evaluated by feeding trials involving 600 day-old, unsexed, broiler chicks, and 20 weanling pigs. Chicks were fed diets containing graded levels of rice mill feed (replacing 60, 80 or 100% of corn) which had been heat treated (high heated, 100 to 105°C; low heated, 85 to 90°C; boiling-water treated, and unheated) previously. The pigs were fed diets containing 85% of the diet as wet heated or untreated rice mill feed.

Heat treatments, dry and wet, reduced the free fatty acid rise in the rice mill feed during the storage period of 32 days. Dry and wet heating lowered the trypsin inhibitor factor. Heat treatments had no apparent effect on the measured nutrient concentrations in rice mill feed as characterized chemically.

Chicks and pigs gained significantly more on heat treated rice mill feed diets than on untreated diets. The

high-heat treatment was more effective in enhancing the feeding value of rice mill feed for broilers than other treatments. Chicks on heat treated rice mill feed diets required lesser amounts of diets per unit of gain than the chicks on untreated rice mill feed diets. Chicks on diets containing lower levels (60 or 80%) of rice mill feed gained faster and were more efficient than the chicks fed high level of rice mill feed replacing corn. Pigs on the wet heated rice mill feed diet tended to require less feed per gain than the pigs on untreated material.

Dedicated to my parents
Mr. and Mrs. Tej Prasad Sapkota

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KEY TO ABBREVIATIONS

ADFI	Average daily feed intake
ADG	Average daily gain
BWR	Boiling water treated rice mill feed
CP	Crude protein
DE	Digestible energy
F/G	Feed per unit of gain ratio
GE	Gross Energy
HHR	High heated rice mill feed
LHR	Low heated rice mill feed
MBM	Meat and bone meal
ME	Metabolize energy
UR	Untreated rice mill feed

INTRODUCTION

Rice is the principal cereal in the tropical parts of the world. The total world's production of rough rice in the year 1978 was 376.45 metric tons, and that in Nepal and Belize was 2400 thousand metric tons and 7 thousand metric tons (FAO, 1978), respectively. When 100 kilograms of rough rice is milled, it not only produces 70 kilograms of white rice, but also 30 kilograms of by-products. Depending upon the section of a paddy rice grain where the by-product comes from, it is termed as hull (or husks), bran, polishings or groats. There are a number of rice by-products available as animal feedstuffs such as bran, polishings and groats (or broken rice). The rice hull which forms a major portion of rice by-product is not commonly utilized as an animal feedstuff because of its rough texture, high silica content, high lignin and poor digestibility by animals. However, the hull can be treated with chemicals and used as a ruminant feedstuff.

Rice by-products such as bran, polishings and groats can form a substantial portion of the supplemental animal feedstuffs in the rice-producing areas of the world. This is especially true in the rice-producing areas of the developing countries where the larger portion of the grain goes directly to human consumption.

The type and quality of rice by-products depend upon the milling methods which vary from simple hand pounding with a mortar and pestle to large-scale processing in highly mechanized milling plants. Hand pounding and pedaling, although declining in use, still are the major processes in many areas. A substantial portion of rough rice is milled by hand pounding and pedaling in Nepal, and more than 75% of the rough rice processing is done by hand pounding in Indonesia. In these primitive methods all of the by-products come together so it is necessary to sieve the mixed materials and separate other by-products from the husks. However, it is practically impossible to obtain bran, polishings or groats separately. When milling is performed in modern sophisticated mills, two procedures are used. The system which is common in the U. S. is one-break milling, where total bran is removed in a single separation and provides a single product containing inevitably small amounts of hull particles. The other procedure is multi-break milling, where the bran removal may take place in as many as three to five steps. In this case, hull particles come in the first product milled off and then come the bran fractions. The polish, which is obtained after the bran, is quite similar in both cases.

Bran production amounts to some 5 to 9% of the weight of rough rice milled, but commonly it will be 8 to

Figure 1. The Big Falls Ranch paddy rice field. Mills are at the rear.

Figure 2. Burning the excess rice husks in the Big Falls Ranch, Belize.

9%. The lower values occur in those countries where the percentage of bran removal is regulated. Besides bran, polishings (or white bran) production amounts to 2 to 3% of the weight of the rough rice milled. Groats production is extremely variable depending upon the moisture content in the rough rice, stage of harvest and the variety. Therefore, a general figure of 10% may represent the proportion of the combined rice by-products other than husks. The rest of the by-products will be the husks. The estimated production of rice bran in the world in the year 1978 was 37.645 million metric tons and that in Nepal and Belize was 240 thousand metric tons and 700 metric tons respectively. Rice by-product is often an economical source of protein, oil and calories than grain, but it is yet under-utilized and frequently wasted. Some is fed to pigs, poultry and cattle. A small proportion is consumed as food in the form of brown rice, therefore the recent trend of exporting brown rice has been reducing potential U. S. bran supplies.

Considerable amounts of bran are not utilized for animal feedstuffs in some countries and serve only as fertilizer, mulch or fuel. In view of its nutritional value as feed, and as a potential source of oil and protein, there is a great potential for a general upgrading of the feeding value of rice bran. Therefore, it is vitally important to generate appropriate technology for preventing the rapid deterioration of the bran, thus providing a stable material for use as an animal-feed ingredient, particularly when bran is used in a high proportion of the diet.

Objective of the Current Studies

1. To establish an appropriate technology in small farming systems to treat rice mill feed

2. To ascertain the degree to which various heat treatments of rice mill feed would affect the deleterious factors of free fatty acid and trypsin inhibitor

3. To chemically evaluate the treated and untreated rice mill feed

4. To biologically evaluate the treated and untreated rice mill feed through feeding experiments with poultry and swine

5. To maximize the inclusion of rice mill feed in monogastric animal diets while retaining higher levels of efficiency of utilization and animal growth

REVIEW OF LITERATURE

Rice bran and polishing are widely used for ruminants such as cattle, sheep, water buffalo and bullocks (Houston, 1972). However, the by-products are also fed to monogastric animals such as poultry (Chaturvedi et al., 1967; Rao, 1974; Majun, 1977), swine (Loosly et al., 1954; Campabadal et al., 1976; Lal, 1976) and horses (Houston, 1972). But the adoption of rice by-products as a feed was retarded by the availability of lower-cost grains higher-yielding varieties. However, skyrocketing grain prices, especially in the developing countries, compel the farmers of those countries to look for cheaper feed sources. Rice by-products, being one of the cheapest and most abundant, and frequently under-utilized or wasted (Barber et al., 1980), can substitute for other ingredients as a substantial portion of animal feed (Freivalds, 1975). Therefore, it is important to improve our knowledge of the feeding value of various by-products and types of treatments to enhance their feeding value for different animal species. This idea has stimulated the interest of researchers to define the feeding value of rice by-products for animals.

Cultivated Species of Rice

Paddy rice is one of the leading food crops in the world. Most varieties currently in production are in the species *Oryza sativa*, L. However, some varieties grown in Africa are in the species *Oryza glaberrima*, Steud (Adair, 1972). The cultivated rice *Oryza sativa*, L. is classified into two subspecies such as *Oryza sativa*, L. subsp. indica, Kato and *Oryza sativa*, L., subsp. japonica, Kato. These subspecies, Indica and Japonica, are very similar taxonomically.

Rice Milling By-Products

The type, quantity and quality of each of the rice milling by-products depend upon paddy species, variety, maturity, moisture content, milling methods and other physical conditions such as whether the grain has been parboiled, is moldy, or is infested with insects. Nevertheless, the rice milling by-products are categorized into the following groups based on the physical location of the paddy seed from which they come and their texture, structure, quantity and quality.

The total by-products of milling are sometimes utilized as rice mill feed, which usually contains about 61% hulls, 35% bran, and 4% polishings (Morrison, 1956; Adair, 1972). However, the rice milling by-products are broadly termed as:

1. Hulls or husks

2. Bran

3. Polish or polishings or white bran

4. Groats, brewers rice, broken rice or rice pollards.

Physicochemical Characteristics of Rice Milling By-Products

Rice milling by-products are of highly variable quality, depending upon rice varieties (Juliano et al., 1964), season of production, irrigation intensity, soil types, soil pH, and methods of milling (Arnott et al., 1966). The nutrient content of rice bran depends on the quantity of hulls included with bran. The presence of finely ground hulls can be revealed by microscopic analysis when they are added to bran and polishings, and it is more difficult to detect adulteration (Arnott et al., 1966).

1. Husks

The outer coat of paddy grain is called rice hull or rice husk. The usual range of sievable husk with a 72-mesh sieve ranges from 40 to 80% but in some cases it goes as high as 89% (Arnott et al., 1966). About one-fifth the weight of the harvested and dried crop is hulls or husks (FAO, 1957).

A recent practical survey of actual and potential hull uses has been prepared by Beagle and Beagle (1971) based on their extensive personal experience. General bibliographies on rice also (GBII, 1918; Kuilman, 1949; Univ. Phil. 1958 to 1962; IRRI, 1963) contain information on hulls. An excellent bibliography on rice hulls and straw prepared by the National Agricultural Library (Larson, 1957) covers much of the literature up to 1955.

The harsh woody covering around the caryopsis of kernel of paddy grain consists of two interlocking halves; the larger of the two is the flowering glume or lemma and the smaller is the palea (Houston, 1972). The outer tip of the lemma may be extended into a bristle-like awn. However, in most cultivars this is either small or vestigial. Outer surfaces of the lemma and palea may contain short stiff hairs, though they may have been eliminated in some cases by breeding programs to develop smooth-hulled cultivars. There are two sterile glumes at the base of the grain. They are separated from the flowering glumes by a short section of the rachilla. All of these components appear in the commercial hull fraction, but the flowering glumes form the predominant material.

The appropriate analysis of husks studied by Houston (1972) shows that the average values were, crude protein, 4.48%; crude fat, 1.68%; nitrogen free extract, 31.74%; crude fiber, 40.82%; and ash, 21.20%. Thus, due to the tough, woody, abrasive nature of the hulls, their low nutritive properties, resistance to weathering, great bulk, and high ash content, each rice-producing country has the challenging problem of utilization or disposal of rice husks.

Probably the best estimate of rice husks utilization in the U. S. is the one made by Beagle (1970) presented in Table 1.

TABLE 1. USES OF RICE HUSKS

Use	Thousand of tons
Feeds, whole or ground hulls	142
Feeds, ammoniated or chemically altered	58
Feeds and allied agricultural products mixed	120
Litter and bedding	94
Pressing and filtering aids	18
Furfural and other chemicals	17
Various miscellaneous uses	32
Rice hull ash (hull equivalent)	39
Excess hulls	300
Total	820

This table shows that a large quantity of husks is utilized in the agricultural rather than industrial classification. It also makes clear that over one-third of the hulls is still not utilized.

Feeding hulls to animals was considered to be harmful in the early years of the century. Early feeding experiments led to comments that feeding in large quantities was attended with some danger (Fraps *et al.*, 1904), that use in livestock feed was dangerous (Gobert, 1921) and that animals died from the feed (Browne *et al.*, 1904).

Later, when it was found that ground rough rice could be satisfactorily fed to cattle, hogs, horses and mules (Dalrymple, 1910; Jordan et al., 1921; Bray, 1943), it was recognized that rice husks could safely be included as one of the ingredients of animal rations. Investigations of Noland (1953) and Noland et al. (1953, 1954) in the early 1950s probably first established the potential value of hulls as roughage for steers and ewes. Then various workers (Ray et al., 1963; White, 1966; Horton et al., 1967; White et al., 1969; Hutanuwatr et al., 1974; Hamad et al., 1976) investigated the feeding value of rice hulls and proved that rice hulls can be used successfully for finishing steers when 12% protein was supplied from soybean meal (Ray, 1963). However, if a large quantity of untreated rice hulls is added to livestock rations, inflammation and ulceration of the gastrointestinal-tract lining will develop and will consequently reduce the digestibility of feeds, thereby reducing the growth rate of animals (Loosli et al., 1954).

As stated above, rice husks can be used for various purposes such as animal feeds, fuel and various industrial uses, but little work has been done to investigate the utility of rice husks. This is one of the reasons that more than one-half of the husks produced is wasted (Hough et al., 1966; Beagle et al., 1971).

Since heating improves the feeding value of rice bran (Kratzer et al., 1974), and bran is cheaper than the grain, it is desirable to heat the bran to improve its feeding value. The heating of rice bran or drying of grains using fossil fuels such as diesel oil, kerosene, and liquefied petroleum gas, is becoming beyond the economic reach of small farmers, especially in the developing nations. For instance, rice husks are available free of cost in Belize. Since rice husks are available as a waste by-product in the rice-milling industry, it is of economic importance to find ways and means by which its heating value can be utilized for heating rice bran, drying rough rice and other cereal grains.

Rice hulls are of concave-convex structure (Beagle et al., 1971) with a bulk density of 7 to 9 pounds per cubic foot (10.43 kg to 13.41 kg/m^3). The apparent density of ground rice hull was 17 to 25 pounds per cubic foot (25.32 to 37.24 kg/m^3) and the absolute density was approximately 45 pounds per cubic foot (67.03 kg/m^3). Tucker (1944) reported that the heating value of rice hull was 6,274 Btu per pound (3485.58 kcal/kg) of material at a density of 6.24 pounds per cubic foot (9.30 kg/m^3).

Acasio et al. (1973) studied the effects of four levels of primary air (20, 35, 40, 45 CFM or 0.57, 0.99, 1.13, 1.27 CMM) and three levels of fuel use (4.9, 6.5 and 9.55 pounds per hour or 2.22, 2.95 and 4.08 kilograms per hour) on the effecient burning of rice hulls and found that the effect of any level of primary air was not significantly different from the other levels of primary air used. They found that the difference among the responses due to the effect of three levels of fuel feed rate was highly significant. They concluded that the best feed rate was 9.55 pounds (or 4.33 kg) of rice hulls per hour. At that level, they found a high burning efficiency. The optimum depth of the fuel bed was 3.0 inches with a furnace volume of 4.0 cubic feet and a grate area of 1.0 square feet. In their experiment, temperature fluctuation in the furnace was affected more by the rates of fuel feeding than by the levels of primary air used.

2. Bran

Large-scale milling involves many processes which consist of (a) cleaning by sieve, screw, blowers, and magnetic separators to remove extraneous material (Arnott et al., 1966), (b) a drying stage to reduce the moisture below 15%, and (c) hulling to remove the epicarp, mesocarp, cross-layer, testa and aleurone layer.

The germ and outer layer are removed in one or two stages and form the product known as bran, of which there may be more than one grade. Based on the type of mill used, the bran is made up of pericarp, some germ, rachilla, small fragments of endosperm, some hulls, as well as dust and soil particles. Bran removal amounts to some 5 to 9% of the weight of paddy milled (Houston, 1972). However, the amounts are usually in the upper part of the range, or 8 to 9% of the paddy milled. Lower values can occur in countries where the percentage of bran removal is regulated.

Broadly, two types of machines are involved to mill paddy rice, shellers, and whiteners. The material produced by sheller machines will be mainly of hulls, a small portion of pericarp, some germ and some rachilla and small fragments of endosperm, some dust and soil particles. The under-runner disc huller performs coarse work (Barber, 1980). Pressure and friction are applied to remove the hulls, and the under-runner disc huller produces 1 to 2.5% bran with reference to paddy. In the process of whitening the pericarp, the tegmen and the aleurone layer, together with the germ, are removed from the brown rice. In the majority of countries, commercial bran includes the polishings, germ and groats but in others, sieving in combination with an air stream is used to separate major fractions such as bran, polishings, germ and broken rice of various sizes. In Italy and Spain, separation of the germ is a general practice (Barber, 1980).

There are a number of particles which can be recognized in rice bran, such as fragments of sterile glumes, trichome fragments, pedicel fragments, pericarp fragments, starchy endosperm fragments, entire germ or fragments of it, fragments of seed coat, fibers from knots of the panicula base, and the aleurone layer (Barber, 1980). Besides these, there are other particles such as dusts from paddy leaves or stems and soil particles which contribute a small fraction of inert materials to the commercial bran.

Nutrients in Rice Bran

Rice bran feed is made up of seed-coat layers, starchy endosperm, pericarp, the embryo or germ, and some hulls. The seed-coat layers and the embryo contain more than one-half of the mineral of the grain, a fourth of the protein, practically all the vitamins and about three-fourths of the fat (Sreenivasan, 1938 cited by Kik, 1956). Kik (1956) also pointed out that the oil is largely contained in the germ and about 85% of the entire oil content of the hulled rice goes into the by-products. Therefore, rice bran is a potential source of proteins, oil, nutrients, and energy for animal-production systems (Kondo et al., 1949; Kondo and Morita, 1954; McDowell, 1974; Ranjhan, 1972; Barber, 1980).

The nutrient content of rice bran is summarized in Tables 2-4.

TABLE 2. PROXIMATE ANALYTICAL VALUES OF RICE BRAN (HOUSTON, 1972)[a]

DM %	Protein %	Fat %	Ash %	NFE %	Crude Fibers
88.45	12.60	15.05	13.85	40.15	13.30

[a]Average of about 15 observations.

TABLE 3. AMINO ACID CONTENT OF RICE BRAN (9.1% PROTEIN) (KIK, 1956)

Amino acid	Percent of Dry matter	Percent of Protein
Arginine[a]	0.91	10.00
Aspartic acid	0.31	3.40
Cystine	0.11	1.22
Glutamic acid	0.71	7.80
Glycine	0.80	8.80
Histidine[a]	0.30	3.30
Isoleucine[a]	0.48	5.27
Leucine[a]	0.70	7.70
Lysine[a]	0.56	6.15
Methionine[a]	0.34	3.73
Phenylalanine[a]	0.44	4.83
Proline	0.61	6.70
Serine	0.71	7.80
Threonine[a]	0.37	4.06
Tryptophan[a]	0.36	3.95
Tyrosine	0.50	5.49
Valine[a]	0.61	6.70

[a]Nutritionally essential for the rat.

TABLE 4. VITAMINS AND OTHER CONSTITUENTS IN RICE BRAN (KIK, 1956)

Item	Amount
Thiamin, mg/g	24.00
Riboflavin, mg/g	2.00
Nicotinic acid, mg/g	336.00
Pantothenic acid, mg/g	
Total	27.70
Free	11.60
Biotin, mg/g	0.60
Folic acid	
Total	1.46
Free	0.16
Pyridoxine, mg/g	25.00
Inositol, mg/g	4627.00
Choline, mg/g	1700.00
p-Aminobenzoic acid, mg/g	0.75
Calcium, %	1.31
Phosphorous, %	1.48
Iron, %	
Total	0.019
Available	0.010
Nitrogen, %	1.53
Protein (N x 5.95), %	9.10
Fat, %	13.66
Moisture, %	9.80
Ash, %	12.00

Rice bran feed is not considered to be protein-rich feed because it is of highly variable husk-fiber content. Fiber content is sometimes raised by adulteration with husk. This is a particular problem in the Philippines (Arnott et al., 1966). It is fairly palatable when fed fresh but turns rancid in storage. Thus, unless the bran is fresh, animal intake levels may lower, resulting in a decrease of growth (Arnott et al., 1966). However, the growth depression on rice-bran diets is not totally understood (Kratzer, 1980). Fresh rice bran has a pleasant smell and taste which enhances its palatability and aids in secretion of digestive juices resulting in the more-efficient digestion of food by swine (Arnott et al., 1966). Various workers found that rice bran tends to produce soft pork (Morrison, 1937; Thrasher et al., 1965a, 1965b) but this effect could be diminished by the exclusion of rice bran during the finishing period prior to marketing the animals (Gunn et al., 1951 cited by Arnott, et al., 1966). However, it was not definitely stated that for how many days the rice bran should be excluded from the diet before marketing the pigs.

Rice bran, now used as animal feed, contains considerable protein that can be used for human nutrition (Chen et al., 1969). Efforts have been made to make human foods such as bread, muffins, pancakes, cookies (Lynn, 1969) and 40 to 80% bran protein concentrate (Chen et al., 1969). Rice bran is a good source of oil. For years rice-bran oils have been available through solvent extraction of rice bran. However, rice-bran oil has not gained importance as an edible vegetable oil because rice-bran oil is very unstable and does not have a presently acceptable color. Besides these factors, there are a number of reasons such as low oil yields and processing difficulties, e. g., bran instability, wax contaminants in oil and problems in removing defatted fine rice polish solids (Lynn, 1969). Therefore, the use of rice-bran oil is only a fraction of the potentially available world supply of about 2.72 billion kilograms (USDA, 1966).

3. Polishings

When husks and bran layers are removed from the rice grain, it becomes nearly white, but the grain is still rather rough and it is polished by one or two machines. As a result of this process, polishings are produced. Polishings are also known as polish or white bran. In some areas, rice polishings are included in commercial rice-bran feed. Polishings have a much lower fiber content and a very low silica content, but have much higher crude protein and oil than the bran. Arnott *et al*. (1966) suggested that oil, silica, and crude fiber content can be used either singly or in combination to distinguish between bran and polishings. If the product has not been solvent extracted, bran could be defined as material having less than 12% oil and more than 8% fiber or 1.3% silica, and polishings can be defined as material having more than 12% oil and less than 8% fiber or 1.3% silica. However the chemical composition of polishings determined by various workers are listed in Tables 5-7.

TABLE 5. PROXIMATE ANALYTICAL VALUES OF RICE POLISHINGS (LIMCANGO-LOPEZ, ET AL., 1962)

DM, %	Protein, %	Fat, %	Ash, %	NFE, %	Crude Fiber, %
90.5	12.04	16.56	7.97	56.24	7.33

TABLE 6. AMINO ACID CONTENT OF RICE POLISHINGS (10.40% PROTEIN) (KIK, 1956)

Amino Acid	Percent of Dry Matter	Percent of Protein
Arginine[a]	0.83	7.92
Aspartic acid	0.50	4.77
Cystine	0.15	1.43
Glutamic acid	0.76	7.25
Glycine	0.88	8.40
Histidine[a]	0.39	3.72
Isoleucine[a]	0.54	5.15
Leucine[a]	0.68	6.49
Lysine[a]	0.62	5.92
Methionine[a]	0.43	4.10
Phenylalanine[a]	0.48	4.58
Proline	0.68	6.34
Serine	0.77	7.95
Threonine[a]	0.39	3.72
Tryptophan[a]	0.34	3.24
Tyrosine	0.70	6.68
Valine[a]	0.63	6.01

[a]Nutritionally essential for the rat.

TABLE 7. VITAMINS AND OTHER CONSTITUENTS IN RICE POLISHINGS (KIK, 1956)

Item	Amount
Thiamin, mg/g	22.00
Riboflavin, mg/g	2.20
Nicotinic acid, mg/g	330.00
Pantothenic acid, mg/g	
Total	33.30
Free	9.90
Biotin, mg/g	0.57
Folic acid, mg/g	
Total	1.92
Free	0.18
Pyridoxine, mg/g	20.00
Inositol, mg/g	4536.00
Choline, mg/g	1020.00
p-Aminobenzoic acid, mg/g	0.73
Calcium, %	0.91
Phosphorous, %	2.44
Iron, %	
Total	0.028
Available	0.012
Nitrogen, %	1.76
Protein (N × 5.95), %	10.47
Fat, %	16.40
Moisture, %	9.80
Ash, %	13.20

4. Groats

Groats, also known as broken rice, brewer's rice or pollards, are the small broken kernels that do not meet the kernel-size requirements. These broken kernels of rice will generally be less than three-fourths the size of whole kernels. The nutrient contents of groats are the same as those of rice kernels. The nutrient contents of polished rice are protein, 9.75%; fat, 0.44; crude fiber, 0.34%; ash, 0.56%; and NFE, 88.91% (Juliano *et al.*, 1964).

Deleterious Components in Rice By-Products

A number of toxic substances in rice seeds and ultimately in rice by-products have been discovered by various researchers (Arnott et al., 1966; Goering et al., 1970; Horiguchi et al., 1971; Kratzer et al., 1974; Tsai, 1976; Majun et al., 1977; Kratzer et al., 1977; Tashiro et al., 1978). Among the known toxic substances are trypsin (protease) inhibitor, high free fatty acids level, high silica content and unknown growth depressing factors which are deleterious to animal performance.

When more than 30% rice bran was added to swine (Thrasher et al., 1965) and poultry diets (Mahadevan et al., 1957), a reduction in growth was observed. But Kratzer et al. (1974) found that when rice bran was used at a 60% level in poultry diets, the growth of chickens was reduced by 30%. When the bran was autoclaved or steamed the growth depressing factor was destroyed. When antitryptic substance was extracted by mild acid, the growth of chickens was improved (Tsai, 1976), but Kratzer et al. (1977) found that the growth inhibition of rice bran was not due to its trypsin inhibitor activity. They found that autoclaving, hot-water treatment and parboiling improved the growth of the chickens. Lipase activity in rice bran was destroyed by autoclaving or parboiling, and they predicted that these processes of treating rice bran would be adequate to improve growth. When they used ethoxyquin as an antioxidant it did not improve growth of chicks fed diets containing rice bran and was less effective than autoclaving or parboiling in preventing the development of rancidity. Thus, it appears that the growth depressing factor, protease inhibitor and lipase are heat labile.

Besides the known chemical factors there are mechanical and physical factors which determine the quality of rice bran. For example, environmental conditions such as temperature, humidity and duration of storage, have a great bearing upon the protein content of rice bran (Houston, 1972). If the temperature is about 24^{o}C or higher and moisture is 14% or higher, mold develops in the rice mill feed. The digestibility of bran is lowered by adulteration with husks. Rice husks have 11 to 19% silica, whereas good quality bran will have only 1.3% silica (Arnott et al., 1966).

From a survey conducted by Arnott et al. (1966) on the variation of quality of bran and polishings, it has been established that there was a significant negative correlation between the crude-fiber content and the crude-protein content. They found that the percentage of crude fiber was positively correlated to percentage of silica. Thus, a significant negative correlation exists between crude protein and silica content of the rice by-products.

The deleterious components in rice by-products are discussed in detail below.

1. Trypsin inhibitor

The low-molecular weight proteins which inhibit the activity of proteolytic enzymes such as trypsin, chymotrypsin and some microbial proteinases are present in cereal and legume seeds in variable quantities (Liener et al., 1969; Vogel et al., 1969). These low molecular weight proteins may interfere with activation of the pancreatic zymogens (enzyme precursors), trypsinogen and chymotrypsinogen, in the small intestine and ultimately they may interfere with efficient proteolytic enzyme activity. When high levels of inhibitors are present in feeds, dietary protein may not be utilized efficiently, and may be excreted. The feedback mechanism to the pancreas regulated by trypsin levels in the intestine also may be seriously disturbed. Snook (1969) found that the gastrointestinal hormone pancreozymin is involved in this mechanism. The release of pancreozymin is stimulated by protein products in the small intestine (Wang et al., 1951), and pancreozymin enhances synthesis of other pancreatic enzymes (Rathman et al., 1967). As a result of this process there is an increased demand for zymogen output. This causes hypertrophy of the pancreas and elevated demands for sulfur-containing amino acids (Liener, 1975). Therefore, when fed high rice bran rations animals will have an enlarged pancreas (Kratzer et al., 1974). Different plant seeds contain variable quantities of inhibitors. Soybean seeds contain 6% of the total protein in the form of trypsin inhibitors (Rackis *et al.*, 1964), potato tubers contain from 2 to 5% of soluble protein in the form of a specific chymotrypsin inhibitor (Ryan *et al.*, 1968), and of the water soluble protein in barley, 4 to 5% may be a specific trypsin inhibitor and an additional 4 to 5% may be inhibitors affecting chymotrypsin and microbial proteinases (Kirsi *et al.*, 1971).

There may be variable quantities of inhibitors in different parts of the same plant seeds. Horiguchi *et al.* (1971) separated rice seeds into embryo, bran and endosperm and assayed for trypsin inhibitor. They found that the inhibitor was especially localized in the embryo. The bran contained only 7.4% of the total inhibitor. They did not find any trypsin inhibitor activity in the endosperm. The inhibitor concentrate was the highest in the embryo. An inhibitor for *Aspergillus* protease exists in bran containing the embryo of rice seed, though its content is less than that in other plant seeds (Matsushima, 1955). When protease inhibitor in rice seed was investigated physiologically in connection with plant development, it was found that the inhibitor was localized in the embryo and its activity decreased upon germination (Horiguchi *et al.*, 1971). It was also established that the inhibitor was a protein-like substance which was non-diffusible through a cellophane membrane, salted out on addition of ammonium sulfate, was denatured on heating at 100°C and adsorbed into ion-exchange cellulose. The protease lost its activity within 10 minutes during incubation at 70°C but the inhibitor activity remained unchanged after 30 minutes of treatment. The protease and the inhibitor could be separated from each other by chromatography on a TEAE-cellulose column, and it was found that the inhibitor reduced the activity of rice seed protease.

Tashiro et al. (1978) extracted a trypsin inhibitor from rice bran with 1% sodium chloride and partially purified by 40 to 80% ammonium sulfate fractionation. The crude product obtained inhibited the activity of trypsin but not that of α-chymotrypsin or pepsin. The crude inhibitor was stable at acidic and neutral pHs but was gradually inactivated by the long-time incubation with pepsin. The estimated molecular weight of the inhibitor by polyacrylamide gel electrophoresis in the presence of sodium dodecyl sulfate was 13,500.

The trypsin inhibitor content of different parts of the rice seed is given in Table 8.

TABLE 8. INHIBITOR CONTENT IN RICE SEED (HORIGUCHI ET AL., 1971)

Part	Dry weight[a] (g)	Inhibitor Content[a] (IU)	Inhibitor Concentration (IU/dry weight)
Embryo	1.70	75.60	44.50
Bran	1.80	6.00	3.30
Endosperm	33.50	0.00	0.00
Total	37.00	81.60	47.80

[a]Figures represent values for 2,000 grains.

Tsai (1976) conducted an experiment to find the contribution of protease inhibitors to the deleterious effects of rice bran fractions and heat treated rice bran when fed to chickens. He concluded that removal of the antitryptic substance by mild acid extraction improved the growth response of chicks and the feeding efficiency of rice bran. He pointed out that most of the antitryptic activity in rice bran was not destroyed by dry heating even when heating time was as long as 30 minutes and there was no improvement of growth nor of feed efficiency. Autoclaving and steaming were the most-effective methods to destroy the antitryptic substance, resulting in a signficant improvement of feed efficiency and growth. He found that there was a positive correlation between pancreatic hypertrophy in chicks and the antitryptic activity in rice bran. However, Kratzer _et al_. (1974) found that dry heating of bran improved its feeding value and destroyed the growth-depressing factor. Further studies of Kratzer _et al_. (1977) revealed that the growth inhibition of rice bran was not due to its trypsin inhibitor activity because of the fact that the hot-water treatment improved the growth of the chicks; however, it did not lower the trypsin inhibitor. It is apparent that the issue of growth depression by trypsin inhibitor or other heat-labile substances needs further investigation.

2. Oil and free fatty acids of rice bran

The oil content of rice bran is variable depending upon the country, rice varieties and environmental factors. Arnott et al. (1966) found that the poor brans adulterated with ground husks, from Malaya, had 3 to 10%, good bran had 11 to 16%, and polishings had 11 to 21% of oil content. Similarly, the boiled-rice bran from India had 18 to 25% whereas the boiled-rice bran from Burma had only 12 to 18% of oil. When oil was extracted in the laboratory with petroleum ether, it was clear and sweet smelling but of varying color from yellowish green or brown to red depending upon the original material (Arnott et al., 1966). Thus, good-quality bran and polishings which have 15 to 20% oil do have a great potential for oil production in the future. Defatted rice bran is a good source of protein. Alkaline extraction of defatted California rice bran removed 33.3 to 82.5% of total crude protein (Chen et al., 1969) but the highest amount of protein removal from full fat rice bran was 70% (Lew et al., 1975). As oil is removed from the rice bran and polishings, the percentage of crude protein is increased, and the keeping quality is improved.

The fatty-acid compositions of rice by-product (bran-polish) revealed by Lynn (1969) were: oleic acid, 44.0%; linoleic acid, 35.5%; palmitic acid, 21.0%; linolenic acid, 2.7%; stearic acid, 2.0%; arachidic acid, 1.1%; and myristic acid, 0.4%.

A problem of rice-bran oil is that it is very unstable, and just after milling, free fatty acid development proceeds rapidly. Experiments conducted by Arnott et al. (1966) showed that in one sample the free fatty acids rose from 9.2 to 78% in 32 days. Therefore, in order to arrest free fatty acid development in rice bran, treatments must be applied as early and as quickly as possible. When volatile acids and phenols in the steam distillate of rice bran were fractionated and identified, it was observed that the acidic fraction had a rancid, butter-like odor (Fujimaki et al., 1977). The enzyme lipase present in rice bran (Aizono et al., 1971; Shastry et al., 1971, 1972, 1975a, 1975b; Funatsu et al., 1971; Aizono et al., 1973, 1976, 1978; Fujiki et al., 1978) is very active at the optimum pH between 7.5 and 8.0, and the optimum temperature at about 37°C and preferentially splits fatty acid at the 1, 3-position of substrate (Aizono et al., 1973). The lipase activity is known to persist in the paddy grains for as long as 15 years (Kondo et al., 1950 cited by Shastry et al., 1971).

The purified lipase from rice bran catalyses hydrolysis of long and short chain synthetic triglycerides in the oils from rice bran and groundnut (Shastry et al., 1971). The lipase was found to be stable for at least a month at 0 to 4°C, when adsorbed on calcium phosphate gel. The enzyme is activated by lower concentrations of calcium ions and bile salts, and inhibited by cupric ions and partially inhibited by diisopropylfluorophosphate, ethylenediaminetetraacetate and p-chloromercuribenzoate (Shastry *et al.*, 1971). In order to stabilize the bran and oils, rice-bran lipase must be inactivated. The enzyme is stable at temperatures below 40°C (Aizono *et al.*, 1973) but loses activity by heating at 57°C for 15 minutes (Aizono *et al.*, 1976). However, the earlier work of Shastry *et al.* (1971) indicated that when lipase was heated at 50°C, there was a rapid diminution in specific activity during the first minute and then it remained constant over a period of at least 10 minutes. When heated to 60°C the activity diminished during the first two minutes and then remained constant. When heat was applied at 105°, 110° and 120°C for 3, 4½ and 6 hour periods, all heat treatments successfully arrested the rise in free fatty acids (Arnott *et al.*, 1966), with higher temperatures and longer times increasingly effective in doing so.

3. Unavailability of nutrients in rice by-product

A number of nutrients present in rice by-products are in bound form and thus biologically unavailable. Some minerals are seriously deficient and some are imbalanced.

Rice bran is a phosphorus-rich by-product of the food industry that has established feeding value for both swine (Campabadal *et al.*, 1976) and poultry (Kratzer *et al.*, 1974; Mandal *et al.*, 1974) but the problem is that much of the phosphorus in rice bran, 5.1% (Nelson *et al.*, 1968) exists in the phytate form (O'Dell *et al.*, 1972) and is largely unavailable to non-ruminants (Corley et al., 1969; Bayley et al., 1975) indicated that the availability of phosphorus in complete diets could be increased by steam pelleting. However, Summers et al. (1968) did not get improvement in phosphorous availability due to pelleting when individual ingredients were pelleted prior to mixing. This work agrees with the findings of Corley et al. (1980) that pelleting did not improve the availability of phosphorus. They found that, as compared to total phosphorus, the availability of phosphorus was 17.6% for rice bran. They also found that the dietary organic phosphorus sources had no effect on utilization of phosphorus from inorganic sources and the addition of 13% corn oil did not influence phosphorus utilization. When two phosphates from rice bran such as phosphomonoesterase, and phosphodiesterase, were partially purified and studies were done of their nature, it was found that both enzymes were partially inhibited by inorganic phosphate (Shastry et al., 1972). However, no details of the relationship between phytic acid phosphorus and phosphatases are available. Therefore, an intensive study is needed of the biological utility of phosphorus present in phytate form in rice by-products.

A large part of vitamin B_6 present in rice bran is in bound form. When rice-bran extracts were fractionated by gel filtration, it gave a variety of pyridoxine-containing compounds which were unavailable to the assay microorganisms unless hydrolyzed (Yasumoto et al., 1976). Thus, it is obvious that the availability of these compounds as vitamin B_6 is very limited. Yasumoto _et_ _al_. (1977) isolated one of the bound forms of vitamin B_6, occurring in rice bran, in a faintly yellowish syrup by repeated ion-exchange and paper-partition chromatographic techniques.

Total folic acid and iron present in rice bran were 1.46 mg/g and 0.019% respectively, and their free and available quantities only 0.16 mg/g and 0.01%, respectively (Kik, 1956).

Some of the trace minerals, such as zinc, in rice bran are seriously low. Therefore pigs on rice bran-cassava based diets developed parakeratosis, gained slowly and digested feed poorly (Maust _et_ _al_., 1972).

4. Unidentified growth depressing factor

The presence of a growth-depressing factor in rice bran is undoubted (Kratzer _et_ _al_., 1974; Tsai, 1976); however, the biochemical properties and the mechanism of growth depression of this noxious substance, which is thermolabile (Kratzer _et_ _al_., 1974), are not understood.

Rice by-products did not make a satisfactory substitute for corn, wheat and oats and their by-products in laying diet (Smith, 1934) and reduced egg production (Smith, 1948). When rice bran was used at 60% of the diet, replacing corn as an energy source in diets containing fish meal or soybean meal, growth of chicks was depressed by approximately 30%, and the weight of the pancreas was significantly greater than on the control diets (Kratzer *et al.*, 1974). The hypertrophy of the pancreas was somewhat similar to the trypsin inhibitor effect in soybeans (Chernick *et al.*, 1948). Therefore, it was thought that the growth depression in rice-bran diets might be its trypsin-inhibitory action. Later, Tsai (1976) found that there was a positive correlation between pancreatic hypertrophy in chicks and the antitryptic activity in rice bran. Removal of the antitryptic substance by mild acid extraction improved the growth response of chicks and the feed efficiency of rice bran. However, when boiling water and rice bran were mixed at a ratio of 1:1 for 40 minutes and dried in the sun, there was no reduction in trypsin-inhibitor activity but there was an increase in growth rate of chicks fed this diet by about 40% (Kratzer *et al.*, 1977). The feeding value improved to some extent when rice bran was soaked in hot water but was improved significantly when an enzyme,[a] 0.5% of the diet, was added to the bran (Din *et al.*, 1979).

Pigs on rice bran-cassava diets also gained slowly and digested feed poorly (Maust *et al.*, 1972). When rice bran was autoclaved (Kratzer *et al.*, 1974; Tsai, 1976; Majun *et al.*, 1977; Din *et al.*, 1979), steamed (Kratzer *et al.*, 1974; Tsai, 1976), dry heated (Kratzer *et al.*, 1974)

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[a]The enzymes they used were commercial enzyme complex, mixture of proteinases with some amylas from B subtilis and food-grade alpha amylase from B subtilis.

or hot-water treated (Kratzer et al., 1977; Din et al., 1979), there was an improvement in growth of chicks on rice-bran diets, possibly due to the destruction of a growth-depressing factor. The heat treatments also destroyed the lipase and slowed the development of free fatty acids in rice bran, but it is yet unknown whether the free fatty acids have a significant role in the growth reduction of animals.

Further investigation is needed to ascertain the biochemical characteristics of the so-called growth-depressing factor and the contribution of growth depression by free fatty acids.

Treatment of Rice By-Product

Efforts have been made to improve the feeding value of rice bran by heat treatment (Upp, 1933; Arnott et al., 1966; Kratzer et al., 1974; Tsai, 1976; Majun et al., 1977), chemical treatment (Arnott et al., 1966; Kratzer et al., 1974; Tsai, 1977; Horiguchi et al., 1978; Din et al., 1979), and pressure pelleting (Kratzer et al., 1977).

1. Heat treatments

Heat treated rice bran was used in chicken trials to investigate the effect of heat treated rice bran upon egg production as early as 1933 (Upp, 1933). It was found that winter egg production was higher when layers were fed heat treated rice bran diets. However, it was not confirmed that the increase in egg production was due to the effect of heat treatment. Heating rice bran to 65.56°C (150°F) did not lessen the percentage of free fatty acids present after several months' storage. Later, it was found that heat treatment ranging from 105°C to 200°C was effective in inactivating lipolytic-enzyme activity and checking the development of free fatty acids (Arnott *et al.*, 1966) in freshly milled rice bran.

Autoclaving rice bran markedly improved its feeding value (Kratzer *et al.*, 1974; Tsai, 1976; Kratzer et al., 1977; Majun *et al.*, 1977; Din *et al.*, 1979). Steaming was as good as autoclaving (Kratzer *et al.*, 1974). Hot-water treatment of rice bran was effective in improving the feeding value of rice bran, but it was not as effective as autoclaving or steaming (Kratzer *et al.*, 1974; Din *et al.*, 1979). The growth rate of chickens on dry heated rice bran diets was higher than on unheated rice bran diets; however, it was not as high as on autoclaved or steamed rice bran (Kratzer *et al.*, 1974). The feeding value of rice bran from parboiled rough rice was as good as autoclaved or steam-treated rice bran, and was not influenced by further autoclaving (Kratzer *et al.*, 1977).

2. Chemical treatment

When studies were conducted to determine if the metabolizable energy value was influenced by addition of reserpine as a tranquilizer at a rate of 0.5 mg/kg diet in diets containing 20 to 30% rice bran, it was found that reserpine had no significant influence on metabolizable energy values for chicken (Maust et al., 1972).

When oxidants such as Topanol OF, Topanol OC (Arnott et al., 1966) and ethoxyquin (Kratzer et al., 1977) were used in treating rice bran, they were not effective in reducing free fatty acids and also were not effective in improving the growth of chickens. When fed ethoxyquin treated rice bran diets, chicks did not gain significantly faster than chicks on autoclaved or steam treated rice bran diets (Kratzer et al., 1977). The feeding value of rice bran from parboiled rough rice was not improved by ethoxyquine treatment (Kratzer et al., 1977). The growth-depressing factor could not be extracted with hexane or methanol (Kratzer et al., 1974). However, a trypsin inhibitor was salted out on addition of ammonium sulfate (Horiguchi et al., 1971) and was extracted from rice bran with 1% sodium chloride and partially purified by 40 to 80% ammonium sulfate fractionation (Tashiro et al., 1978).

3. Pressure pelleting

When studies were conducted on the effects of cold pressure pelleting upon the feeding value of rice bran, it was found that growth of chickens was reduced irrespective of whether the rice was untreated or autoclaved (Kratzer et al., 1977). However, reasons for reduced growth of chickens on cold pressure pelleted rice bran diets have not been established.

The Feeding Value of Deoiled Rice By-Product

When experiments were conducted to find the feeding value of deoiled rice bran (Reddy et al., 1972) and rice polishings (Mandal et al., 1974), it was found that the growth response of chickens on deoiled rice bran was significantly higher than on whole oil rice bran (Reddy et al., 1972). Reddy et al. (1972) found that the addition of tallow to deoiled rice bran diet either at 2 or 4% levels did not appreciably improve feed utilization. They also found that as compared to whole oil rice bran, the deoiled rice bran was a good source of protein, nitrogen-free extract and major elements, such as calcium and phosphorus.

Feeding of Rice By-Product to Poultry and Swine

1. Poultry

In the process of conducting trials on different levels of rice by-product in diets fed to different strains of poultry at different physiological stages, mixed animal performance has been observed by researchers. Different researchers have used varying levels of rice by-products, ranging from 0 to 60% in poultry diets (Upp, 1933; Smith, 1934, 1948; Fraps et al., 1939; Mahadevan et al., 1957; Scott et al., 1976; Tsai et al., 1976; Majun et al., 1977; Din et al., 1979). Studies conducted by Upp (1933) showed that when large amounts of rice by-products were included in laying pullet mashes, growth rate was comparable with that on control diets containing corn. Pino (1962) obtained the best results when rice polishings were substituted for 10% of the corn in a corn-soy chick diet. There was no evidence that rice by-products influenced the body weight of experimental birds, when rice bran constituted up to 46% of the layer mashes (Smith, 1934). However, Desai et al. (1961) found that the maximum desirable level of rice polishings in poultry rations was 20%. The more-recent work reveals that when rice bran was used at 20% of broiler diets, a reduction of growth was observed; but when the bran was deoiled and used in the same ratio, a significant improvement in growth response resulted (Reddy et al., 1972). Marked improvement in broiler growth was not occurred in groups to which tallow was added at different levels in diets containing deoiled rice bran. Feed utilization was poorest for the group fed 20% rice bran. When rice bran was used at 60% of the diet to replace corn as an energy source in diets containing fish meal or soybean meal, the growth of chicks was depressed by approximately 30% (Kratzer et al., 1974). The higher level of rice bran in chicken diets not only caused growth reduction but also caused diarrhea. It was not possible to extract the growth-depressing factor with hexane or methanol. Even an addition of casein or soybean oil to the diet containing 60% rice by-product produced no marked improvement in growth (Kratzer *et al*., 1974). There was no evidence that there was any interference in trace-mineral availability; however, frayed feathers in chickens, due to low zinc in high rice by-product diets, has been observed (Bird, 1978). Higher levels of rice by-products, when not treated, reduced egg production (Smith, 1948). When 60% rice bran was included in layer diets, there was an adverse effect on egg production, shell thickness and yolk color (Majun *et al*., 1977). The optimum amount of rice bran suggested by Mahadevan *et al*. (1957) for layer diets was 20%. Buvanendran (1961) found that in chick-starter diets, a level of 20% was the most satisfactory from the standpoint of growth and sexual maturity, and in layer rations 30% was satisfactory for egg production, when other essential nutrients were provided in the mash. When 50% rice bran was used in the diet, a significant depression in egg production resulted.

When antitryptic substance was extracted by mild acid the growth response of chicks and the feed efficiency of rice bran was improved (Tsai, 1976). Autoclaving or steaming the rice by-products destroyed the growth-depressing factor and caused a marked improvement in growth (Upp, 1933; Kratzer *et al*., 1974; Tsai, 1976) even though a high level of rice bran was included in the poultry diets. Dry heating and hot-water treatment improved the feeding value of rice by-products as compared to untreated rice by-products (Kratzer *et al*., 1974, 1977;

Din, *et al*., 1979). However, Tsai (1976) found that most of the antitryptic activity in rice bran was not destroyed by heating even though heating time was as long as 30 minutes and had no effect upon the improvement of growth response in chicks and feed efficiency of rice bran. Autoclaving the rice bran at 120°C for 20 minutes prior to mixing of diets overcame its deleterious effects on eggs and egg production. The bran from parboiled rice was equivalent to autoclaved rice and there was no further improvement by autoclaving (Kratzer *et al*., 1977). Heat treatments, whether dry or wet, were effective in reducing free fatty acid development in rice by-products (Arnott *et al*., 1966; Kratzer *et al*., 1974).

Metabolizable energy values were studied by various workers (Hill and Runner, 1960; Hill *et al*., 1960). When studies were conducted to determine the metabolizable energy value of rice bran, Maust *et al*. (1972) found slightly lower value, 3.03 kcal/g, than 3.40 kcal/g which was previously determined by Zablan *et al*. (1963). However, Zablan *et al*. (1963) used fine rice bran which had lower fiber content and was substituted for glucose at the 25% level. Although the gross energy value of rice bran was the highest (4896 cal/g) as compared to that of cassave flour, raw cowpeas, germinated cowpeas or autoclaved cowpeas (4306 cal/g, 4320 cal/g, 4217 cal/g, and 4400 cal/g, respectively), the metabolizable energy value of rice bran (3.03 kcal/g) ranked below that of cassave flour (4.31

kcal/g) and autoclaved cowpeas (3.29 kcal/g) (Maust et al., 1972).

The metabolizable energy of the rice-bran samples was about 12.55 kJ/g[a] and was not influenced by autoclaving, steaming, dry heating or hot-water treatment (Kratzer et al., 1977).

A positive correlation has been found between pancreatic hypertrophy in chicks and antitryptic activity in rice bran. However, the causative entity of growth depression in rice by-products is as yet unknown. Previous researchers (Kratzer et al., 1974; Tsai, 1976) reported that the growth depression of chickens fed rice by-products was due to trypsin inhibitors, but Kratzer et al. (1977) found that the growth inhibition of rice bran was not due to its trypsin-inhibitor activity.

The development of free fatty acids, which cause rancid feed and reduce feed intake, is another problem in rice by-products. Chemical treatments with antioxidants such as Topanol OF and Topanol OC when applied at the rate of 0.5 to 0.1% were inefficient in preventing the development of free fatty acids (Arnott et al., 1966). Ethoxyquin also did not improve growth of chicks fed diets containing rice bran and was less effective than autoclaving or parboiling in preventing the development of rancidity (Kratzer

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[a]1 Joule = 0.239 cal
1 kcal = 4.185 Joules

et al., 1977). Heat treatments were quite effective in reducing free fatty acid development in rice bran (Arnott et al., 1966; Kratzer et al., 1974).

Thus, it appears that the maximum level of rice bran that can be included in poultry diets is approximately 30%. However, when it is autoclaved or steamed, it can be used at 50 to 60% without an appreciable loss in growth rate or egg production.

2. Swine

Feed costs which alone constitute 74% of total production costs (Sycip et al., 1965) determine the profitability of a swine enterprise. Therefore, it is essential to lower feed costs so that swine producers will realize an adequate profit margin. Rice by-product, being one of the cheapest and most abundant feed ingredients, can be used to a great advantage (Bistoyong et al., 1968). Rice by-product, especially bran and polishings, are rich in energy (Maust et al., 1972; Kratzer et al., 1977), rich in certain vitamins, particularly thiamin and niacin, and relatively high in crude protein (Bistoyong et al., 1968).

Researchers used different levels of rice bran in swine diets ranging from 0% to 80% of the total diet (Tirol, 1933; Emasiri, 1940; Thrasher et al, 1965a, 1965b; Bistoyong et al., 1968; Sagar et al., 1968; Campabadal et al., 1976; Chicco et al., 1976; Lal et al., 1976). Thrasher et al. (1965) conducted an experiment to re-evaluate rice bran in modern swine rations. In their experiment, rice bran replaced mostly corn but also some soybean meal, since rice bran had a higher protein content (15% in their experiment) than corn. Both 20 and 30% rice bran significantly reduced rate of gain and increased the feed required per 45.36 kilograms (100 pounds) of gain. Pigs on diets containing rice bran required about 14 more days to reach 90.72 kilograms (200 pounds). This loss in time probably represents more value than the slightly reduced cost of gain due to including rice bran in the ration. Based on feed efficiency alone, the value of rice bran in this trial was about 85 to 90% that of corn. The quality of protein in the diets containing rice bran was seriously reduced. At the 20 and 30% level, rice bran accounted for 19 and 26%, respectively, of the total protein in the grower diet. The carcasses of pigs fed rice bran were heavier, had less backfat, and higher iodine numbers. Subjective estimates of carcass firmness showed that carcasses from pigs fed rice bran were slightly softer, whereas those from pigs fed on corn were very firm.

Later, Thrasher _et al_. (1965) replaced corn in swine diets with rice bran and found that 20% rice bran was the maximum level that could be fed to pigs to produce acceptable carcasses, fat, firmness, and rapid, economical gains. This investigation also indicated that rice bran should not replace any of the protein supplement in order to avoid a serious reduction in gains due to a decrease in protein quality. As the level of rice bran increased, rate of gain and feed efficiency were depressed much less in the lots that averaged 26.31 kilograms (58 pounds) to 30.39 kilograms (67 pounds) initially. Their experiment showed that pigs fed the basal diets required significantly less feed than those receiving rice bran, but the inclusion of rice bran reduced cost of gain, especially among the heavier groups fed the 20% level. Carcass evaluation revealed that the inclusion of rice bran significantly decreased dressing percentage, backfat thickness, and the firmness of the carcass. Lean-cut yield tended to increase as the level of rice bran increased and was significantly increased when expressed as a percentage of carcass weight. This work agrees with that of Campabadal et al. (1976). A total of 233 pigs was used to determine the effects on live weight gain and feed conversion of adding graded amounts of rice bran to weaner (starter) and grower-finished diets and to examine the factors limiting the inclusion of rice bran at high rates. Rice bran at up to 15% for weaners and 30% for growing-finishing pigs did not affect performance and in one of the experiments a 40% rice-bran diet was fed to weaners without appreciable reductions in performance. Addition of fat to rice-bran diets improved performance apparently by increasing palatability and/or digestibility of the diets due to reducing dustiness. However, the addition of fat to rice-bran diets also increased energy density.

When trials were conducted with three levels of rice bran ranging from 0 to 80% of the diets, it was observed that the digestibility of rice-bran diets was generally lower than that of corn-soy diets (Brook _et al._, 1975a, 1975b). Rate of gain was depressed in a linear fashion by rice-bran additions and the differences of weight gains were significant (0.5) between the lower and higher levels of bran.

a. Digestibility

When trials were conducted to study the effect of crude fiber upon animal performance, Loosli _et al._ (1954) found that rice bran with less crude fiber had more digestible organic matter and protein than rice bran high in fiber content. The digestibility of concentrates containing two kinds of rice bran also varied appreciably. Depending upon the percentage of husks in the bran, the fiber content will be different in different rice bran. The more husks or husk particles in rice bran, the higher the crude-fiber content in rice bran will be (Arnott _et al._, 1966). Husks are not only high in fiber but also high in silica (11 to 19%) which reduces the digestibility of rice bran and also causes intestinal irritation and a swollen colon (Arnott _et al._, 1966; Campabadal _et al._, 1976).

Mean apparent digestibility coefficients for dry matter, crude protein and ether extract in rice bran were found by Campabadal _et al._ (1976) to be 79.4, 66.9 and

74.10%, respectively. These low digestibility coefficients were associated with lowered digestibility of diets containing rice bran and appeared to be directly related to the poorer performance of pigs fed these diets. Inflammation and ulceration of the gastrointestinal-tract lining was observed in pigs fed rice-bran diets, but the contribution of this condition to the depressed performance was not established. Little work has been performed that was designated to overcome the depressing effects of rice-bran diets fed to swine. Tillman et al. (1951) and Leighton (1958) demonstrated that lypolytic enzyme activity in rice bran resulted in a rise in rancid free fatty acids which rendered it offensive to livestock and, as a result, reduced feed intake.

Some mineral problems are also encountered while feeding high rice bran diets to swine. Most of the phosphorus in rice bran is in phytate form (O'Dell et al., 1971) which was not available to nonruminants (Nelson et al., 1968; Corley et al., 1980). As far as trace minerals are concerned, zinc is very low in rice bran. Maust et al. (1969, 1972) reported that pigs on rice bran-cassava based diets developed parakeratosis, gained slowly and digested feed poorly.

b. Effects of protein levels

When a trial was conducted (Bistoyong et al., 1968) using 48 cross-bred weanling pigs to determine the effects of rice bran-fish meal combinations with varying protein levels from 12 to 22% on growth rate and feed efficiency of growing pigs, the average daily gains increased from 0.41 to 0.66 kilograms as the protein level of the diet was increased. Daily gains of pigs fed 18, 20, and 22% protein diets were significantly higher than those fed a 12% protein diet. The average feed gain ranged from 2.92 to 5.72. In general, growth rate, feed efficiency, and efficiency of energy utilization improved as the protein level of the diet was increased. Pigs on the 18% protein diet made the cheapest gain and those on the 14% diet made the most expensive.

Although rice bran is high in crude fiber it is rich in some vitamins, particularly thiamin and niacin, and relatively high in crude-protein content. But the protein of rice bran is of poor quality. Therefore, rice bran should not replace any of the protein supplement in order to avoid a serious reduction in gains due to a decrease in protein quality (Thrasher *et al.*, 1965).

c. Effects of fat treatment

Addition of fat to rice-bran diets improved performance apparently by increasing palatability and digestibility of the diets (Campabadal *et al.*, 1976). The 20% bran diet resulted in significantly poorer gains and feed conversion when compared to the control and bran-plus-fat diets (Campabadal *et al.*, 1976). Dry-matter digestibility was depressed by the addition of bran but was restored when fat was added to this diet. Crude-protein digestibility was significantly reduced by bran and was not affected by addition of fat. Digestible energy of the 20% bran diet was lower than the control by 93 kcal/kg. Addition of fat brought digestible energy of the diet to within 18 kcal/kg of the control. It is, therefore, important to avoid husks in rice bran, and supplement with protein, fat and trace minerals to high rice bran diets. Various treatments of rice bran may also improve its feeding value.

In summary, previous workers using different levels of rice bran ranging from 0 to 80% in swine diets have, in general, concluded that the use of untreated rice bran in swine diets up to approximately 30% reduced the cost of production without adversely affecting carcass quality and growth rate.

MATERIALS AND METHODS

A. Heat-Exchange Systems

1. Solar cabinet

Principle: The sun is the source of by far the greatest part of all the heat received at the earth's surface, outweighing that due to distant stars, universal space, and radioactive discharge (Platt et al., 1972). It is continuously emitting energy but only about four ten-billionths (0.0000000004) of which is received by the Earth and its atmosphere in the form of radiation. No country in the world uses as much energy as is contained in the sunlight that strikes just its buildings (Hayes, 1977). Thus, the only safe, dependable, renewable and non-polluting energy source is the solar radiant energy. Nevertheless, the trapping of solar radiant would not be cheap or easy because of the complexity of technology involved for large-scale production, but its benefits would far outweigh the costs and difficulties in the long run.

The radiant power (flux) from the sun outside the Earth's atmosphere is constant within 2%. Approximately 96% of the radiant power per unit area arriving at a surface will penetrate through a clear glass. Only 4% of the total radiation will be reflected back. Thus, glass is considered

Fig. 3. Plan for the Solar Cabinet Cooker

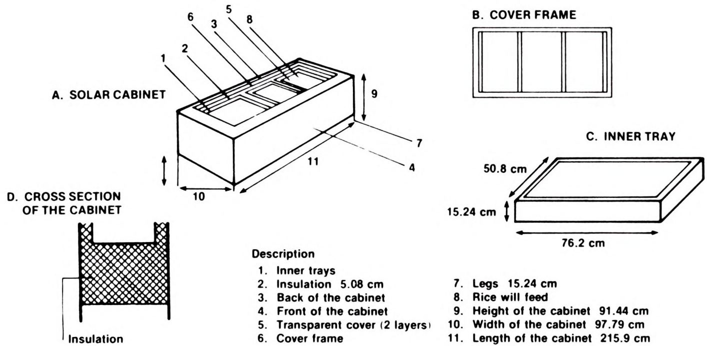


Figure 4. The solar cabinet.

as the best material for the cover frame of the solar cabinet. Most meteorological stations of the world report solar ratiation, measured on a horizontal surface, in langley, which is expressed as energy per unit area (1 calorie/cm^2). The intensity of the solar radiation varies with geographical location, time of day, season, clouds, dust particles in the air, and atmospheric moisture. These principles must be taken into account, if possible, in constructing any kind of device to trap the solar radiant power.

The dimensions and materials of the construction of all parts of the solar cabinet are given in Appendix B-1.

Construction of the cabinet frame

The solar cabinet consisted of a rectangular angle iron frame divided crosswise by means of retaining bars at the bottom and sides. The frame was strengthened with galvanized sheet metal. The procedures of the construction of the cabinet frame are given in Appendix B.

Construction of glass frame

The gover glass frame was made of wood. Two 215.9 cm × 5.08 cm lengthwise, and four 83.82 cm × 3.81 cm × 3.81 cm pieces of wood were used to construct the glass frame. A 1.27 groove in one side of each of the wooden pieces was cut to fit the glass. At equidistance, two wooden strips were fitted across the glass frame to avoid the risk of breakage of the glass, ultimately to give the inside of the cabinet an appearance of a three-room box. Three glass pieces sized 86.36 cm × 66.04 cm × 0.95 cm were then inserted in the grooves and the joints were paved with puddings and woodwax. In the front portion of the cover frame, two strong handles were fitted to make easy handling while opening and closing the cabinet. Then the cover frame with glass attached was fitted with the cabinet frame with the help of three pairs of hinges.

The empty space was then filled with rice husks as an insulating material, leaving 15.24 cm deep space on the top portion of the cabinet in order to fit the inner trays where rice by-product was cooked afterwards. A layer of insulating material was fitted all around the trim of the box and was wrapped with a high temperature resistant tape. Thus, the cabinet except the inner trays was completed.

Construction of inner trays

Three pieces of equal sized, 91.44 cm × 66.04 cm sheet metal were bent over 15.24 cm from each side and pop-riveted to make three equal sized, 76.2 cm × 50.8 cm × 15.24 cm, 15.24 cm deep inner trays. The trays were then placed in the cabinet on the top of rice husks in a series leaving approximately 5.08 cm space between them and 5.08 cm apart from the innter surface of the cabinet frame. The empty spaces between trays were filled with rice husks as insulating material.

The cabinet was placed on wooden blocks on a raised ground to avoid the possibility of condensation of moisture on the bottom of the cabinet and consequently it was also helpful to minimize the rusting of cabinet legs. It is very important to avoid shade over the cabinet during any time of the day to obtain full intensity of solar radiation on the cabinet.

All the exposed surfaces of the solar cabinet were then painted flat black. The inner trays and the cover slips of the inner trays made of sheet metal were also painted in flat black for maximum radiation absorption and heat-energy retention.

Sample preparation in the solar cabinet

In order to operate the cabinet the cover glass frame (door) was opened, the rice-mill feed put in the inner trays and covered with dark painted cover sheet metal pieces. The door was then closed.

Although the cabinet was not fully air tight, the air flow in and out of the cabinet was minimized by minimizing the gap between the cabinet frame and the cover frame. The solar rays strike the glass, pass through it and subsequently strike on the dark painted cover sheet metal which absorbed energy. The rice-mill feed which was placed in the inner trays was heated by conduction from the sheet metal. The cabinet was designed to cook the material rather than drying, where the free air movement becomes crucial. Therefore, the air movement in the cabinet and

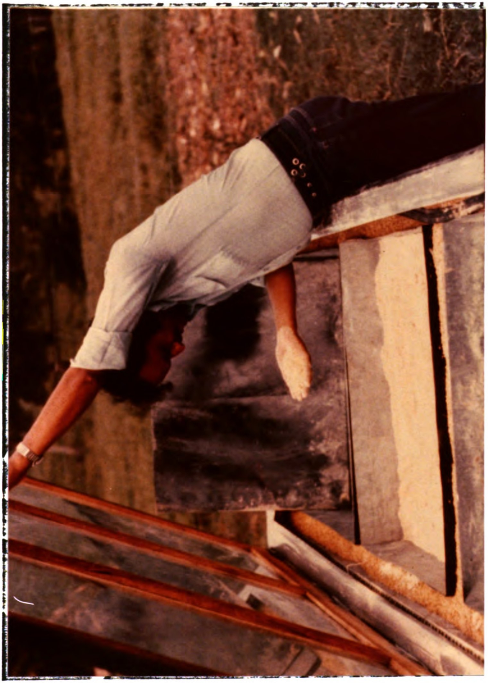


Figure 5. Examining the heated rice mill feed in the solar cabinet.

out of it was minimized by tightly fitting the joints of the pieces of materials. The temperature of the rice by-product at three sites in a depth of 5.08 cm (2"), 7.62 cm (3"), and 12.70 cm (5") were measured three times a day for a period of one month, e.g., May 1980 (Table 9). The temperature was measured by thermocouple using a Fluke digital readout thermometer. Nevertheless, the temperature below 60°C was not recorded because of the fact that that temperature was not effective to treat rice-mill feed in order to enhance its feeding value (Bird, 1978). The means of the temperature data for the month of May, 1980 are as follows.

When it was observed that the temperature was the lowest when 12.7 cm deep rice by-product was used, it was used only about 7.62 cm deep to cook it per sample preparation. The rice by-product was then continuously heated in the solar cabinet for three days, stirring once a day, and mixed well and samples were taken and stored in bags. Except during the transit period, the samples were stored in a refrigerator until chemical analysis was performed.

It was not possible to heat adequate quantity of rice-mill feed in the solar cabinet, especially during the starting period of the rainy season when the trials were conducted. Therefore, the solar heated rice mill feed was chemically characterized but was not used in the feeding trials of poultry and swine.

TABLE 9. TEMPERATURE[a] OF RICE BY-PRODUCT AT DIFFERENT DEPTHS AND SITES IN THE INNER TRAYS OF SOLAR CABINET IN THE MONTH OF MAY, 1980.

Item	Depth of Thermocouple Placement in the Rice-Mill Feed																	
	5.1 cm (2")						7.6 cm (3")						12.7 cm (5")					
Temperature Measurement Site	A		B		C		A		B		C		A		B		C	
Temperature Measurement Time	Range	Mean[d]	Range	Mean	Range	Mean	Range	Mean	Range	Mean	Range	Mean	Range	Mean	Range	Mean	Range	Mean
10 a.m.	60-63	61	60-64	62	60-62	61	60-62	61	60-64	63	60-63	61	<60	<60	<60	<60	<60	<60
12 Noon	60-81	76	60-88	81	60-83	78	60-80	70	60-76	69	60-75	69	60-70	65	60-76	66	60-71	64
3 p.m.	60-80	74	60-86	80	60-79	73	60-73	68	60-72	67	60-70	66	60-70	63	60-71	66	60-69	65
Mean of the Means		70		74		71		66		66		65		64		66		64

[a]All temperatures are expressed in Centigrade scale.

A = Right corner of the cabinet.

B = Center of the cabinet.

C = Left corner of the cabinet.

[d]Means of a month.

2. Rotary drum heating system

A "rotary drum heating system" was developed to use for dry heating the rice-mill feed (Figures 6, 7, 8, and 9).

Materials of construction and dimensions are given in Appendix B-2. Locally available materials were used to construct the machine wherever it was possible.

Methods of construction of furnace

A rectangular groove of 86 cm wide and 10 cm deep was dug allowing an area of 76 cm × 71 cm. The groove was paved with bricks. Then a floor of bricks, one brick in thickness, was established to serve as the foundation. The walls of the rectangular furnace were raised to a height of 48 cm, leaving a distance of 28 cm in the front side of the rectangle to serve as oven mouth to feed the fuel. The furnace was made of bricks, and a cement-sand mixture which was mixed in a ratio of 1:4. Three parallel iron rods were placed over the empty portion of one side of the rectangular furnace wall, and on the top of the rods bricks were placed and were strengthened with the cement-sand mixture. Similarly, 4 iron rods, two on each side, were placed crosswise to strengthen the furnace wall and to control the fire flame to the desired direction. Bricks and cement-sand mixture were layered over the top. The rectangular furnace wall was then raised 5 cm further which gave the furnace wall to a total height of 53 cm. The 28 cm × 48 cm opening in the front was designed for feeding fuel, for draft and for ash removal. However, an air supply system was established to provide sufficient air in order to obtain less smoke and more heat energy.

The walls of the furnace were further paved with the cement-sand mixture to make sure that that would not break while cooking the material.

Construction of heat exchange machine

One end of a 55-gallon drum was cut giving a hole of 27 cm x 23 cm which was used as a door to put in and remove the heated material out. Strips of iron were welded around the door cover. A sliding door cover was fitted in the groove on the drum and was used to open and close the door. A handle was fixed with the door cover to facilitate opening and closing of the door. The 5 blades, 80 cm x 5 cm each, made of sheet metal·were bolted on the inner surface of the drum to turn over the material in the drum.

Two holes, 5 cm in diameter, were made one in each side of the drum to allow the pipe to pass through.

A measurement of 84 cm at the middle portion of the pipe was taken and was marked at 4 points of equal distance of 21 cm. Four holes were drilled at the four points to fix the thermocouples in order to take the temperature of heated material at different points.

The galvanized aluminium pipe with 4 holes in a distance of 21 cm was inserted through the drum and was welded

Figure 6. Loading and unloading the rice mill feed in the rotary drum heating system.

Figure 7. The rotary drum heating system.

with the drum. Four cupper-constantone thermocouples were inserted through the holes (one through each hole) of the pipe. The sensitive portion of the thermocouple was protruded 5 cm in the drum and the other ends of the thermocouples were collected through one end of the pipe. A Z-shaped handle was fixed to the other end of the pipe to turn the machine while cooking the material.

Installation of the poles

The wooden poles of 183 cm each were installed at a distance of 92 cm away from each side of the furnace, allowing the poles a height of 92 cm above the ground surface. Then the heat exchanger machine was hung on the Y-shaped poles above the furnace. The distance between the furnace and the machine was 20 cm. A grease was used on the Y-shaped poles to facilitate the revolution of the machine.

Similarly, two Y-shaped poles of 198 cm each were installed 2 meters away from the furnace at a distance of 244 cm apart. This system was used while loading and unloading the materials cookes.

Fuel system

The main source of the fuel was strips of wood obtained free of cost from the lumber mills. However, rice husks were also mixed with the wood strips to generate more stable heat energy.

Figure 8. Temperature measurement system with fluke digital thermometer using thermocouples.

Standardization of the machine

a. Load determination

It was essential to determine the capacity of the machine which can heat the material most efficiently. Therefore, rice mill feed was heated in the machine at a rate of 10 kg, 20 kg, 30 kg, 50 kg and 75 kg. When rice mill feed was used below 20 kg, it was difficult to measure the temperature of it, because it was not possible to establish the time range when the material would get required temperature. When 20 kg to 30 kg rice mill feed was used, it was easier to establish the temperature and time ranges, but when more than 50 kg was used at a time, the material was not heated evenly. When the higher amounts were used, it was difficult to handle the machine while taking temperature and was also difficult to turn the material inside the machine. When the material was not uniformly mixed by turning the machine, part of it was charred and the other part was not heated well. Therefore, 30 kg rice mill feed was heated in the machine at one time.

b. Speed determination

When the machine was cranked at low speed (less than 100 rpm) the materials touching the inner surface of the drum stuck on the wall and charred, and when the machine was cranked at high speed (>200 rpm), the material inside the machine did not get sufficient time to mix uniformly. However, when the machine was cranked at a speed of 140 rpm to 150 rpm the material got sufficient time to mix uniformly, and there was less problem of sticking of material on the inner surface of the drum. Therefore, the speed of the machine maintained about 145 rpm to obtain the best heating result.

c. Temperature measurement

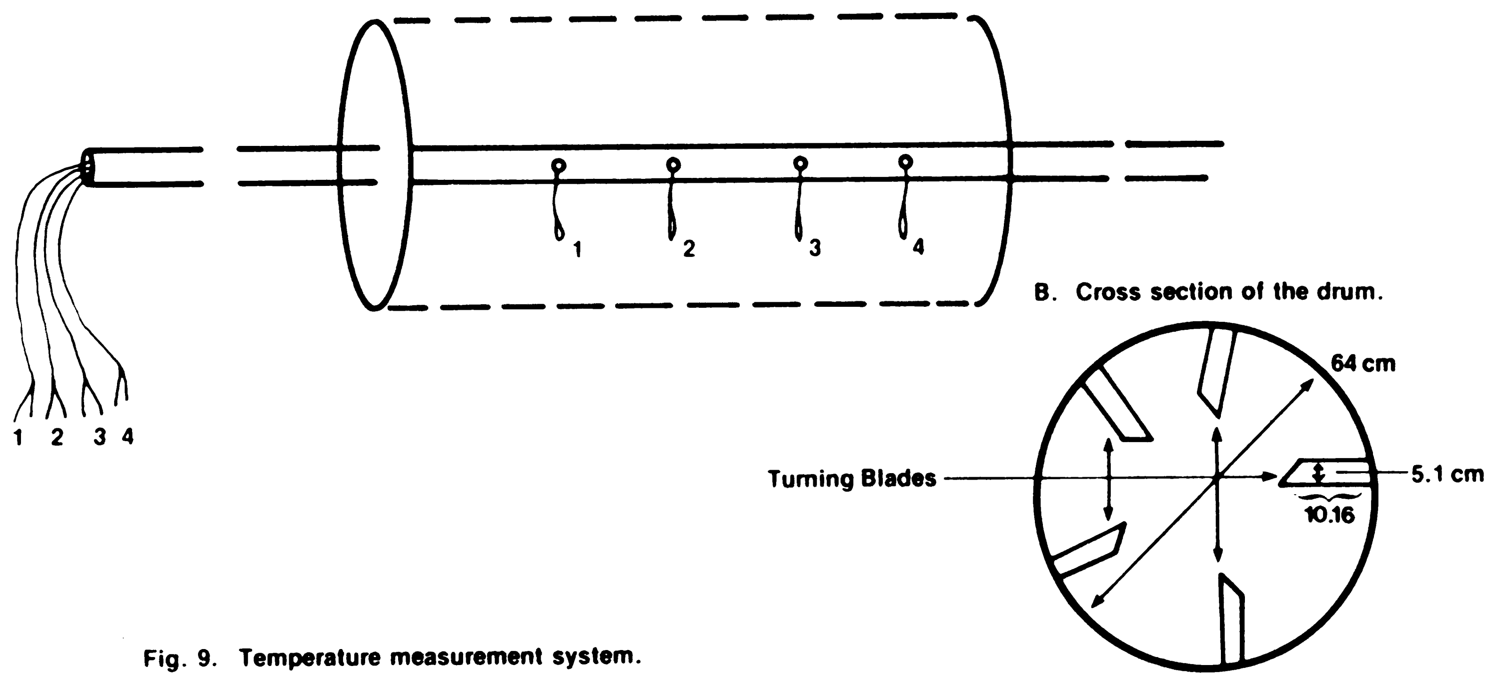
All the temperature measurements of the rice mill feed when heated in the drum were taken using the Fluke digital readout thermometer. During standardization period, the temperature of the heated material was taken for 6 times in an interval of 10 minutes, when a fixed quantity of 30 kg rice mill feed was heated in the machine. The averages of 5 different temperature readings of the heated rice mill feed was as follow,

Batch	Time interval	Temperature, °C[a]
1st	0	30.8
2nd	10	54.4
3rd	10	75.4
4th	10	95.4
5th	10	102.8
6th	10	112.4
7th	10	120.8[b]

[a]Each value is the mean of 5 readings.

[b]When the material was heated for one hour, the rice mill feed particles started sticking on the inner surface of the drum.

A. Drum heating system with thermocouples attached.



B. Cross section of the drum.

Fig. 9. Temperature measurement system.

1,2,3,4 Thermocouples to join with the Fluke Digital Readout Thermometer.

1',2',3',4' Shuttered ends of thermocouples corresponding to 1, 2, 3, and 4, respectively. Also see in Fig. 8.

Dimensions

Length of the drum:	84 cm
Circumference of the drum:	180 cm
Diameter of the drum:	64 cm
Length of the pipe:	366 cm
Diameter of the pipe:	5.1 cm

Dry heating the rice mill feed

The rice mill feed was heated at two different temperatures for this trial, one high heated rice mill feed (HHR) at 100 to 105°C and the other low heated rice mill feed (LHR) at 85 to 90°C. Whether the temperature was 100 to 105°C or 85 to 90°C, the method of the heating was the same. Only the difference was the length of heating time.

The rice mill feed to be heated was weighed 30 kilograms at a time and put in the heating machine and the machine was placed over the furnace hanging on the Y-shaped poles and was cranked continuously at a rate of approximately 145 rpm till the required temperature of the heated material was achieved. It took 40 to 45 minutes to reach a temperature of 100 to 105°C in the material, whereas 85 to 90°C was obtained in 25 to 30 minutes of heating time.

A continuous supply of wood-strips and rice husks was maintained to generate a uniform heat energy to heat the material. The higher temperature could be obtained in the material heated for shorter duration, but when the higher heat intensity and shorter time were used the material was not heated evenly. Therefore, it was important to control the heat intensity by controlling the fuel supply. The material was heated when the machine was cranked in clockwise as well as anticlockwise directions shifting from one direction to the other after each 4 to 5 minutes.

Figure 10. A. Dry heated rice mill feed at 100 to 105°C.
B. Dry heated rice mill feed at 85 to 90°C.
C. Unheated rice mill feed.

3. Wet heating system

The same furnace which was used for rotary drum heating system was also used for boiling the water. The methods of boiling water, treating rice mill feed and processing the treated wet materials are described in swine and poultry sections.

B. Chemical Characterization of Rice Mill Feed

1. Preparation of samples

a. Free fatty acids: Fresh rice mill feed was obtained from the Big Falls Ranch Mill, mixed well and divided into 3 equal portions. Two of them were placed separately in two shallow pans to a thickness of 2 to 2.5 cm and were heated at 85^{o}C in an oven, one for 2 hours and the other for 4 hours. The samples were removed from the shallow trays, collected in burlap bags and stored in a room till the analyses were completed. The raw sample was stored in the same manner. On the day of analysis, samples were removed from the burlap bags, placed in polyethylene bags and taken to the laboratory.

A dried boiling water treated sample was prepared in a subsequent year by adding fresh rice mill feed to an equal weight of boiling water, and was stirred vigorously till all the dry particles were wet. The mixture was spread on a polyethylene sheet to a thickness of 2 to 3 cm, dried for 3 days in the sun, ground in a hammer mill, mixed and collected in burlap bags, stored as described previously, and used for free fatty acid analysis.

b. Nutrient analysis of treated and untreated samples: The high heated (100 to 105^{o}C), low heated (85 to

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$90^{o}C$), boiling water treated and solar heated rice mill feeds were prepared as described in "Heat-Exchange Systems." Each of them was mixed well, and the samples were collected in polyethylene bags, made air tight and stored in a refrigerator until analyses were done. The fresh, untreated rice mill feed was obtained from the same mill, mixed well and stored in the same manner. In order to determine the chemical changes, each kind of treated and untreated rice mill feed was stored in burlap bage for 45 days in the feed-mixing room, and samples were taken, collected in polyethylene bags, made air tight and stored in a freezer until the analyses were done.

2. Methods of analyses

Dry matter, ash, silica and free fatty acid were determined by the A. O. A. C. method (AOAC, 1975). However, fat for free fatty acid analysis was extracted using Soxhlet apparatus, and the free fatty acid was determined using A. O. A. C. methods (AOAC, 1975) for crude fat. The crude oil was mixed well and 7.05 g were weighed into a 250-ml flask to which 50 ml of ethanol (previously neutralized by adding 2 ml phenolphthelin solution and enough 0.1 N NaOH to produce a faint permanent pink color) was added. The mixture was titrated with 0.25 N sodium hydroxide with vigorous shaking until a permanent faint pink color appeared and persisted for more than one minute. Free fatty acid concentrations were reported in percent as oleic acid (AOAC, 1975).

Nitrogen was determined by the semi-micro Kjeldahl method and the estimated amount of crude protein was determined by multiplying the percent nitrogen by 6.25. Ether extract was determined with a Goldfisch apparatus. Gross energy was determined using a Parr[a] adiabatic oxygen bomb calorimeter. Neutral detergent fiber (NDF), acid detergent fiber (ADF), cellulose (Cel) and Lignin (Lig) were determined using the methods described by Van Soest (1963, 1965). Hemicellulose (Hem) was determined by subtracting ADF from NDF. Amino acids (AA) were determined by the proposed MSU methods (Makdami et al., 1971; Bergen et al., 1973). For minerals, approximately 1 g of each sample in duplicate was wet ashed using 10 ml of concentrated nitric acid followed by 2 ml of concentrated perchloric acid. Standards were processed in the same manner. Concentrationf of calcium, magnesium, iron, copper, manganese and zinc were determined by atomic absorption, and sodium and potassium by atomic emission as described by Ullrey et al. (1967). Phosphorus was determined by the colorimetric method of Gomeri (1942) using visible-light spectrophotometry.

In vitro trypsin inhibitory assay

Twenty milligram samples of rice-mill feed were placed in 40 ml centrifuge tubes to which 1 ml of acedified water (pH 4.9) was added. Extraction was accomplished in 2 hours without agitation at 4 to 5°C. Twenty-two milligrams

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[a]Parr Corp., Moline, Illinois.

of Azocol,[a] a general proteolytic substrate, were added to each tube. To facilitate the reaction between the water-insoluble substrate and tube contents, a glass marble was placed in each tube. The 1 ml of phosphate buffer (pH 7.0) and 1 ml of a trypsin stock solution were added to the tubes including the blanks. The trypsin[b] stock solution was prepared (6 mg in 400 ml of 0.001 M HCl) weekly and was refrigerated. The trypsin stock solution was warmed to 37°C prior to use. Sample tubes were also warmed at the same temperature prior to assay initiation. The tubes containing samples and trypsin standard solution were placed in the water bath and shaken vigorously for a 10-minute incubation period at 37°C. The reaction was stopped by the addition of 30% acetic acid to each tube in the same order as when adding the standard trypsin solution. The tubes were then centrifuged for 10 minutes at 10,000 × g. The supernatant fluid was removed and absorbance was determined against a water blank at 520 nm in a spectrophotometer.

C. Feeding Trials

Broiler Trials

Three levels of each type of treated rice-mill feed were compared with the same level of untreated rice-mill feed

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[a]Calbiochem, La Jolla, California.

[b]Type IX, No. T-0134 from hog pancreas, crystallized, dialyzed and lyophilized powder, Sigma Chem. Co., St. Louis, Missouri.

in order to evaluate the type of heat treatment of rice-mill feed upon level of inclusions in the diet. There were 12 dietary regimens made up as follows:

Code		Type of diet
1A	=	High (100 to 105^{o}C) dry heated rice mill feed (HHR) diet, HHR replacing 80% of corn in diet.
1B	=	HHR diet, HHR replacing 80% of corn in diet.
1C	=	HHR diet, HHR replacing 100% of corn in diet.
2A	=	Low (85 to 90^{o}C) dry heated rice mill feed (LHR) diet, LHR replacing 60% of corn in diet.
2B	=	LHR diet, LHR replacing 80% of corn in diet.
2C	=	LHR diet, LHR replacing 100% of corn in diet.
3A	=	Boiling-water treated and dried rice mill feed (BWR) diet, BWR replacing 60% of corn in diet.
3B	=	BWR diet, BWR replacing 80% of corn in diet.
3C	=	BWR diet, BWR replacing 100% of corn in diet.
4A	=	Untreated rice mill feed (UR) diet, UR replacing 60% of diet.
4B	=	UR diet, UR replacing 80% of diet.
4C	=	UR diet, UR replacing 100% of diet.

Dry-heat treatment

The dry-heat treatments consisted of two levels of heat, the higher being 100 to 105^{o}C and the lower being 85 to 90^{o}C. The dry-heating system as described in "Heat-Exchange Systems" was used to heat the rice-mill feed for both levels of temperature.

The solar heated rice mill feed was chemically characterized but was not used in either of the feeding experiments because it was not possible to generate the temperature above 85^{o}C constantly during the time when trials were conducted.

The rotary drum (dry heating machine) was placed over the fire flame and warmed to evaporate the moisture stuck on the inner surface of it. The machine was suspended over the fireplace with the help of 5.08 cm (2") galvanized zinc pipe and two Y-shaped wooden poles. After a few minutes when the machine became warm enough to evaporate the condensed moisture, it was shifted from the fire to another Y-shaped pole away from the flame. The door of the machine was kept open till the moisture evaporated. Then 30 kilograms of rice mill feed which was to be heated was put in the machine and the machine was shifted over the fireplace. Then the machine was continuously cranked at a rate of about 140 rpm for about 20 minutes and the temperature of the rice mill feed was measured. Heating was resumed for another 10 minutes and the temperature measurements were taken. Similarly, the material in the machine was heated and temperatures were measured till the temperature of the rice mill feed reached 100 to 105^{o}C after about 45 minutes of heating. As the desired temperature was obtained, the machine was shifted away from the fire flame over a Y-shaped pole and cranked for about 5 minutes to make sure that the particles of the rice mill feed did not stick on the surface of the machine. Then the heated material was collected in a tray and kept there for about 25 minutes to cool the material. The material was then collected in burlap bags till it was used in broiler diets.

The low dry heated rice mill feed was also prepared in the same way as that of high dry heated material except that the low-heated material was removed from the machine when the temperature of the machine reached 85 to 90°C. It took about 30 minutes for the temperature of the rice-mill feed to reach 85 to 90°C.

However, the time factor was directly proportional to the intensity of the flame which in turn depended upon the type of fuel used. Therefore, efforts were made to have a constant supply of heat by regulating the amount of fuel input.

Wet-heat treatment

The wet heating of the rice-mill feed was done according to the method described in the swine section (p. 95). The wet material was then removed from the vat and was spread on a polyethylene sheet to a thickness of about 2 cm and air-dried with frequent stirring for 3 days. During nights the material was covered with polyethylene sheet to protect from condensation of moisture on the surface of wet rice mill feed. However, air passage was allowed to absorb the moisture and to facilitate quicker drying of the material. A sour odor developed but no mold developed as was also observed by Kratzer et al. (1977) during 3 days of drying period. However, when it rained for a day or more during the drying period, the material did not dry, and besides a sour odor, mold also developed. Nevertheless, no wet treated rice mill feed, which took more than 3 days to dry, was included in the broiler diets.

In spite of the efforts to break down the chunks which were formed during drying of the material, it was not possible to break all of them into powdery form which could be used in the chicken mash. Therefore, the chunks were broken by a hammer mill and stored in sacks till the diets were prepared.

The raw rice mill feed was used in the broiler diets as it was obtained from the mill.

Efforts were made to use fresh rice mill feed in all treatment diets during the entire trial period. The use of rice mill feed older than 3 weeks was avoided in the diets. The wet heated rice mill feed older than 2 weeks after the treatment was avoided in the diets.

Trial procedures

The poultry houses which had thatched roofs and each pen separated by chicken-wire were disinfected a week before they were used to house the chicks for trials. All pens were filled with wood shavings to a thickness of about 8 cm (3").

Six hundred unsexed, day-old broiler strain chicks were obtained from a commercial Mennonite Hatchery Farm[a] and were weighed in groups of 25 birds and then randomly assigned to 12 different treatment diet groups having 50 chicks per group. Each treatment group was put on deep litter base in electrically heated brooders and fed the

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[a]Hatching eggs were obtained from C. W. T. Farms, Inc., P. O. Box 1396, 1180 Airport Parkway, Gainsville, Georgia 30501.

TABLE 10. COMPOSITION OF STARTER DIETS

Ingredient	Composition, %		
	Percent rice mill feed of total corn		
	A = 60[a]	B = 80[b]	C = 100[c]
Meat & bone meal	22.975	22.975	22.975
Soybean meal	9.0	8.0	7.0
Molasses	4.0	4.0	4.0
Corn	24.88	12.64	-0-
Rice by-product	37.32	50.56	64.2
Vitamin premix	0.5	0.5	0.5
Trace-mineral premix	0.5	0.5	0.5
Salt	0.5	0.5	0.5
Amprolium	0.025	0.025	0.025
Methionine	0.3	0.3	0.3
	100.0	100.0	100.0

[a] Similar in diets 1A, 2A, 3A, and 4A.

[b] Similar in diets 1B, 2B, 3B, and 4B.

[c] Similar in diets 1C, 2C, 3C, and 4C.

TABLE 11. CALCULATED NUTRIENT COMPOSITION OF THE BROILER DIETS FOR STARTER PERIOD

Nutrient[a]	Composition		
	Percent rice mill feed of total corn		
	A = 60[b]	B = 80[c]	C = 100[d]
ME, kcal/kg	2191	1965	1731
Crude protein, %	22.0	22.00	22.00
Methionine, %	0.63	0.63	0.62
Lysine, %	1.14	1.16	1.18
Cystine, %	0.19	0.18	0.17
Tryptophan, %	0.20	0.20	0.20
Calcium, %	2.42	2.43	2.43
Avail. phosphorus, %	1.46	1.48	1.51
Ca/P ratio	1.66	1.63	1.61
Ether extract, %	7.86	9.11	10.40
Crude Fiber	6.23	7.40	8.60
Ash	8.67	9.27	9.89

[a]Nutrient contents of the diets were calculated using the nutrient composition of untreated rice mill feed given in Table and "Ingredient Analysis Chart" used in Belize.

[b]Similar in diets 1A, 2A, 3A, and 4A.

[c]Similar in diets 1B, 2B, 3B, and 4B.

[d]Similar in diets 1C, 2C, 3C, and 4C.

TABLE 12. COMPOSITION OF FINISHER DIETS

Ingredient	Composition		
	Percent rice mill feed of total corn		
	A=60[a]	B=80[b]	C=100[c]
Meat and bone meal	17.0	17.0	17.0
Soybean meal	5.0	4.0	3.0
Molasses	4.0	4.0	4.0
Corn	28.96	14.68	0
Rice mill feed	43.44	58.72	74.4
Vitamin premix	.5	.5	.5
Trace mineral premix	.5	.5	.5
Salt	.5	.5	.5
Methionine	.1	.1	.1
	100.0	100.0	100.0

[a]Similar in diets 1A, 2A, 3A, and 4A.

[b]Similar in diets 1B, 2B, 3B, and 4B.

[c]Similar in diets 1C, 2C, 3C, and 4C.

TABLE 13. CALCULATED NUTRIENT COMPOSITION OF THE BROILER DIETS FOR FINISHER PERIOD

Nutrient[a]	Composition		
	Percent rice mill feed of total corn		
	A = 60[b]	B = 80[c]	C = 100[d]
ME, kcal/kg	2224	1961	1691
Crude protein, %	18.00	18.00	19.00
Methionine, %	0.39	0.38	0.38
Cystine, %	0.16	0.15	0.14
Lysine, %	0.91	0.94	1.97
Tryptophan, %	0.17	0.17	0.18
Calcium, %	1.81	1.82	1.82
Avail. phosphorus, %	1.18	1.21	1.24
Ca/P ratio	1.54	1.50	1.47
Ether extract	8.27	9.71	11.18
Crude fiber	6.56	7.92	9.31
Ash	7.51	8.21	8.93

[a]See footnote (a) in Table 12.

[b]Similar in diets 1A, 2A, 3A, and 4A.

[c]Similar in diets 1B, 2B, 3B, and 4B.

[d]Similar in diets 1C, 2C, 3C, and 4C.

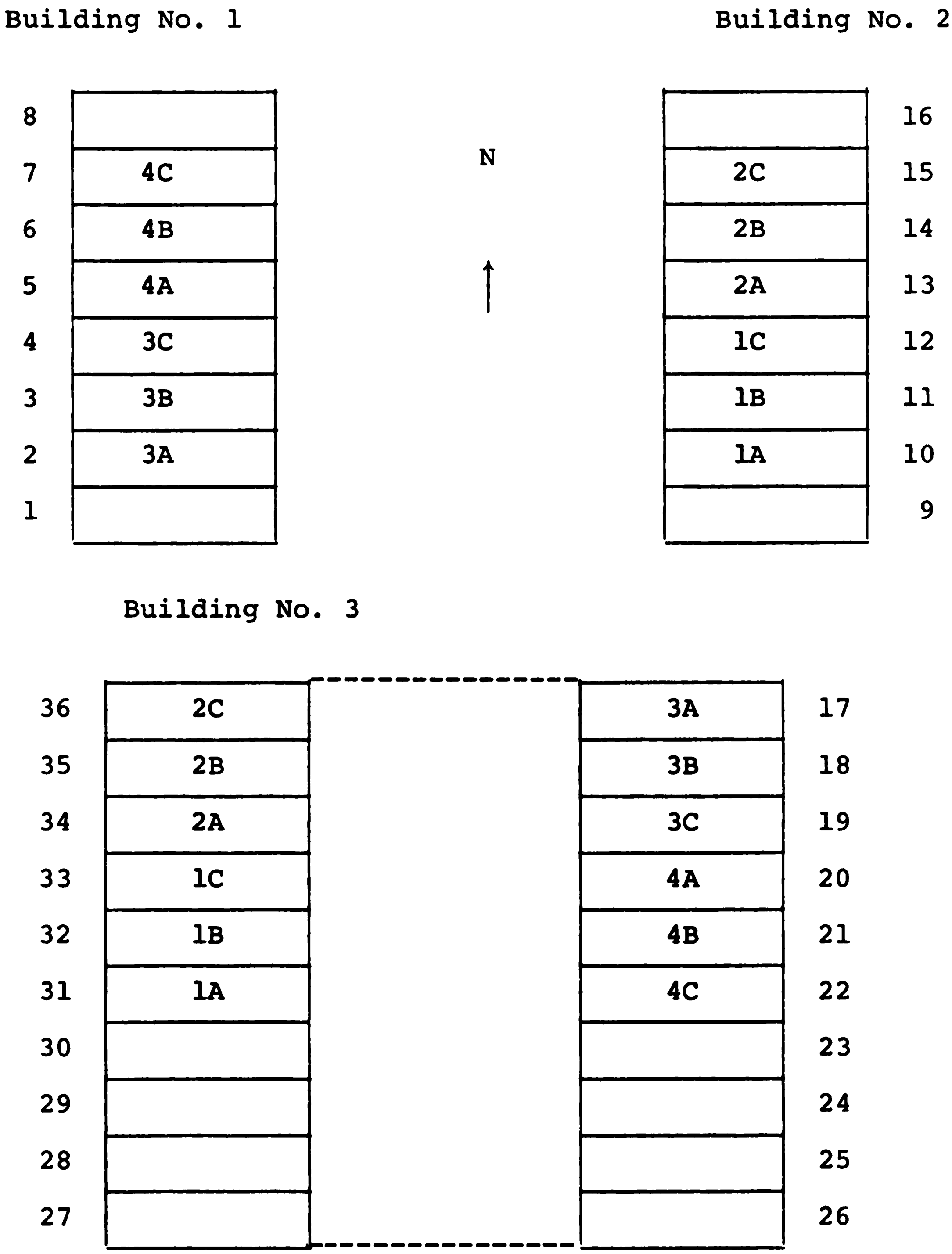

FIGURE 11. DESIGN FOR BROILER EXPERIMENT, INITIAL 2-WEEK PERIOD.

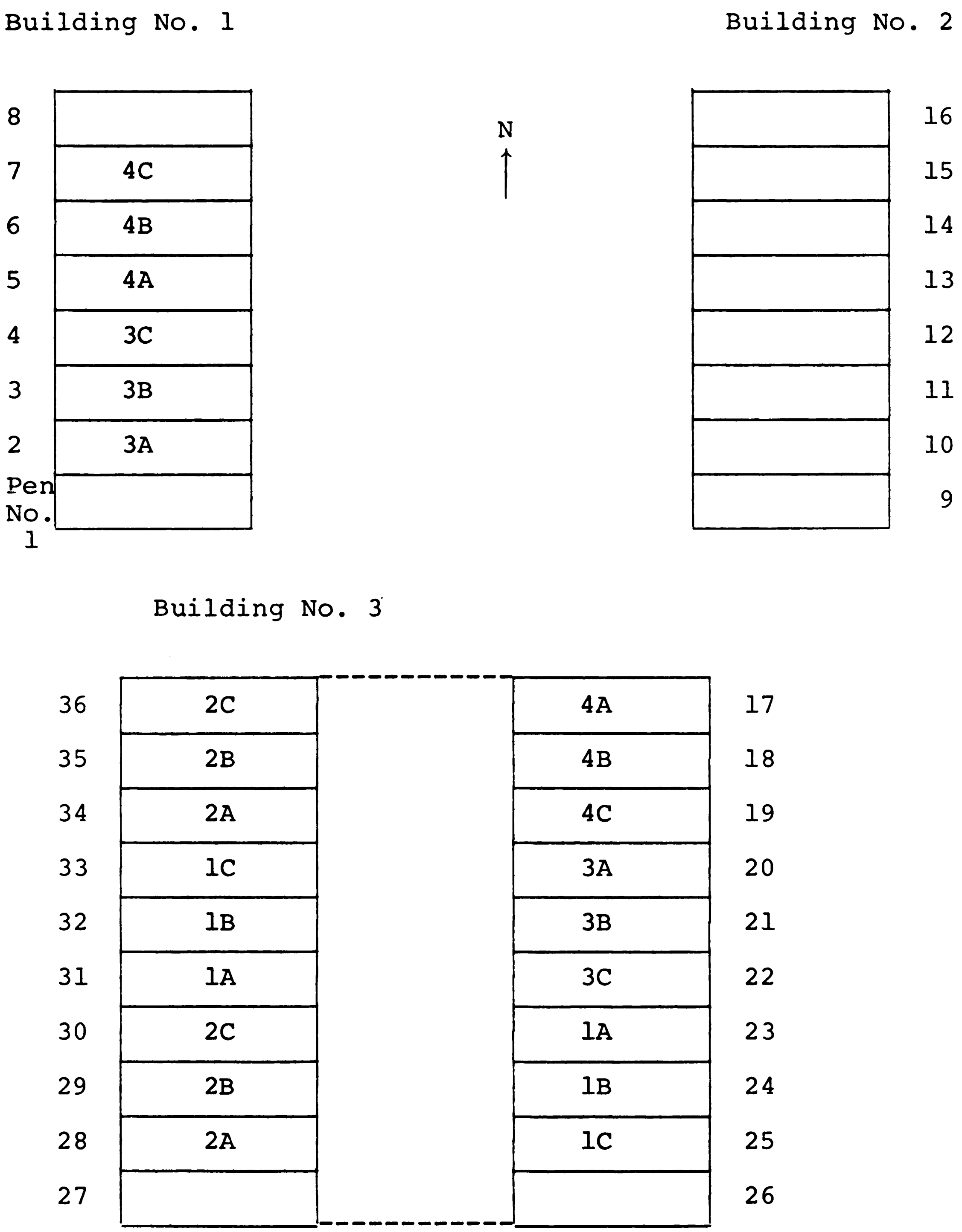

FIGURE 12. DESIGN FOR BROILER EXPERIMENT FOR FINAL 6 WEEKS OF EXPERIMENT PERIOD.

Figure 13. Chicks in the brooder with a trough feeder and a gravity-fed waterer.

Figure 14. Chicks in the pen with gravity-fed feeders and waterers.

experimental diets for one week. Light and heat were provided 24 hours during brooding. The experimental diets were provided *ad libitum* in trough feeders whereas the water was provided *ad lib* through automatic nipple waterers. Chicks were vaccinated against smallpox on the third day of hatching. A coccidiostat was added to the diets and fed during the starter period.

The week-old chicks were wing banded, weighed individually, and the treatment group was divided and assigned randomly to two respective replicate groups. There were then 24 groups on 12 treatment diets. The chicks were weighed individually on the second, fourth, sixth, and eighth week of trial periods. Diets and water were in the pen during weighing the chicks, and pen feed consumption was recorded at weighing time.

During the second week of trial a portion of the roof of building No. 2 (Figure 11) was blown away. Therefore, the chicks housed in that building were shifted over to building No. 3 as illustrated in Figure 12. However, the rest of the chicks were maintained in the original pens. Trials involving boiling water treated rice mill feed (both replicates of ration 3A, 3B and 3C) were discontinued after a four-week period because the wet-heated material could not be sun dried due to heavy rainfall. However, the rest of the trials were continued to 8 weeks.

At the end of the feeding trial, six heaviest birds, three males and three females, from each pen (replicate)

were selected and sacrificed in a commercial slaughter house to determine the dressing percentage.

Statistical procedures

Six hundred day-old chicks were assigned to an experimental design of a randomized complete block with 12 treatments in a 4 × 10 factorial arrangement up to 4 week period. After 4 week period, three treatments involving boiling water treated rice mill feed were discontinued; therefore, the experimental design was a randomized complete block with nine treatments in a 3 × 3 factorial arrangement.

The method of analysis common to all the experiments was the Analysis of Variance (ANOVA) using the Statistical Package developed at M. S. U. for the CDC 6500 computer. Individual bird data were used for weights, average daily gains whereas the pen averages were used for the average daily feed consumption. Live weights, average daily gains, feed consumptions, feed conversions, and dressing percentages were the parameters used to evaluate the feeding trial. Bird days was used to calculate the feed-conversion ratio. Approximate Studentized range test using the average number in a treatment as the number in each treatment was used to test for statistically significant differences among the means. The least-square procedure as outlined by Harvey (1960) was used for weights and average daily gain since there were unequal numbers in the groups. The conventional ANOVA for equal numbers was used for average daily feed intakes, feed conversion and dressing percentages.

Swine Trial

Twenty cross-bred (Large White × Hampshire) × Large White pigs from two different litters were weaned at an age of six weeks. There was a difference of one day in age between the litter groups. Pigs were ear notched for the purpose of identification. They were obtained from the Central Farm Experimental Station herd. Males were castrated at an age of five weeks. All pigs were dewormed with a recommended dose of dichlorvox (Atgard)[a] one week before the trial started.

Pigs were assigned to two replicated treatment groups by complete randomization of litter, sex and weight. The pigs were fed treatment diets for four dats before data collection started.

The ten pigs in treatment group I were provided with dry ration in self-feeders whereas ten other pigs in treatment group II were provided with wet rations which had been treated with boiling water. The wet diets were fed in trough feeders. One automatic nipple waterer was permanently fixed in each pen to have access to the drinking water for the pigs.

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[a]Swine wormer: Diamond Shamrock Corp., Nutrition and Animal Health Division, 1100 Superior Avenue, Cleveland, Ohio 44114.

TABLE 14. ASSIGNMENT OF PIGS TO DIFFERENT TREATMENT GROUPS.

Item	Treatment I		Treatment II	
	Repl. 1	Repl. 2	Repl. 1	Repl. 2
No. of pigs	5	5	5	5
Initial pen average wt., kg	11.02	11.52	12.16	11.61
Initial treatment mean, kg	11.27		11.88	
Mean of the total experimental animals, kg	11.58			

Sources of ingredients and preparation of diets

The treatment diets consisted of rice mill feed, meat and bone meal, salt, vitamin premix and mineral premix. Rice mill feed was obtained from the Belize Big Falls Ranch rice mill. It was a mixture of rice bran, rice polishings, very small portion of broken rice and the unavoidable part of rice husks. The detailed analysis for nutrient contents of rice mill feed is given under subtitle "Chemical Characteristics of Rice By-Product" Tables 16 and 17. The rice mill feed not obtained from a single rice paddy variety but was from a mixture of several varieties. During the experiment period no rice mill feed was used which was older than three weeks. Meat and bone meal was obtained from the Belize Beef Corporation (BBC) and was also not stored longer than three weeks. The sources of mineral and vitamin premixes are given in Appendix A.

Preparation of dry ration

The composition of rations for treatment number I and II are as follows:

Figure 15. Homemade trough feeders for the swine.

TABLE 15. SWINE GROWER RATION COMPOSITION

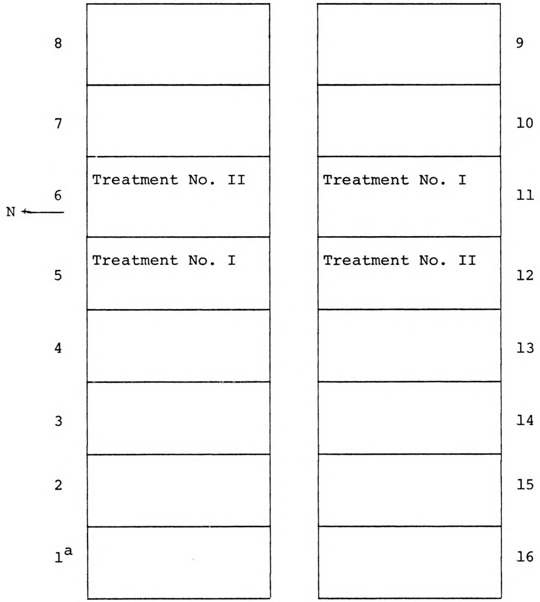
Ingredient	Treatment I	Treatment II	
Unheated rice mill feed, %	88.5	0.0	
Boiling water treated rice mill feed, %	0.0	88.5	
Meat and bone meal, %	10.0	10.0	
Salt, %	.5	.5	
Trace mineral premix[a]	.5	.5	
Vitamin premix[b]	.5	.5	
Calculated Nutrient Composition			**NRC, 1979 Requirement**
DE, kcal/kg	3,576.0	3,576.0	3,380.0
CP, %	15.95	15.95	16.0
Lysine, %	.74	.74	.7
Tryptophan, %	.14	.14	.12
Methionine + ystine, %	.36	.36	.45
Calcium, %	.85	.85	.6
Phosphorus, %	.97	.97	.5

[a]See Appendix A-2.

[b]See Appendix A-1.

The ration for treatment I was mixed once weekly. All the feed ingredients were weighed separately and were mixed in a horizontal mixer. Then the rations were collected in sacks till they are fed. Each feeder was stirred during the time of wet meal feeding to push the ration down so that the pigs would have continuous access to the diets throughout the day.

Figure 16. Swine house where the swine trials were conducted.



Pen size = 8 x 7 square feet.

[a]Pen number 1 to 16

FIGURE 17. EXPERIMENTAL DESIGN FOR SWINE TRIAL.

Preparation of wet ration and feeding

The required quantity of meat and bone meal, vitamin premix, mineral premix and salt to make a fixed amount of diet for pigs as wet ration was weighed and stored in bags. Seven such bags were prepared for seven days period once weekly. On the same day, the required quantity of rice mill feed for seven days meal was also weighed and stored separately. The diets were prepared on the basis of the body weight of pigs (NRC, 1979) and were provided to them as much as they consume. The required quantity of ingredients for wet diets were weighed on the same day as those of dry diets in order to avoid bias of deterioration of ingredients during storage period.

Each morning water was boiled in a vat and then added to rice mill feed by equal weight. This was followed with continuous stirring of the wet mixture which dropped after 20 minutes to about 67^{o}C. The wet mixture was then removed from that vat and spread on a polyethylene sheet to a thickness of approximately five centimeters. After one hour when the wet rice mill feed cooled, other ingredients were mixed. After thorough mixing the ration had a dough-like consistency.

Approximately one half of the wet ration was weighed and fed immediately after mixing and the other one half was fed in the afternoon. Thus the pigs were fed twice a day for the trial period of 42 days. However, the diet

Figure 18. Wet rice mill feed before mixing other ingredients.

Figure 19. Method of processing wet diet.

Figure 20. Pigs on wet diet.

consumption on the fifth or sixth day of the week was higher than the first or second day of the week and pigs on cool pleasant days consumed more diets than on very hot days. Therefore, at times when pigs required additional amount of diets, another batch of ration was prepared in the same manner as described above and fed more than twice a day. Since the leftover ration in the troughs after 24 hours developed a sour taste due to degradation of carbohydrate the pigs refused it. Therefore, the leftover diets were collected, weighed back and discarded. The moisture content of wet diets was determined immediately after mixing the ration after 6, 12 and 24 hours on the 14th, 28th and 42nd day of the trial period and on the basis of feed less weigh back of it, the pen average feed consumption was determined. After removing the leftover diets, the troughs were washed and the fresh diets were fed in the same order as described previously.

Attempts were made to keep diets constantly available to the pigs.

The pen feed consumption of the pigs on dry diet was recorded weekly at the time of weighing pigs.

Statistical design

The data of final weight, average daily weight gain average daily feed intake and feed to gain ratio were subjected to analysis of variance (ANOVA) as described by Gill

(1978). A 2 × 2 factorial design was performed for the feeding trial. Heat treatments and locations were used as the treatment factors.

RESULTS AND DISCUSSIONS

RESULTS

Chemical Characterization of Rice Mill Feed

The results of the chemical characterization of the rice-mill feed for dry matter, crude protein, ether extract, ash, neutral detergent fiber (NDF), acid detergent fiber (ADF), hemicellulose, cellulose, acid detergent lignin and gross energy determinations are shown in Table 16. They are calculated on as-fed basis. The dry-matter content ranged from 51.8% for fresh boiling water treated to 93.0% for solar heated rice mill feed. There was little difference in dry-matter content of freshly sampled boiling water treated rice mill feed and that, after 12 hours' storage (0.4%). Nevertheless, the difference in dry-matter content of dry heated and unheated rice mill feed was 1.10% and that of fresh wet heated and fresh dry heated samples was 32.1%. The crude-protein content of rice-mill feed was similar to that found by Lynn (1969) for bran containing both polishings and germ, and was not altered by heat treatment. This is in agreement with the report of Rao <u>et</u> <u>al</u>. (1974) for soybean protein. Slightly higher values of protein for dry-heated samples overall because of their higher dry-matter content. Ether-extract level was similar to that of rice bran from Formosa or boiled-rice brans from Burma, India or Japan and ash content was slightly higher than polishings and lower than pure bran as reported by Arnott et al. (1966). This is because the rice-mill feed obtained from the Big Falls Ranch mill was a mixture of bran, polishings containing germ, unseparable portions of broken rice and unavoidable proportions of husks. The neutral detergent fiber (NDF) and acid detergent fiber (ADF) were also lower than values reported by Maust et al. (1972). The NDF is a measure of total fiber and the ADF is a measure of lignocellulose. The main difference between NDF and ADF is hemicellulose which is thought to have a somewhat higher digestive value in chickens than cellulose (Scott et al., 1968). In previous studies which were conducted by Keys et al. (1969), it was found that hemicellulose was digested to a greater extent than cellulose in both the rat and the pig. Maust et al. (1972) found that 4.9% of the total protein in rice bran was bound in ADF and was largely unavailable to the nonruminants.

The gross energy levels of rice mill feed were slightly higher when expressed on dry-matter basis than the report on rice bran (Maust et al., 1973), which was 4.896 kilocalories per gram dry matter. The results of the mineral determinations, calculated on an as-fed basis, are given in Table 17. The total phosphorus content is quite similar to that reported by Arnott et al. (1966) and Corley et al. (1980). The silica content was lower than that

TABLE 16. PROXIMATE[a] ANALYSIS OF RICE MILL FEED

Sample	Dry Matter	Crude Protein	Ether Extract	Ash	Neutral Detergent Fiber	Acid Detergent Fiber	Hemi-cellulose	Cellulose	Acid Detergent Lignin			Gross Energy
	%	(N x 6.25) %	%	%	%	%	%	%	%			k cal/g
HHR	92.72	15.4	17.67	9.44	20.9	12.3	8.6	7.6	3.97			4.57
LHR	92.85	13.3	18.18	9.40	23.2	10.2	13	6.2	3.17			4.49
BWR, dried	91.65	14.1	16.14	9.72	27.9	15.9	12	6.6	4.86			4.41
SHR	93.02	14.0	18.38	9.39	43.0	16.8	26.2	10.2	5.25			4.65
UR, Fresh	91.75	12.9	16.18	9.28	25.9	12.3	13.6	7.8	3.63			4.22
UR, 45 days old	92.00	14.8	17.20	9.58	24.4	11.6	12.8	7.5	3.64			4.53
BWR, fresh	51.80	8.20	7.80	3.9	ND	ND	ND	ND	ND			ND
BWR, 12 hrs old	52.2	8.3	7.8	4.0	ND	ND	ND	ND	ND			ND
BWR, 24 hrs old	55.3	10.5	8.0	4.5	ND	ND	ND	ND	ND			ND

ND = not determined.

[a]Dry matter, crude protein, ether extract and ash determinations were done in the Agricultural Chemistry Laboratory of Central Farms Station, Belize. Neutral detergent fiber, acid detergent fiber, hemicellulose, cellulose, acid detergent lignin and gross energy were analyzed in the Animal Science Laboratory, M. S. U. Each value is the mean of duplicate determinations.

TABLE 17. MINERAL COMPOSITION OF RICE MILL FEED.

Sample designation	Mineral								
	Ca, %	P, %	K, %	Si,[a] %	Fe, mg/kg	Mg, %	Mn mg/kg	Na, %	Cu mg/kg	Zn mg/kg
HHR	.07	1.38	1.18	.12	258	.80	260	.088	11.96	53.06
LHR	.06	1.26	1.16	.12	247	.63	252	.086	10.20	42.56
BWR, dried	.07	1.08	1.12	.12	351	.70	264	.085	10.00	50.77
SHR	.08	1.44	1.24	.14	261	.65	274	.089	10.41	50.40
UR	.06	1.26	1.22	.13	221	.70	242	.082	11.60	48.86
NRC, 1979										
Rice bran	.07	1.50	1.73	NA	.019,%	.95	324	.07	13.0	30.0
Broken rice	.08	.39	0	NA	NA	.11	18	.07	NA	17.0
Polishings	.05	1.31	1.06	NA	.016,%	.65	NA	.10	NA	26.0

[a]Silica analysis was carried out in the Agricultural Chemistry Laboratory of Central Farms Station, Belize and the other analyses were conducted in the Animal Nutrition Laboratory, M. S. U.

NOTE: Figures are means of duplicate determinations.

NA = not available.

reported by Arnott *et al.* (1966). This is in agreement with the previous report that percentage of crude fiber content is positively correlated with silica. The remaining mineral concentrations are close to those of NRC (1979) values.

Amino acids

The results of the amino acid analyses from duplicate hydrolyses and chromatographic determinations expressed as percentage of total protein, calculated on the as fed basis are given in Table 18. There are some variations among the amino acid contents of different samples. The hydrolysis step is probably the major cause for variability in the chromatographic analytical procedure. The chromatographic method might also produce low values for certain amino acids by destruction during acid hydrolysis, by incomplete hydrolysis or by oxidation. (Canr, 1965; Kohler *et al.*, 1967). Serine and threonine have slightly lower values and are destroyed in moderate degrees by dry heat (100 to 105^{o}C) as was also pointed out by Houston *et al.* (1969). Valine was only released slowly during hydrolysis but was probably activated by heat treatment. Therefore, the values for valine are higher for heated samples than for unheated. Variations among the methionine, histidine and glutamic acid contents of different samples are in agreement with the previous findings for different rice varieties (Houston *et al.*, 1969). The results of

TABLE 18. DETERMINATION OF AMINO ACIDS[a] IN TREATED AND UNTREATED RICE MILL FEEDS.

Amino Acid	Belize Project Data[b] Treatment				Comparative Data Houston *et al.* (1969)
	HHR	BWR, dried	UR	Ave.	
Aspartic acid	9.32	8.57	9.31	9.07	9.05
Threonine	3.12	4.10	3.44	3.55	3.82
Serine	3.10	3.38	3.62	3.37	4.53
Glutamic acid	13.62	14.76	14.85	14.41	13.10
Proline	4.59	4.19	5.37	4.72	4.16
Glycine	4.52	4.06	4.88	4.49	5.57
Alamine	7.95	5.30	5.52	6.26	6.25
Valine	10.20(?)	9.21(?)	6.58	8.66	5.80
Cystine	2.78	3.38	4.09(?)	3.42	2.40
Methionine	2.48	3.44	2.30	2.74	2.04
Isoleucine	5.44	4.71	5.58	5.24	3.77
Leucine	8.07	8.45	7.23	7.92	6.56
Tyrosine	4.25	3.71	4.38	4.11	2.90
Phenylalamine	4.98	5.49	5.79	5.42	4.24
Lysine	4.34	4.56	4.92	4.61	5.06
Histidine	3.18	3.82	3.50	3.50	2.78
Arginine	8.06	8.87	8.64	8.53	7.98
Tryptophen	ND	ND	ND	ND	ND

[a]Amino acids were analyzed in the Animal Nutrition laboratory, M. S. U.

[b]Means of duplicate determinations, and expressed as percentage of protein. The protein content of high heated (HHR), boiling water treated (BWR) and unheated (UR) rice mill feed was 15%, 14.43% and 14.54%, respectively.

[c]Amino acids of laboratory-milled bran including polish, and presented as gram amino acid per 16 grams nitrogen.

Houston et al. (1969) for rice bran, polish and germs combined and determined for laboratory milled samples are given in Table 18 to compare with the present findings.

Since the rice mill feed is used in swine and poultry diets, the present results on essential amino acids for poultry are compared with recent literature values in Table 19. Houston et al. (1969) used bran, polishings and the embryo but Tamura et al. (1963) did not include the embryo in their samples. This would affect the results. Very low value of tyrosin, probably by oxidation during hydrolysis, was also observed in Tamura. Houston et al. (1969) found that the 24 hour reflux in 6N HCl used by Lyman et al. (1956; 1958) would result in losses of methionine and would not completely liberate valine and isoleucine. The low amino acid data of Laiń et al. (1965) are likely the results of refluxing with 6N HCl at 120°C under nitrogen for 22 to 24 hours. The high values for methionine and cystine may be due to limited oxidative destruction of these acids during hydrolysis. The value for methionine was close to that reported by Lynn et al. (1967). The averages of the present findings are close to the previous reports on rice by-products (Schweigert, 1947; 1948; Kik, 1956; Lyman et al., 1956; 1958; Tamura et al., 1963; Laiń et al., 1965; Combs et al., 1967; Houston et al., 1969).

TABLE 19. COMPARATIVE DATA ON RICE MILL FEED AND RICE BRANS FOR ESSENTIAL AMINO ACIDS FOR CHICKS.

Amino acid	Belize Project Data[a]				Lyman et al. (1956,1958)[b]	Tamura et al. (1963)[b]	Laiń et al. (1965)[b]	Combs et al. (1967)[b]	Houston et al. (1969)[c]
	HHR	BWR, dried	UR	Ave					
Lysine	4.34	4.56	4.92	4.61	5.34	3.83	4.11	4.61	5.06
Histidine	3.18	3.82	3.50	3.50	2.79	2.21	1.34	2.77	2.78
Arginine	8.06	8.87	8.64	8.53	8.53	5.86	5.85	8.46	7.98
Threonine	3.12	4.10	3.44	3.55	3.91	3.25	3.10	3.84	3.82
Glycine	4.52	4.06	4.88	4.49	ND	4.99	3.93	7.69	5.57
Tryptophan	ND	ND	ND	ND	1.91	ND	1.34	1.85	ND
Methionine	2.48	3.44	2.30	2.74	1.91	1.73	2.55	1.85	2.04
Cystine	2.78	3.38	4.09	3.42	ND	1.97	1.15	0.77	2.40
Valine	10.20	9.21	6.58	8.66	5.98	5.22	5.34	6.00	5.80
Isoleucine	2.78	3.38	4.09	3.42	4.38	3.45	4.70	4.38	3.77
Leucine	8.07	8.45	7.23	7.92	7.10	6.73	8.72	6.92	6.56
Phenylalanine	4.98	5.49	5.79	5.42	4.62	4.23	5.57	4.61	4.24
Tyrosine	4.24	3.71	4.38	4.11	3.48	2.04	4.73	6.15	2.90

[a]Amino acids were determined in the Animal Nutrition Laboratory, M. S. U.

[b]These data are on rice brans, and are presented as grams amino acid per 16 grams nitrogen.

[c]These data are on rice bran and polish, and are presented as grams amino acid per 16 grams nitrogen.

Free fatty acids

The results of heat treatments as compared to no treatment on the free fatty acids in oil from rice mill feed samples (expressed as oleic acid as a percent of total oil) are given in Table 20. The results of the analyses show that in untreated samples the free fatty acids rose from 2.4 to 36.6% whereas the sample which was heated at 85°C for 4 hours had only 4.5% after 32 days of storage. All the heat treatments were effective in slowing free fatty acid development during storage by inactivating the lipolytic enzymatic action. The boiling water treatment was less effective than the dry heat treatments.

The percentage free fatty acid content of the dry heated samples (85°C for 4 hours) was similar to that of Arnott *et al*. (1966) values when their samples were heated at 160°C for 15 minutes. However, their values for untreated bran ranged from 46.4 to 78% whereas the present studies show 34.6% for 32 days storage periods. These differences might have occurred due to difference in moisture content of the samples as well as humidity, because in the presence of moisture the glycerides of the rice oil hydrolyze to glycerol and a mixture of free fatty acids.

Rice by-product with high free fatty acids will be found to have an unpleasant taste associated with rancidity. In order to produce palatable rice mill feed which may be stored for some time it is obvious that the

TABLE 20. FREE FATTY ACID ANALYSIS[a] OF TREATED AND UNTREATED RICE MILL FEED.

Duration of Storage, days	Free fatty acids[b] (expressed as oleic acid as % of total oil)			
	Unheated	Heated at 85°C for 2 hrs	Heated at 85°C for 4 hrs	Boiling water treated (dried)
0	2.4	ND	ND	ND
1	3.3	ND	2.4	ND
2	3.6	ND	2.8	ND
4	6.8	4.8	3.0	ND
8	10.0	5.5	3.5	ND
16	13.0	6.9	4.4	8.6
32	34.6	13.0	4.5	14.8

[a]Analyses were done in the Agricultural Chemistry Laboratory of Central Farms Station, Belize.

[b]Each value is a mean of duplicate determinations.

ND = Not determined.

development of rancidity must be checked. This can be done by removing most of the oil by solvent extraction or by heat treatment. Parboiling might be an acceptable method in arresting free fatty acid and enhancing the feeding values in large-scale production systems.

In vitro trypsin inhibitor assay

Kakade *et al*. (1969) defined one trypsin unit (TU) as an increase of .01 absorbance units at 410 nm per 10 ml of total reactions mixture under the prescribed conditions. Trypsin inhibitor activity was defined as the number of trypsin units inhibited (TUI) under the same conditions.

The optical density readings obtained from the trypsin inhibition assays of the treated and untreated samples are given in Table 21. Trypsin units (TU), trypsin units inhibited (TUI), or trypsin inhibitory activity were extrapolated from optical density readings according to the derivations described by Kakade *et al*. (1969). All types of heat treatments denatured the trypsin inhibitors. Dry heating at 100 to 105^{o}C was as effective as that described by Horiguchi *et al*. (1971) in destroying the trypsin inhibitor. Boiling water treatment was effective in denaturing the trypsin inhibitor. This is different than the results found by Kratzer *et al*. (1977). This might be due to the fact that they soaked the bran for 40 minutes whereas in the present studies the material was

TABLE 21. TRYPSIN INHIBITOR ACTIVITY[a] IN TREATED AND RAW RICE MILL FEEDS.

Sample designation	Spectrophotometric absorbance[b]		
	Repl. I	Repl. II	Average
High heated (HHR), fresh	.83	.78	.80
HHR, 45 days old	.81	.75	.78
Low heated (LHR), fresh	.60	.58	.59
LHR, 45 days old	.56	.57	.56
Boiling water treated (BWR), fresh (dried)	.85	.83	.84
BWR, 45 days old (dried)	.83	.86	.84
Solar heated (SHR), fresh	.73	.71	.72
SHR, 45 days old	.66	.68	.67
Untreated (UR), fresh	.15	.24	.20
UR, 45 days old	.12	.14	.13
Blank	.90	.86	.88

[a]Analyses were conducted in Dr. D. Penner's Laboratory, Dept. of Crops and Soil Science, M. S. U.

[b]Absorbance at 520 nm (OD) and are the means of duplicate determinations.

TABLE 22. EXPRESSION OF TRYPSIN INHIBITOR ACTIVITY.

Sample Designation	Trypsin Units (TU)	Trypsin units Inhibited (TUI)/20 mg meal
HHR, fresh[a]	80	8
HHR, old[b]	78	10
LHR, fresh	59	29
LHR, old	56	32
BWR, fresh (dried)	84	4
BWR, old (dried)	84	4
SHR, fresh	72	16
SHR, old	67	21
UR, fresh	20	68
UR, old	13	75
Blank	88	

[a]See in Table 21.

[b]Forty-five days after milling.

soaked for 4 hours.

Feeding Trials

Poultry

The composition of the starter and the finisher diets for the broiler trials are presented in Tables 10 and 12. The feeding trials are evaluated on the basis of the parameters as stated in Methods.

The analyses of variances (ANOVA) for the overall performance of chicks on the feeding trials during different periods show that there was a very strong interaction ($P<0.001$) between the levels of rice mill feed and treatments as they affected weights and average daily gain for each period. Observations of the subcell means indicate the interaction is caused by the relationships that as the level of rice mill feed in the broiler diets increases the heat treatment becomes increasingly effective.

The results of the broiler trials for each feeding period and trait are presented in the following. Each mean is the average of daily basis.

Starter period with 4 treatments (0-4 weeks)

The 4-week weight of chicks on high heated rice mill feed 100% replacement of corn was higher ($P<0.05$) than that of chicks on other treatments for the same level of corn replacement diets as presented in Table 24. When the diets were devoid of corn the body weights were higher ($P<0.05$) for groups on treated rice mill feed diets (e. g.

TABLE 23. PATTERNS OF DIETS FOR BROILER TRIAL[a].

Levels of rice mill feed in replacements of corn	Treatments				
	1=HHR	2=LHR	3=BWR[b]	4=4R	Total cells for treatments
C=100, %	1C	2C	3C	4C	4
B=80, %	1B	2B	3B	4B	4
A=60, %	1A	2A	3A	4A	4
Total cells for levels	3	3	3	3	12

[a]See in methods section for details.

[b]The treatment within the dotted lines was discontinued after 4 weeks trial period.

1C, 2C and 3C) than those on untreated rice mill feed diets (4C). For instance, chicks on diet 1C, 2C and 3C were heavier by 48 grams, 39 grams and 56 grams than the chicks on diet 4C. When 80% of the corn was replaced by the boiling water treated rice mill feed the chicks were significantly heavier than the chicks on other treatments. The chicks on diet 2B were lighter than the chicks on other treatments, however, they consumed less amount of diet ($P<.05$) diets per gain than the chicks on untreated rice mill feed diets. When the higher levels of corn (80 or 100%) were replaced by heat treated rice mill feed, the chicks on treated rice mill feed diets required less ($P<.05$) amount of diet per unit of gain as compared to

TABLE 24. LEAST-SQUARE MEANS FOR EACH HEAT TREATMENT AND LEVEL SUB-GROUPS FOR 0-4 WEEK PERIOD.

Level		Trait[a]	Treatment				Average Overall Treatments
			1=HHR	2=LHR	3=BWR	4=UR	
100, %	(C)	Feed conversion, g diet/g gain	1.94^{Ac}	2.04^{Ac}	2.29^{Ac}	2.74^{Ab}	2.25^{B}
		Feed consumption, g/bird	42^{Ab}	38^{Ab}	45^{Ab}	48^{ABb}	43^{B}
		Weight gain, g	19^{Bbc}	19^{Abc}	20^{Ab}	18^{Ac}	19^{B}
		Four-week weight, g	585^{Bbc}	576^{Ac}	593^{Bb}	537^{Bd}	573^{B}
80, %	(B)	Feed conversion, g diet/g gain	1.86^{Ad}	2.34^{Ac}	2.03^{Bc}	2.93^{Ab}	2.29^{B}
		Feed consumption, g/bird	43^{Ac}	41^{Ac}	42^{Ac}	56^{Ab}	46^{B}
		Weight gain, g	19^{Bc}	17^{Cd}	21^{Ab}	19^{Ac}	19^{B}
		Four-week weight, g	570^{Bc}	531^{Bd}	627^{Ab}	577^{Ac}	576^{B}
60, %	(A)	Feed conversion, g diet/g gain	1.73^{Ac}	2.09^{Ab}	2.49^{Ab}	2.37^{Bb}	2.17^{B}
		Feed consumption, g/bird	36^{Ac}	37^{Abc}	43^{Ab}	46^{Bb}	40^{B}
		Weight gain, g	21^{Ab}	18^{BCcd}	17^{Bd}	19^{Ac}	19^{B}
		Four-week weight, g	621^{Ab}	546^{Bd}	525^{Cd}	575^{Ac}	567^{B}
Average overall levels							
		Feed conversion, g diet/g gain	1.84^{d}	2.16^{c}	2.27^{c}	2.68^{b}	
		Feed consumption, g/bird	40^{d}	39^{d}	43^{c}	50^{b}	
		Weight gain, g	20^{b}	18^{c}	19^{b}	18^{c}	
		Final weight, G	592^{b}	551^{c}	582^{b}	563^{c}	

[a]Error mean square for feed conversion, feed consumption, weight gain and final weight was 0.024, 4.99, 6.64, and 5209, respectively.

[b,c,d,e]Means in a line for the same trait bearing a superscript letter in common do not differ significantly at the $P<0.05$ level.

[A,B,C]Means in a column for the same trait bearing a superscript letter in common do not differ significantly at the $P<0.05$ level.

that on untreated rice mill feed diets. However, when 60% of the corn was replaced by the low heated or boiling water treated rice mill feed in the broiler diets, the chicks on treated diets tended to require less diets per unit of gain than the chicks on untreated diets, but there was no significant difference at the $P<.05$ probability level. This indicates that when the higher percentages of corn (80 to 100%) was replaced in the diets, the growth response of chicks to the heat treatment of rice mill feed becomes increasingly effective. When mean comparisons are made under the same treatment (Table 24) the chicks on diet 4A required significantly less ($P<.5$) diet per unit of gain than the chicks on 4B or 4C diets. There was no difference ($P<.05$) of feed required per unit of gain for the chicks on diets 1A, 1B and 1C. Similarly, the feed per unit of gain was the same ($P<.05$) for chicks on diets 2A, 2B and 2C. Chicks on diet 3B needed less diet than the other (3A or 3C), but there was no difference of the amount of diet needed per unit of gain for chicks on diets 3A and 3C.

A separate means comparisons were performed for 2 to 4 weeks period to determine whether there was an effect upon the traits of interest by a possible variation in the initial weight. The results of 2 to 4 weeks performance and the mean comparisons are presented in Table 25. Chicks on diets 1C, 2C and 3C needed less amount of diets per gain ($P<.05$) than the chicks on diets 4C. Chicks on

TABLE 25. LEAST-SQUARE MEANS FOR EACH HEAT TREATMENT AND LEVEL SUB-GROUPS FOR 2-4 WEEK PERIOD.

Level	Trait[a]	Treatment				Average Overall Treatments
		1=HHR	2=LHR	3=BWR	4=UR	
100, %	(C) Feed conversion, g diet/g gain	2.05^{Ac}	2.12^{Ac}	2.28^{Ac}	2.83^{Ab}	2.32^{B}
	Feed consumption, g/bird	51^{Ab}	52^{Ab}	60^{Ab}	65^{Bb}	57^{B}
	Weight gain, g	25^{Bb}	26^{Ab}	26^{Bb}	23^{Bb}	25^{C}
	Four-week weight, g	585^{Bb}	576^{Ab}	593^{Bb}	537^{Bc}	573^{B}
80, %	(B) Feed conversion, g diet/g gain	1.95^{Ad}	2.52^{Ac}	1.94^{Ad}	3.05^{Ab}	2.37^{B}
	Feed consumption, g/bird	48^{Ac}	56^{Ac}	56^{Ac}	78^{Ab}	60^{B}
	Weight gain, g	25^{Bc}	22^{Cd}	29^{Ab}	26^{Ac}	26^{B}
	Four-week weight, g	570^{Bc}	531^{Bd}	627^{Ab}	577^{Ac}	576^{B}
60, %	(A) Feed conversion, g diet/g gain	1.75^{Ac}	2.23^{Abc}	2.56^{Ab}	2.48^{Bb}	2.26^{B}
	Feed consumption, g/bird	50^{Ac}	51^{Abc}	59^{Abc}	61^{Bb}	56^{B}
	Weight gain, g	29^{Ab}	24^{Bc}	23^{Cc}	24^{Bc}	25^{C}
	Four-week weight, g	621^{Ab}	546^{Bcd}	525^{Cd}	575^{Ac}	567^{B}
Average overall levels						
	Feed conversion, g diet/g gain	1.92^{d}	2.29^{c}	2.26^{c}	2.79^{b}	
	Feed consumption, g/bird	50^{d}	54^{cd}	58^{c}	68^{b}	
	Weight gain, g	26^{b}	25^{bc}	26^{b}	24^{c}	
	Final weight, g	592^{b}	551	582^{b}	563^{c}	

[a] Error mean square for feed conversion, feed consumption, weight gain and final weight was 0.052, 19.97, 20.72 and 5209, respectively.

[b,c,d] Means in a line for the same trait bearing a superscript letter in common do not differ significantly at the $P<0.05$ level.

[A,B,C] Means in a column for the same trait bearing a superscript letter in common do not differ significantly at the $P<0.05$ level.

diet 1B and 3B needed less (P<.05) diet per gain than the other. Chicks on diets 2B needed less diets per gain than the chicks on diet 4B. However, there was no significant difference between the amount of diets required per unit of gain for the chicks on diets 1A and 2A.

Grower period (0-6 weeks)

The chicks on heated rice mill feed diets except the chicks on 60% low heated rice mill feed diet were more efficient in feed conversion (P<.05) than the chicks on raw rice mill feed diets as shown in Table 26. The treatment effects were significant when corn was completely replaced by the rice mill feed in the diets. When 100% of the corn was replaced in the experimental diets by rice mill feed, chicks on heated rice mill feed diets were significantly heavier (P<.05), gained more (P<.05) and required less feed per unit of gain (P<.05) as compared to that of the chicks on raw rice mill feed diets. Chicks on diet 2C (low heated rice mill feed diet with 100% replacement of corn) were heavier (P<.05), gained more (P<.05) and were more efficient (P<.05) in feed conversion than the chicks on 4C (unheated rice mill feed diet with 100% replacement corn). The bird performance response to heated rice mill was not as great when levels of rice mill feed in the diet was lower.

The mean comparisions of the average overall levels show that chicks on high heat treated rice mill

TABLE 26. LEAST SQUARE MEANS FOR EACH HEAT TREATMENT AND LEVEL SUB-GROUPS FOR 0-6 WEEK PERIOD.

Level		Trait[a]	Treatment 1=HHR	Treatment 2=LHR	Treatment 4=UR	Average Overall Treatments
100, %	(C)	Feed conversion, g diet/g gain	2.30^{Ac}	2.50^{Ac}	3.33^{Ab}	2.71^{B}
		Feed consumption, g/bird	63^{Ac}	64^{Ac}	75^{Bb}	67^{C}
		Weight gain, g	28^{Bb}	26^{Ac}	23^{Cd}	26^{D}
		Six week weight, g	1199^{Bb}	1130^{Bc}	1008^{Cd}	1112^{C}
80, %	(B)	Feed conversion, g diet/g gain	2.17^{Ac}	2.48^{Ac}	3.10^{Ab}	2.58^{B}
		Feed consumption, g/bird	62^{Ac}	68^{Ab}	80^{Ab}	70^{C}
		Weight gain, g	28^{Bb}	27^{Abc}	26^{Bc}	27^{C}
		Six week weight, g	1239^{ABb}	1197^{Abc}	1142^{Bc}	1193^{B}
60, %	(A)	Feed conversion, g diet/g gain	2.14^{Ac}	2.56^{Abc}	2.61^{Bb}	2.43^{B}
		Feed consumption, g/bird	63^{Ac}	67^{Ac}	72^{Cb}	68^{B}
		Weight gain, g	30^{Ab}	26^{Ad}	28^{Ac}	28^{B}
		Six week weight, g	1282^{Ab}	1142^{Bd}	1199^{Ac}	1208^{B}
Average overall levels						
		Feed conversion, g diet/g gain	2.20^{d}	2.51^{c}	3.01^{b}	
		Feed consumption, g/bird	63^{d}	66^{c}	76^{b}	
		Weight gain, g	29^{b}	26^{c}	26^{c}	
		Six week weight, g	1240^{b}	1156^{c}	1116^{d}	

[a] Error mean square for feed conversion, feed consumption, weight gain and final weight was .042, 7.76, 10.68 and 18839, respectively.

[b,c,d] Means in a line for the same trait bearing a superscript letter in common do not differ significantly at the $P<.05$ level.

[A,B,C,D] Means in a column for the same trait bearing a superscript letter in common do not differ significantly at the $P<.05$ level.

feed diets were heavier ($P<.05$), by 124 grams gained more ($P<.05$) and were more efficient ($P<.05$) in feed conversion than the chicks on raw rice mill feed diets. Chicks on low heat treated rice mill feed diets were heavier ($P<.05$) and required less feed ($P<.05$) than the chicks on diets which were incorporated with untreated rice mill feed. As expected, the mean comparison on the average overall treatments indicate that the chicks on diets containing lower percentages of rice mill feed (60 or 80%) were heavier and gained more ($P<.05$) than the chicks on diets which was without corn. However, there was no significant ($P<.05$) difference for the amount of feed required per unit of gain.

Finisher period (6-8 weeks)

The results of the performance of chicks from 6 to 8 weeks period are given in Table 27. Chicks on diets 1A, 1B and 1C were heavier ($P<.05$) and gained more ($P<.05$) than the chicks on diets 4A, 4B and 4C[a]. Chicks on diet 1C needed less ($P<.05$) feed per unit of gain as compared to that of the chicks on diet 4C. Chicks on diet 2B were heavier ($P<.05$) and gained more ($P<.05$) than the chicks on diet 4B. There was no difference among the means of

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[a]Although diets 3A, 3B and 3C were not used in the finisher phase, the diet numbers 4A, 4B and 4C are as they were defined in the methodology.

TABLE 27. LEAST SQUARE MEANS FOR EACH HEAT TREATMENT AND LEVEL SUB-GROUPS FOR 6-8 WEEK PERIOD.

Level	Trait[a]	Treatment			Average Overall Treatments
		1=HHR	2=LHR	4=UR	
100, % (C)	Feed conversion, g diet/g gain	2.93^{Ac}	3.24^{Bbc}	3.59^{Ab}	3.25^{B}
	Feed consumption, g/bird	146^{Ab}	135^{Ab}	137^{Ab}	139^{B}
	Weight gain, g	51^{Ab}	45^{Cc}	40^{Bd}	45^{B}
	Eight week weight, g	1907^{Bb}	1755^{Bc}	1711^{Bc}	1791^{C}
80, % (B)	Feed conversion, g diet/g gain	2.94^{Ab}	2.61^{Ab}	3.20^{Ab}	2.91^{B}
	Feed consumption, g/bird	146^{Ab}	139^{Ab}	147^{Ab}	144^{B}
	Weight gain, g	50^{Ac}	54^{Ab}	46^{Ad}	50^{B}
	Eight week weight, g	1942^{Ab}	1948^{Ab}	1794^{ABc}	1895^{B}
60, % (A)	Feed conversion, g diet/g gain	2.88^{Ab}	2.94^{Ab}	2.89^{Bb}	2.9^{B}
	Feed consumption, g/bird	141^{Ab}	141^{Ab}	137^{Ab}	140^{B}
	Weight gain, g	50^{Ab}	48^{Bb}	47^{Ab}	48^{B}
	Eight week weight, g	1987^{Ab}	1814^{Bc}	1857^{Ac}	1886^{B}
Average overall levels					
	Feed conversion, g diet/g gain	2.92^{c}	2.93^{c}	3.23^{c}	
	Feed consumption, g/bird	145^{a}	138^{a}	140^{a}	
	Weight gain, g	50^{a}	49^{a}	44^{b}	
	Eight week weight, g	1945^{b}	1839^{c}	1787^{d}	

[a]Error mean square for feed conversion, feed consumption, weight gain and eight week weight was .079, 56.69, 68.86 and 2877, respectively.

[b,c,d]Means in a line for the same trait bearing a superscript letter in common do not differ significantly at the $P<.05$ level.

[A,B,C]Means in a column for the same trait bearing a superscript letter in common do not differ significantly at the $P<.05$ level.

the feed required per unit of gain of the chicks on diets 1A, 1B and 1C but chicks on 4A needed significantly less units of diets per unit of gain than the chicks on either 4B or 4C.

When the average levels means were tested, the chicks on high heated rice mill feed diets were heavier ($P<.05$) and gained more ($P<.05$) than the chicks on untreated rice mill feed diets. When the average overall treatments means were tested, chicks on diets which were devoid of corn were lighter ($P<.05$) than the chicks on 60% or 80% replacement of corn. However, there was no significant differences ($P<.05$) when other traits means (feed conversion, feed consumption and weight gain) were tested.

Overall treatment period (0-8 weeks)

The least square means for each heat treatment and level sub-groups for 8 weeks period which consisted of two different dietary periods are given in Table 28. The average overall levels and treatments means and their comparisons are also presented in the same table. As expected, chicks on diets 1A, 1B and 1C, except feed per gain ratio in diet 4B performed significantly ($P<.05$) better in each parameter, (body weight, average daily gain and feed per unit gain) tested as compared to chicks on diets 4A, 4B and 4C. The average daily feed consumption

TABLE 28. LEAST SQUARE MEANS FOR EACH HEAT TREATMENT AND LEVEL SUB-GROUPS FOR 8 WEEK PERIOD.

Level	Trait[a]	Treatment 1=HHR	2-LHR	4=UR	Average Overall Treatments
100, % (C)	Feed conversion, g diet/g gain	3.18^{Ac}	3.36^{Abc}	3.59^{Ab}	3.38^{B}
	Feed consumption, g/bird	104^{Ab}	99^{Ab}	106^{Ab}	103^{B}
	Weight gain, g	33^{Bb}	31^{Bc}	30^{Bd}	31^{C}
	Final weight, g	1907^{Db}	1755^{Bc}	1711^{Bc}	1791^{C}
80, % (B)	Feed conversion, g diet/g gain	3.07^{Ac}	3.05^{ABc}	3.67^{Ab}	3.26^{BC}
	Feed consumption, g/bird	104^{Ac}	104^{Ac}	113^{Ab}	107^{B}
	Weight gain, g	34^{ABb}	34^{Ab}	31^{Ac}	33^{B}
	Final weight, g	1942^{ABb}	1948^{Ab}	1794^{Ac}	1895^{B}
60, % (A)	Feed conversion, g diet/g gain	2.96^{Ac}	3.29^{ABb}	3.20^{Bbc}	3.15^{C}
	Feed consumption, g/bird	102^{Ab}	104^{Ab}	105^{Ab}	104^{B}
	Weight gain, g	35^{Ab}	32^{Bc}	32^{Ac}	33^{B}
	Final weight, g	1987^{Ab}	1814^{Bc}	1857^{Ac}	1886^{B}
Average overall levels					
	Feed conversion, g diet/g gain	3.07^{d}	3.24^{c}	3.49^{b}	
	Feed consumption, g/bird	104^{bc}	102^{c}	108^{b}	
	Weight gain, g	34^{b}	32^{c}	31^{d}	
	Final weight, g	1945^{b}	1839^{c}	1788^{d}	

[a] Error mean square for feed conversion, feed consumption, weight gain and final weight was .016, 12.14, 9.18 and 28776, trespectively.

[b,c,d] Means in a line for the same trait bearing a superscript letter in common do not differ significantly at the P<.05 level.

[A,B,C] Means in a column for the same trait bearing a superscript letter in common do not differ significantly at the P<.05 level.

was not different significantly except that chicks which were on diets 4B consumed significantly more ($P<.05$) diets than the chicks either on diet 1B or 2B. Chicks on diets 2B and 2C gained significantly more ($P<.05$) than chicks on diets 4B and 4C, respectively. Chicks on diet 2B were more efficient in diet conversion ($P<.05$) than the chicks on diet 4B.

When the means are compared for the average overall levels, chicks on treatment HHR were heaviest, gained most, consumed same amount of diets and needed least amount of diets per unit of gain ($P<.05$) as compared to either chicks on LHR or chicks on UR treatments. For instance, chicks on HHR diets were heavier by 157 grams than the chicks on UR diets. However, chicks on treatment LHR were heavier, gained more, consumed less diet and needed less amount of diet per unit of gain ($P<.05$) than the chicks on treatment UR. Chicks on LHR diets were also heavier by 51 grams than the chicks on UR diets. This overall results ascertains the findings of Kratzer et al. (1974) that the dry heat treatment is effective in enhancing the feeding value of rice by-products.

Chicks on diets which were devoid of corn were significantly lighter, gained less, consumed same amount of diets and were less efficient in feed conversion as compared to 80% replacement of corn in the diets. This is in agreement to the previous findings as described in the results of 0 to 4 weeks trial period.

Effects of heat treatments upon the dressing percentages of chickens

Chicks on diet 1C were heavier ($P<.05$) and had higher dressed weight ($P<.05$) and had higher dressing percentage ($P<.05$) than the chicks on diets 2C or 4C. The live weight and dressed weight of chicks on diets 1B, 2B and 4B were not different ($P<.05$). Chicks on diet 2A were lighter than the chicks on diets on 1A or 4A, however, there was no significant different ($P<.05$) among the dressing percentages.

When average overall levels means were tested, chicks on treatment HHR were heavier ($P<.05$) and had higher dressed weight than the chicks either on treatment LHR or UR, but there was no significant difference among the dressing percentages. When overall treatments means were tested, chicks on diets having no corn were higher and had less dressed weight than the chicks on diets having 40% or 20% corn. Nevertheless, there was no significant difference among the dressing percentages.

Swine

The composition of treatment diets fed in swine experiments are presented in Table 15. The raw data of the results of the feeding trials are given in Appendix C. The results of the analysis of variance (ANOVA) for final body weight, average daily gain, average daily feed

TABLE 29. LEAST SQUARE MEANS FOR EACH HEAT TREATMENT AND LEVEL SUB-GROUPS FOR 8 WEEK WEIGHTS, DRESSING WEIGHTS AND DRESSING PERCENTAGES OF SAMPLED BIRDS.

Level	Trait[a]	Treatment			Average Overall Treatments
		1=HHR	2=LHR	3=UR	
100, % (C)	Eight week weight, g	1998^{Ab}	1783^{Bc}	1753^{Bc}	1845^{C}
	Dressed weight, g	1421^{Ab}	1242^{Bc}	1212^{Bc}	1292^{C}
	Dressing percentage	71.30^{Ab}	69.67^{Ac}	69.17^{Ac}	70.05^{B}
80, % (B)	Eight week weight, g	1926^{Ab}	1968^{Ab}	1887^{Ab}	1927^{B}
	Dressed weight, g	1362^{Ab}	1352^{Ab}	1328^{Ab}	1348^{B}
	Dressing percentage	71.07^{Ab}	68.74^{Ac}	70.47^{Ab}	70.1^{B}
60, % (A)	Eight week weight, g	2026^{Ab}	1806^{Bc}	1970^{Ab}	1934^{B}
	Dressed weight, g	1400^{Ab}	1245^{Bc}	1367^{Ab}	1337^{B}
	Dressing percentage	69.06^{Ab}	69.03^{Ab}	69.40^{Ab}	69.16^{B}
Average overall levels					
	Eight week weight, g	1984^{b}	1852^{c}	1870^{c}	
	Dressed weight, g	1394^{b}	1280^{c}	1302^{c}	
	Dressing percentage	70.48^{b}	69.14^{b}	69.68^{b}	

[a]Error mean square for eight week weight, dressed weight and dressing percentage was 24644, 11324 and 12.080, respectively.

[b,c]Means in a line for the same trait bearing a superscript letter in common do not differ significantly at the P<.05 level.

[A,B,C]Means in a column for the same trait bearing a superscript letter in common do not differ significantly at the P<.05 level.

consumption and the feed required per unit of gain are presented in Tables 31, 32, 33, and 34, respectively.

The final weights and average daily gains of pigs on wet heated rice mill feed diet were significantly higher at P<.01 for final weight and P<.001 for gain than those of pigs fed diets containing raw rice mill feed. There was no significant difference between the replicates[a], and interaction between treatments and replicates for both traits as mentioned before. Average daily feed intake tended to be slightly higher among the pigs on wet diets than on dry diets.

TABLE 30. OVERALL RESULTS OF THE SWINE TRIALS.

Item	Treatment	
	Dry feed	Wet feed
Number of animals	10	10
Initial average body weight, kg	11.27	11.88
Duration of trial, weeks	6	6
Performance		
Final average body weight, kg	21.95	28.85
Average daily gain, g	254	404
Average daily feed intake, g	937	1030
Feed conversion, F/G	3.76	2.55
Kilogram of feed consumed/ 100 kg body weight	4.27	3.57

[a]Replicates were used as location factor as illustrated in Figures 16 and 17.

TABLE 31. ANALYSIS OF VARIANCE OF FINAL WEIGHT.

Sources of Variation	d.f.	SS	MS	F	P<
Treatments (A)	1	238	238	8.18	.01084[a]
Replications (B)	1	14.9	14.9	.51	
A x B	1	21.8	21.8	.71	
Residual	16	490	30.9		

[a]Significantly different at P<.01.

TABLE 32. ANALYSIS OF VARIANCE OF AVERAGE DAILY GAIN.

Sources of Variation	d.f.	SS	MS	F	P<
Treatments (A)	1	.112	.112	18.76	.00045[a]
Replications (B)	1	.009	.009	1.45	.245
A x B	1	.007	.007	1.16	.296
Residual	16	.101	.006		

[a]Significantly different at P<.001.

TABLE 33. ANALYSIS OF VARIANCE OF AVERAGE DAILY FEED INTAKE.

Sources of Variation	d.f.	SS	MS	F	P<
Treatments	1	.00865	.00865	9.75	.0888
Error	2	.00177	.000884		
Total	3				

TABLE 34. ANALYSIS OF VARIANCE OF FEED CONVERSION, F:G.

Sources of Variation	d.f.	ss	MS	F	P<
Treatments	1	1.48	1.48	6.62	.1236
Error	2	.446	.223		
Total	3	1.92			

The units of feed required per unit of gain for the untreated group was 3.76 and for the treated group was 2.55. However, the samples were not large enough to show statistical difference in feed conversion at the P<.05 level of probability.

The treatments and the time relationship on the performance of pigs fed on different treatment diets is illustrated in Figure 21. The overall performances of pigs are presented in Table 30.

Based on the overall performance of the pigs on wet diet and dry diet, it is observed that pigs on wet feed gained more and had lower average feed requirements per gain than the pigs on dry diets.

The factors which enhanced the feeding value of rice mill feed to the swine are that the boiling water treatment slowed down the development of free fatty acid and reduced the trypsin inhibitor action. The slowing down of the free fatty acid development in the wet heated rice mill feed is in agreement with the findings of Kratzer _et_ _al_. (1977), however, the reduction of trypsin inhibitor action observed

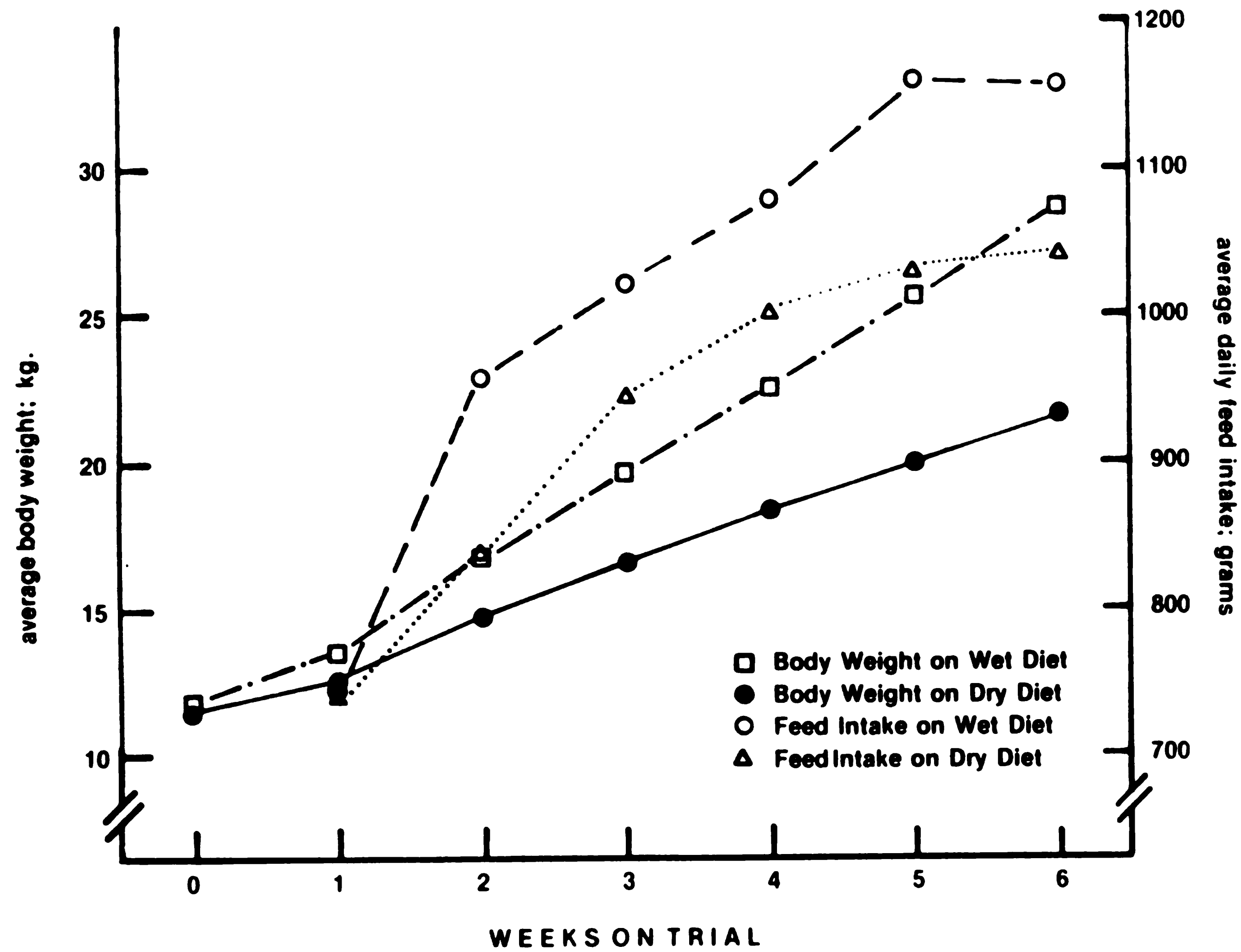

FIG. 21. A COMPARATIVE PERFORMANCE OF SWINE ON TWO DIFFERENT TYPE OF DIETS

in this experiment is in the contrary of their results. This is due to the fact that they soaked the material for shorter time as compared to the present studies.

Economic Analyses of the Feeding Experiments

The purpose of this analysis is to examine the impact which a Process can have upon the production costs by allowing the inclusion of greater quantities of a lower cost feedstuff to a ration system. In a country in which most commodity prices are floating, it must choose the price regime from among the available commodity alternatives. When the prices of ingredients are perfectly flexible, it becomes more difficult to get the cost-profit phenomenon for long term. However, assuming the price of each ingredient is constant in a given time, the economic analyses of the feeding trials are performed.

An overhead cost of $7.72 per 100 kilograms is included for each kind of mixed diet used in the feeding experiments, regardless of the type of diets used either in broiler or in swine trials. An approximate cost of $2.50 per 100 kilograms ($2.25 as labor cost, and $0.25 as machinery depreciation cost) is included for each type of heat treated rice mill feed ingredient. The cost of each individual ingredient, mixed diets for broiler and swine, and the cost per kilogram of gain by broiler as well as swine are illustrated in Tables 35 through 42.

TABLE 35. PRICES OF THE INGREDIENTS USED IN POULTRY AND SWINE DIETS.

Ingredient	Price/kg[a] (Belize cents)
Meat and bone meal	66.14
Soybean meal	83.77
Molasses	11.02
Corn	48.06
Untreated rice mill feed	26.46
Treated rice mill feed[b]	28.96
Vitamin premix	136.68
Trace-mineral premix	85.98
Salt	30.86
Amprolium	110.23
DL-Methionine (98%)	727.52

[a]Prices are as of May 1, 1980.

[b]The price of treated rice mill feed is raised by $2.50 per 100 kg ($2.25 as labor cost, and $0.25 as depreciation cost) regardless of the type of treatment done.

TABLE 36. PRICES OF INGREDIENTS AND MIXED DIETS FOR BROILERS

Item	Total price of ingredients/kg diet (cents)	Price of mixed diets[a]/kg (cents)
Type of diet for starter period		
1C or 2C or 3C	43.56	43.64
1B or 2B or 3B	46.52	46.60
1A or 2A or 3A	49.42	49.50
4C	41.96	42.04
4B	45.26	45.34
4A	48.48	48.56
Type of diet for finisher period		
1C or 2C	37.72	37.80
1B or 2B	39.07	39.15
1A or 2A	44.35	44.43
4C	35.86	35.94
4B	37.61	37.69
4A	43.26	43.34

[a]Cost of mixed diet includes $7.72/100 kg as overhead.

All prices are in Belizean currency, i. e., U. S. $1.00 = Belize $2.00.

TABLE 37. ECONOMIC ANALYSIS OF BROILER TRIAL (0-4 WEEKS)

Type of diet	F/G[a]	Cost/kg gain (Cents)
1C (HHR, 100%)	1.94	84.66
1B (HHR, 80%)	1.86	86.67
1A (HHR, 60%)	1.73	85.64
Mean		85.66
2C (LHR, 100%)	2.04	89.02
2B (LHR, 80%)	2.34	109.04
2A (LHR, 60%)	2.09	103.46
Mean		100.51
3C (BWR, 100%)	2.29	99.94
3B (BWR, 80%)	2.03	94.60
3A (BWR, 60%)	2.49	123.26
Mean		105.93
4C (UR, 100%)	2.74	115.19
4B (UR, 80%)	2.93	132.85
4A (UR, 60%)	2.37	115.09
Mean		121.04

[a]Kilograms of feed required per kg live-weight gain.

TABLE 38. ECONOMIC ANALYSIS OF BROILER TRIALS (0-6 WEEKS)

Type of Diet	F/G[a]	Cost/kg gain (Cents)
1C (HHR, 100%)	2.30	100.37
1B (HHR, 80%)	2.17	101.12
1A (HHR, 60%)	2.14	105.93
Mean		102.93
2C (LHR, 100%)	2.50	109.10
2B (LHR, 80%)	2.48	115.57
2A (LHR, 60%)	2.56	126.72
Mean		117.13
4C (UR, 100%)	3.33	139.99
4B (UR, 80%)	3.10	140.55
4A (UR, 60%)	2.61	126.74
Mean		135.76

[a]Kilogram of feed per kg gain.

TABLE 39. ECONOMIC ANALYSIS OF BROILER TRIAL (6-8 WEEKS)

Type of Diet	F/G[a]	Cost/kg gain (Cents)
1C (HHR, 100%)	2.93	110.75
1B (HHR, 80%)	2.94	115.10
1A (HHR, 60%)	2.88	127.96
Mean		117.94
2C (LHR, 100%)	3.24	122.47
2B (LHR, 80%)	2.61	102.18
2A (LHR, 60%)	2.94	130.62
Mean		118.42
4C (UR, 100%)	3.59	129.02
4B (UR, 80%)	3.20	120.61
4A (UR, 60%)	2.89	125.25
Mean		124.96

[a]Kilogram of feed per kg gain.

TABLE 40. OVERALL ECONOMIC ANALYSIS OF BROILER TRIALS (0-8 WEEKS) FOR THE ENTIRE PRODUCTION PERIOD

Type of Diet	F/G[a]	Cost/kg gain[b] (Cents)
1C (HHR, 100%)	3.18	105.56
1B (HHR, 80%)	3.07	108.11
1A (HHR, 60%)	2.96	116.94
Mean		110.20
2C (LHR, 100%)	3.36	115.78
2B (LHR, 80%)	3.05	108.88
2A (LHR, 60%)	3.29	128.67
Mean		117.78
4C (UR, 100%)	3.59	134.50
4B (UR, 80%)	3.67	139.44
4A (UR, 60%)	3.20	132.72
Mean		135.55

[a]Kilogram of feed per kg gain.

[b]Cost per kg gain for the entire period is the weighted mean of the costs per kg gain for grower and finisher periods.

TABLE 41. PRICES OF INGREDIENTS AND MIXED DIETS FOR SWINE

Type of Diet	Total price of ingredients/kg diet (cents)	Price of mixed diets/kg[a] (cents)
Wet diet	33.50	33.58
Dry diet	31.29	31.37

[a]See Table 35.

TABLE 42. OVERALL ECONOMIC ANALYSIS OF SWINE TRIAL (0-6 WEEKS)

Type of Diet		Cost/kg gain (Cents)
Wet diet	2.55	85.63
Dry diet	3.76	117.95

Poultry

Prices are the dynamic factors in animal industries, therefore, the current analyses are done based on the commodity prices as of May 1, 1980, in Belize.

The gross income comparisons are made through productivity comparisons by comparing the cost per kilogram of gain by the broiler chicks in each treatment for different trial periods.

The costs of corn ingredients are $48.06, treated rice mill feed $29.96, and untreated rice mill feed $26.46 per 100 kilograms, respectively (Table 35), which directly affect the economy of the feeding experiments because of the fact that each of these ingredients are basically incorporated in the diets to supply the same nutrient energy. For instance, the cost of 100 kilograms of untreated rice mill feed diets for the starter period at 40%, 20%, and 0% inclusion of corn is $48.56, $45.34, and $42.02, respectively, and that of treated diets at the same percentile basis is $49.50, $46.60, and $43.64, respectively. Hence, there is a difference of more than $6.00 per 100 kg between the rations containing all rice mill feed and that containing 40% of corn (Table 36).

The average overall cost of one kilogram of gain by the broilers on high heat treatment, low heat treatment, boiling water treatment, and no heat treatment is 85.66¢, 100.51¢, 105.93¢, and 121.04¢ during 0 to 4 weeks feeding period, respectively (Table 37). During the full starter period (0 to 6 weeks), the cost per kilogram gain was 102.47¢, 117.13¢, and 135.76¢ for high heated, low heated, and no heated treatments, respectively (Table 38). The cost per kilogram of gain during the finishing period (6 to 8 weeks) by the chicks on high heated, low heated, and unheated rice mill feed diets was 117.94¢, 118.42¢, and 124.96¢, respectively. The difference of costs per between the high and low heated was 33.29¢ per kg gain during 0-6 weeks period, but that was only 7.02¢ per kg gain during the finishing period. Thus, it is obvious that the cost of gain between the two treatments slopes off as the birds became older because of the fact that they started depositing adipose fat rather than depositing muscle. However, the difference of cost of gain as compared between the treated groups and untreated groups was noticeably lower among treated groups than the cost of gain on untreated rice mill feed diets (Table 39).

When the average overall economic analysis of the broiler trials was performed (0 to 8 weeks), the cost per kilogram gain for high heated, low heated, and unheated rice mill feed diet groups was 110.20¢, 117.78¢, and 135.55¢, respectively (Table 40).

When 100% of the corn was replaced by high heated rice mill feed, the cost per kilogram gain was the lowest (110.20¢/kg gain). Similarly, when 100% of the corn was replaced by low heated rice mill feed, the cost per kilogram gain was lower than when only 60% of the corn was replaced by low heated treated rice mill feed. However, when 100% of the corn was replaced by untreated rice mill feed, the cost per kilogram was higher, indicating that when 100% of corn was replaced by untreated rice mill feed, the chicks utilized diets less efficiently. For instance, the cost of one kilogram gain for HHR was 110.2¢, for LHR was 117.78¢, and per UR was 135.55¢. Thus, when economically evaluated, the heat treatment of rice mill feed was effective to lower the cost of gain, thereby allowing a wider margin of profit.

Swine

The prices of each ingredient are given in Table 35, and the cumulative price of each ingredient to make a kilogram of diet and price of mixed diet per kilogram are presented in Table 41. The cost of treated and untreated rice mill feed diets for the swine is $33.58 and $31.37 per 100 kilograms, respectively, because of the fact that $2.50 per 100 kilograms of treated rice mill feed is added to the market price of it as a labor and machinery cost.

When an average overall economic analysis of swine trial was performed, it was found that the cost per kilogram of gain by the pigs on treated and untreated rice mill feed diets was 85.63¢ and 117.95¢, respectively (Table 42). Thus, it is obvious that the heat treatment enhanced the feeding value of rice mill feed so that the

amount of diet per unit of gain was less in heat treated rice mill feed diet groups than the untreated rice mill feed diet groups.

DISCUSSION

Chemical characterization of rice mill feed

The chemical characterization of rice mill feed as illustrated in the results section revealed that the material used in the current studies had higher protein and fat content than that of rice bran as reported by Arnott *et al.* (1966) for Malayan rice bran and Kratzer *et al.* (1974) used in their experiments. This is due to the fact that the rice mill feed used for the current studies was a mixture of rice bran, rice polishings and a small fraction of rice pollards. The crude protein, fat and gross energy content of the raw rice mill feed was 12.9%, 16.18% and 4.22 kilocalories per gram, respectively. The amino acid content of various types of treated and untreated rice mill feed was comparable to that of reported by Houston *et al.* (1969), Houston and Kohler (1970). Dry heat treatment up to 105°C did not affect the amino acid contents of the material. This is in agreement with the report by Rao *et al.* (1974) that roasting at 120°C did not affect the amino acid content of dehulled soybean.

The free fatty acid for the wet heated, unheated and dry heated at 85°C for 2 and 4 hours were determined and the results are presented in the results section. All types of heat treatments were effective in arresting the rise in free fatty acids during the storage period. Heat treatment of the rice mill feed at 85°C for 4 hours was more effective than the other. This is in agreement with the result reported by Arnott et al. (1966) that when the rice bran was heated at 160°C for 15 minutes the free fatty acid was 6.9% as compared to that of untreated material which had 36.6% after 32 days of treatment. In the present studies, the free fatty acid for untreated, dry heated at 85°C for 2 hours, at 85°C for 4 hours and boiling water treatment after 32 days of storage duration was 34.6%, 13%, 4.5% and 14.8%, respectively.

The free fatty acid for the wet heated samples were not determined for the first few days storage intervals because that samples had to be dried and ground before extracting enough oil for the analysis. There was some mechanical problem with the Soxhlet apparatus also, however, the analyses were carried out at the 16th and 32nd day of storage after fixing the apparatus.

The results of the in vitro trypsin inhibitor assay indicate that all types of heat treatments affected the trypsin inhibitor in rice mill feed. The trypsin units (TI) for blank were 88. The mean TI for high heated (100 to 105°C), low heated (85 to 90°C), wet heated (boiling water treated), solar heated and unheated rice mill feed for the freshly prepared samples were 80, 59, 84, 72 and 20 per 20 miligrams of samples, respectively. Thus, the mean trypsin units inhibited (TUI) for the high heated, low heated,

boiling water treated, solar heated and unheated samples were 8, 29, 4, 16 and 68 per 20 miligrams of sample, respectively. The results are in agreement with the results reported by Tashiro _et al_. (1978). It was reported that the TI extracted from rice bran was heat labile and was completely inactivated during the 10 minutes incubation at pH 10.0 and 90°C. This finding also confirms the results reported by Horiguchi _et al_. (1971) that the inhibitor was denatured on heating it at 100°C. It was also reported that during incubation at 70°C for 30 minutes, the inhibitor activity remained unchanged. Tashiro _et al_. (1978) illustrated that the stability of crude trypsin inhibitor for heating at pH 2.0, 7.0 and 10.0 and claimed that the trypsin inhibitor extracted from the rice bran was stable at acidic pH. It was pointed out that at acidic and neutral pHs, the trypsin inhibitor retained more than 50% of its activity after the 30 minutes incubation at 90°C.

Poultry

While formulating the broiler diets, the protein value of rice mill feed was taken into account. Therefore, as it is presented in the composition of starter and finisher diets, the soybean meal was lowered down by 1% as the percent of rice mill feed was increased, eg. soybean meal for starter diets 9%, 8% and 7% for 60%, 80% and 100% of rice mill feed in replacements of corn, respectively. The DL-methionine was added at .3% level to all the starter diets and .1% level was added to all the finisher diets. As the level of the corn was reduced in the diet, the calculated metabolizable energy value of the diet was also dropped down because of the fact that the metabolizable energy value for corn is higher than that of rice mill feed. However, the protein content was quite similar for all diets. The analyzed value of protein for untreated rice mill feed was used to calculate the protein value of rice mill feed and the "feed ingredients analysis chart" used in Belize was used for the protein content of other ingredients.

As the results of the broiler feeding trials for various period as illustrated in the results section indicated that chicks on diets which consisted of heat treated rice mill feed performed better, eg. for final period the chicks on treated rice mill feed diets were heavier, gained more and required less amount of diets per unit of gain ($P<.05$) than the chicks on untreated rice mill feed diet. This is because of the fact that as described previously, the heat treatment not only arrested the rise of free fatty acid and reduced the trypsin inhibitor action but also perhaps affected the unknown growth depressing factor.

The increase in growth rate of chicks on heat treated rice mill feed diets is also in agreement with the findings reported for rice bran diets by Kratzer et al. (1974).

At the age of 8 weeks old, the selected biggest birds from each treatment were sacrificed in a commercial

slaughter house and the dressed weights were taken without including the heart, liver and gizzard. The chicks on high heated rice mill feed diets were heavier at 8 weeks of age, and had higher dressing weight ($P<.05$) than the chicks on low heated or unheated material. However, there was no significant difference in dressing percentage at the $P<.05$ level of probability except the dressing percentage of chicks on high heated rice mill feed diet 100% in replacement of corn (1C).

The male birds tended to have slightly heavier body weight than the females, however there was no significant difference in the performances at the $P<.05$ level of probability.

Swine

Pigs on diets which consisted of 88.5% of boiling water treated rice mill feed were significantly heavier ($P<.01$) and gained more ($P<.001$) than the pigs on diets which contained the same level of untreated rice mill feed. The reasons of enhancing the feeding value of rice mill feed are that heat treatment affected the deleterious factors of free fatty acid and trypsin inhibitors. It also perhaps affected the growth depressing factor. Yasumoto et al. (1977) pointed out that the bound form of vitamin B_6 in rice bran extracts was available to the assay microorganisms when hydrolyzed. Thus the wet heating enhanced the availability of some bound forms of nutrients such as vitamin B_6. When hydrothermally

processed liquid feed, which had approximately 38% dry matter, was fed to pigs weaned at 3 weeks of age, it was observed that pigs on processed liquid feed digested 88.3% dry matter whereas the pigs on dry diets had 84.8% digestibility for the dry matter (Binder et al., 1978). The liquid diet was manufactured by blending finely ground corn and soybean meal with water, which was then hydrothermally processed at 150°C using direct steam application. It was also reported that the percent energy and protein digested were both higher for the processed liquid diet when compared to the crumbled (dry) diet.

Pigs on wet heated rice mill feed diet tended to consume slightly more diets as compared to the pigs on dry diets, however, there was no significant difference ($P<.05$) between the two. This is in agreement with the report by Binder et al. (1978) that pigs on hydrothermally prepared liquid ration consumed more diet on dry matter basis as compared to the pigs on dry diet.

Grifo et al. (1974) reported that paste (a blend of 1.2 parts dry feed and 1.5 parts water) increased the daily gain and daily feed intake during the growing-finishing periods.

The feeding experiment with the swine on heat treated rice mill feed diets was not found within the limit of available information (review of literature).

CONCLUSIONS

Under the experimental conditions and procedures presented in this thesis, the following conclusions are drawn:

1. Both dry and wet heat treatments of rice mill feed lowered the deleterious factors of free fatty acid and trypsin inhibitor.

2. Heat treatment of rice mill feed did not affect the nutrient content of it.

3. Based on the nutrient content of the samples, the rice mill feed obtained from Big Falls Ranch Mill was of high quality having less than 1% silica as compared to the rice bran reported.

4. The drum-heating and wet-heating systems can be used to enhance the feeding value of rice mill feed diets.

5. When higher levels of rice mill feed are used in broiler diets, the heat treatment becomes more effective. Chicks on diets containing lower levels performed better than the chicks on diets which had higher levels of rice mill feed

6. Wet heat treatment of rice mill feed enhanced the feeding value of it by growing pigs when 88.5% of the wet heated rice mill feed diet was compared with the diet which contained the same level of untreated material.

SUGGESTIONS FOR FURTHER STUDIES

Based on the results and observations made during the current studies on the appropriate technology in small farming systems to treat rice mill feed, and evaluation of a dry heated, wet heated and unheated rice mill feed as feed ingredients for broiler and swine diets, the following areas of further investigations are suggested:

1. Improvement of the drum heating system by fixing one layer of metal all around the 55-gallon drum. This improvement will protect the main drum from direct connection of flame and will slowly but evenly heat the material in the drum.

2. Studies on the feeding values of various types of heat treated rice mill feeds to layers.

3. *In vitro* and/or *in vivo* studies on the availibility of lysine from the treated and untreated rice mill feed.

4. Studies on the effects of addition of graded levels of tallow in treated and untreated rice mill feed diets for broiler and swine to evaluate that whether the oil present in rice mill feed is an energy-contributing factor or not.

5. Studies on the effects of rancid fat with chicken to determine whether the rancidity is one of the growth-

depressing factors of the rice mill feed.

6. Studies on effects of dry as well as wet heated treatments of rice mill feed to enhance the feeding values of it by swine using reasonably more samples to ascertain the present findings.

7. Studies on the effects of high levels of rice mill feed on the body composition of pigs and chickens.

GLOSSARY

own rice--It is the unmilled product, but with hulls removed. It retains the bran coat which consists of seven layers of differentiated types of cells and at one end of the kernel lies the germ or embryo, is attached firmly to the endosperm or starchy body of the kernel.

ryopsis--It is the edible portion of rice grain. It is also called as brown rice because of its brownish pericarp. Red rice has a red pericarp or tegmen or both. The rice caryopsis varies widely among varieties in shape, size and width.

heating--It is a process of treatment where rice by-products are heated or roasted without added moisture.

ats or brewer's or broken rice or rice pollards--Small broken kernels that do not meet the kernel-size requirements second heats and screenings. These kernels of rice will generally be having less than three-fourths of whole kernels.

d rice--It is the whole kernels of milled or polished rice. It is slightly smaller than brown rice.

ls or husks--The harsh woody covering around the caryopsis

is called as husks or hulls. Hulls are tough, woody, abrasive, resistant to weathering, great bulk, high silica and ash content and have low nutritive properties. Usually it amounts about one-fifth of the weight of the paddy.

Milled rice--It is the product from which the bran layer and a part of the germ have been removed.

Paddy or unmilled or rough rice--It is the harvested product received at the rice mill from the farm thresher, and is contained in a hard siliceous hull which encloses the edible kernel. It is made up of the hull, the seed coat (pericarp), the starchy endosperm and the embryo or germ.

Parboiling or boiling or overheating or hydrothermic rice treatment--It is the operation to which the paddy is subjected before milling. This process involves soaking rough rice in water, draining, then pressure cooking in a steam atmosphere to completely gelatinize the starch. Then the rice is dried and milled.

Polish or polishings or white bran--These are finely powdered by-products obtained in polishing the rice kernels after the hulls and bran have been removed. The production of polishings amounts to 2 to 3% of the paddy milled.

Rice bran--A by-product from the milling of rice, consisting of the outer bran layers of the kernel with part of the germ. Depending upon the type of mill, it is made up of pericarp, some germ, rachilla, small fragments of endosperm, some hulls, as well as dust and soil particles. It generally amounts 8 to 9% of the rough rice milled.

Rice mill feed--Rice mill feed, as described in this thesis, is a mixture of rice bran, rice polishings, small amounts of broken rice with only such quantity of hull fragments as is unavoidable in the regular milling of rice. Rice by-product is used as a synonym for rice mill feed. The rice by-product or rice mill feed used by Houston et al. (1969), "defining product comprises total rice milling by-products and may contain 50 to 65% of rice hulls" does not imply in this thesis throughout, because of the fact that rice hulls do not have much feeding value in non-ruminants.

Screenings--Medium broken kernels, not more than 10% of which can be removed by a No. 5 sizing plate.

Second heads--Large broken kernels not more than 7% of which can be removed by a No. 6 sizing plate.

Wet heating--It is a process of heating or cooking rice by-product in a condition where added moisture is involved.

Steaming--It is one of the methods of rice-bran treatment. It is generally carried out by placing samples on shallow trays and subjecting it to live steam in a

losed system.

<u>nits of energy defined</u>

ritish Thermal Unit (BHU)--It is defined as the amount of heat required to raise the temperature of one pound of water $1^{o}F$ (i. e., from $62^{o}F$ to $63^{o}F$).

1 BHU = 252 calories.

alorie (cal)--One calorie = 1/1000 kcal = amount of heat required to raise the temperature of 1 gram (1 ml) of water by $1^{o}C$. One calories = 4.184 Joules.

1 Joule = 10^{7} ergs = 0.239 cal.

ilocalories (kcal)--One kilocalorie of energy is the amount of heat needed to raise the temperature of 1000 gram (1 liter) of water by $1^{o}C$ (i. e., from 14.5 to $15.5^{o}C$). 1 kcal = 4.185 kilo Joules.

One megacalorie (megcal) = 1000 kcal.

APPENDICES

APPENDIX A

TABLE A-1. NUTRIENT CONTENT OF "BELIZE VITAMIN PREMIX - X5"[a,b]

Guaranteed analysis per pound (or per kilogram) is,

Item	Amount/Pound	Amount/Kilogram
Vitamin A	3,636,500 USP Units	8,017,027.0 USP Units
Vitamin D_3	454,500 IC Units	1,001,900.7 IC Units
Vitamin E	9,090 IU[c]	20,039.81 IU[c]
d-Pantothenic acid	5,454.5 mg	12,024.99 mg
Niacin	13,636.5 mg	30,063.03 mg
Riboflavin	1,818 mg	4,007.96 mg
BHT	0.0455 lb	45.50 g
Vitamin B_{12}	9.091 mg	20.24 mg
Choline chloride	136,365 mg	300,630.28 mg

[a]Ingredients used are vitamin A acetate in gelatin, d-activated animal sterol (source of vitamin D_3), vitamin E supplement, menadione sodium bisulfate complex (source of vitamin K activity, added at a rate of 2,885 mg per pound or 6,360.27 mg per kilogram), d-calcium pantothenate, niacin, riboflavin supplement, butylated hydroxytolyene (BTH) (a preservative), vitamin B_{12} supplement, choline chloride and corn fermentation solubles.

[b]One kilogram of this vitamin premix was mixed with four kilograms of carrier and used as a rate of 500 grams per 100 kilograms in broiler as well as in swine diets.

[c]Int. units.

TABLE A-2. NUTRIENT CONTENT OF "BELIZE TRACE MINERAL PREMIX - X5"[a,b]

Guaranteed minimum analysis per pound (or per kilogram) is,

Item	Amount/Pound	Amount/ Kilogram
Manganese (Mn)	5.00 , %	5.00 , %
Zinc (Zn)	7.00 , %	7.00 , %
Iron (Fe)	5.00 , %	5.00 , %
Iodine (I)	0.025, %	0.025, %
Selenium (Se)	45.455 mg	100.21 mg

[a]Ingredients used are manganous oxide, zinc oxide, iron sulfate, ethylene diamine dihydroxide, sodium selenite and corn fermentation solubles.

[b]One kilogram of this trace mineral premix was mixed with four kilograms of carrier and used as a rate of 500 grams per 100 kilograms in broiler as well as in swine diets.

APPENDIX B

The solar cabinet was constructed in the following manner.

Four pieces of 215.9 cm X 5.08 cm and other four pieces of 91.44 cm X 5.08 cm were separated from the long pieces and the longer four pieces were used lengthwise retaining bars, two at the bottom and two at the top, whereas the shorter four pieces were used widthwise retaining bars. Six pieces of 106.68 cm X 5.08 cm angle iron were used to construct the six legs of the cabinet, four at two sides of the frame and two at the middle of the cabinet in order to strengthen it to hold the load. All the pieces of angle iron were joined together with the help of .79 cm nuts and bolts. The pieces at the bottom of the fram were joined leaving a distance of 15.24 cm. The leg pieces at the bottom of the frame were joined leaving a distance of 15.24 cm to allow sufficient space to the legs to stand on the ground and to avoid the rest of the cabinet to touch the ground in order to protect the surface of the iron pieces from rusting. Then three pieces of 228.6 cm X 101.6 cm sheet metal were separated from the long sheet and two of them were fixed with the length of the frame with drilling holes in the sheets and joining to the frame with the help of nuts and bolts. Then the third sheet was laid at the bottom of the frame. Two pieces of 91.44 cm X 91.44 cm sheet metal, one on each side, were also fixed with sides of the frame. Since the size of the frame was 215.9 cm X 97.79 cm X 91.44 cm, the extra lengths of sheets were bent over and turned outside edges inwards to strengthen the cabinet. Each edge of the sheets was strongly bolted with the frame to avoid the possibility of environmental cooler air flow inside the cabinet. Each corner of the sides was supported strongly with iron strips.

Two pieces of 215.9 cm X 5.08 cm X 5.08 cm mahogany wood were fixed lengthwise on the top of the frame with the help of wooden screws, and nuts and bolts.

Two pieces of 215.9 cm X 5.08 cm X 5.08 cm lengthwise and two pieces of 83.82 cm X 3.81 cm X 3.81 cm widthwise mahogany wood were fixed on the top and one piece 215.5 cm X 101.6 cm X 10.16 cm was fixed lengthwise at the top on the back side of the frame in order to allow sufficient space to join the glass frame.

TABLE B-1. SOLAR CABINET.

Dimensions:

Cabinet

Size of the cabinet	:	215.9 cm x 97.79 cm x 91.44 cm (85" x 38.5" x 36")
Supporting legs	:	15.24 cm (6") long beyond the cabinet
Glass frame	:	215.9 cm x 5.08 cm x 5.08 cm (85" x 2" x 2")

Sheet metal[a]

Three pieces of equal size	:	228.6 cm x 101.60 cm (90" x 40")
Two pieces of equal size	:	91.44 cm x 91.44 cm (36" x 36")
Three pieces of equal size	:	76.2 cm x 49.53 cm (29.5" x 19.5")
Three pieces of equal size	:	91.44 cm x 66.04 cm (36" x 26")

Wood

One piece:	215.9 cm x 10.16 cm x 10.16 cm (85" x 4" x 4")
Four pieces:	215.9 cm x 5.08 cm x 5.08 cm (85" x 2" x 2")
Six pieces:	83.82 cm x 3.81 cm x 3.81 cm (33" x 1.5" x 1.5")

Angle iron

Six pieces:	106.68 cm x 5.08 cm (42" x 2")
Four pieces:	91.44 cm x 5.08 cm (36" x 2")
Iron strips (24 pieces of equal size):	12.7 cm x .64 cm (5" x .25")

Miscellaneous

Three pieces of hinges: ordinary door hinge size
Two handles
Three trays: 76.2 cm x 50.8 cm x 15.24 cm (30" x 20" x 6")
Three pieces of transparent glass: 86.36 cm x 66.04 cm x 0.95 cm (34" x 26" x ⅜")
Bolts and nuts--.79 cm (5/16")

Materials of construction

Galvanized sheet metal
Angle iron

[a]The galvanized sheet metal was of 24 gauge galvanized aluminum made rust resistant.

Mahogany wood
Transparent glass
Dark paint
Hinges
Door handles
Rice husks as insulating material
Miscellaneous (nuts, bolts, nails, puddings, wood gum, tape, etc.)

TABLE B-2. ROTARY DRUM HEATING SYSTEM.

Dimensions

- Length of the pipe: 366 cm
- Diameter of the pipe: 5.08 cm
- Length of the drum: 84 cm
- Circumference of the drum: 180 cm
- Diameter of the drum: 64 cm
- Iron rods: 58 cm x 2 cm
- Height of two wooden poles: 183 cm
- Height of other two wooden poles: 198 cm
- The length of each of the wooden poles buried in the ground: 92 cm
- The area of the opening of the drum door: 23 cm x 27 cm

The furnace

- Length: 92 cm
- Width : 86 cm
- Height: 54 cm
- The length of the gate: 48 cm
- The width of the gate: 28 cm
- The thickness of the furnace wall: 10 cm
- The area of the opening of the furnace to allow fire flame: 61 cm x 48 cm
- The distance between the furnace and the drum (dry heating machine): 20 cm
- Tray to collect the cooked material: 64 cm x 51 cm x 20 cm

Materials

- Galvanized aluminum pipe made rust resistant
- 55 gallon drum
- Four wooden poles
- Red bricks
- Cement
- Sand
- Iron rods
- Sheet metal
- Tray
- Miscellaneous (wood strips, rice husks, nuts, bolts, tools such as drill, drill bits, hammer, knives, ranches, etc.)

APPENDIX C

TABLE C-1. AVERAGE BODY WEIGHT, KG

Treatment		Feeding period						
	No. of Animals	Initial	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6
Dry feed Repl. I	5	11.02	12.61	14.56	16.06	17.33	18.14	20.05
Repl. II	5	11.52	13.15	15.20	17.24	19.69	21.86	23.86
		11.27	12.88	14.88	16.65	18.51	20.00	21.95
Wet feed Repl. I	5	12.16	14.15	17.19	20.50	23.04	26.13	29.03
Repl. II	5	11.61	12.88	16.06	19.23	22.27	25.49	28.67
Mean		11.88	13.52	16.62	19.87	22.66	25.81	28.85

TABLE C-2. AVERAGE DAILY GAIN, g.

Treatment		Feeding period					
		Week 1	Week 2	Week 3	Week 4	Week 5	Week 6
Dry feed	Repl. I	227	279	214	181	117	272
	Repl. II	233	291	292	350	311	285
	Mean	230	285	253	266	214	279
Wet feed	Repl. I	285	408	473	363	441	415
	Repl. II	181	454	454	434	460	454
	Mean	233	431	464	399	451	435

TABLE C-3. AVERAGE DAILY FEED INTAKE, g.

Treatment		Feeding period					
		Week 1	Week 2	Week 3	Week 4	Week 5	Week 6
Dry feed	Repl. I	786	850	909	961	922	1026
	Repl. II	708	837	1000	1065	1104	1078
	Mean	747	844	954	1013	1013	1052
Wet feed	Repl. I	797	1045	1001	1121	1127	1150
	Repl. II	715	890	1041	1047	1201	1199
	Mean	756	968	1021	1084	1164	1174

TABLE C-4. UNITS OF FEED REQUIRED PER UNIT OF GAIN (F/G).

		Feeding period					
		Week 1	Week 2	Week 3	Week 4	Week 5	Week 6
Dry feed	Repl. I	3.46	3.05	4.25	5.31	5.44	3.77
	Repl. II	3.04	2.88	3.42	3.04	3.55	3.78
	Mean	3.25	2.96	3.84	4.18	4.49	3.78
Wet feed	Repl. I	2.80	2.56	2.12	3.09	2.56	2.77
	Repl. II	3.95	1.96	2.29	2.41	2.61	2.64
	Mean	3.37	2.26	2.20	2.75	2.58	2.71

APPENDIX D

The least square analyses were performed as described in the statistical procedure section. The comparisons of means were made taking the difference of mean and comparing the mean difference with the standard statistical value (test value). The test value is obtained by dividing the error mean square for the defined trait of a particular period by the number of samples (observations) for that particular trait. Then take the square root of it and multiply the value by "α_i" value as listed by Harvey (1960) for the number of comparison(s) made.

eg. Means comparison for the body weight of week 4 old chicks on 12 different treatment diets:

Error mean square (EMS)=5209.41
Total number of samples for overall treatment (n)=584
Approximate number of sample in one treatment $(n)=\frac{584}{12}$

$=48.67$
$\approx 49.$

Test value=Syi $\cdot \alpha_i$

$$\text{Syi} = \sqrt{\frac{\text{EMS}}{n}}$$

$$= \sqrt{\frac{5209.41}{49}}$$

$$= 10.31$$

Degree of freedom for error mean square (EMS)=559.
The α value for 5% probability using 559 d.f. for EMS and P=2 (pair of comparison) is 2.78 (Harvey's least square Table, 1960)
Test value=10.31 x 2.78
=28.66.

Comparison:

If the difference of means is more than the test value (eg. 28.66), then the two means are significantly different at the $P<.05$ level of probability. All the important information for each parameter tested at different trial periods are presented in Tables "D"s.

TABLE D-1. ANALYSIS OF VARIANCE (ANOVA) FOR OVERALL REGRESSION, WEEK 4 BODY WEIGHT.

	SS	d.f.	MS	F	Sig.
Regression about mean	1085577.11	24	45232.38	8.6828	<.0005
Error	2912062	559	5209.41		
Total about mean	3997639.55	583			

TABLE D-2. ANOVA FOR OVERALL REGRESSION, WEEK 0-4 AVERAGE DAILY GAIN (ADG).

	SS	d.f.	MS	F	Sig.
Regression about mean	1361.38	24	56.72	8.5368	<.0005
Error	3714.37	559	6.64		
Total about mean	5075.75	583			

TABLE D-3. ANOVA FOR OVERALL REGRESSION, WEEK 0-4 AVERAGE DAILY FEED INTAKE (ADFI).

	SS	d.f.	MS	F	Sig.
Regression about mean	777.06	11	70.64	14.1499	<.0005
Error	59.91	12	4.99		
Total amount mean	836.97	23			

TABLE D-4. ANOVA FOR OVERALL REGRESSION, WEEK 0-4 FEED REQUIRED PER UNIT OF GAIN (F/G).

	SS	d.f.	MS	F	Sig.
Regression about mean	2.8815	11	.2619	10.8695	<.0005
Error	.2892	12	.0241		
Total about mean	3.1707	23			

TABLE D-5[a]. ANOVA FOR OVERALL REGRESSION, WEEK 2-4 BODY WEIGHT.

TABLE D-6. ANOVA FOR OVERALL REGRESSION, WEEK 2-4 ADG.

	SS	d.f.	MS	F	Sig.
Regression about mean	4630.93	24	192.96	9.311	<.0005
Error	11584.36	559	20.72		
Total about mean	16215.28	583			

TABLE D-7. ANOVA FOR OVERALL REGRESSION, WEEK 2-4 ADFI.

	SS	d.f.	MS	F	Sig.
Regression about mean	1484.47	11	134.95	6.7579	.001
Error	239.64	12	19.97		
Total about mean	1724.11	23			

TABLE D-8. ANOVA FOR OVERALL REGRESSION, WEEK 2-4 F/G.

	SS	d.f.	MS	F	Sig.
Regression about mean	3.3544	11	3.0494	5.9167	.002
Error	.6185	12	.0515		
Total about mean	3.9728	23			

TABLE D-9. ANOVA FOR OVERALL REGRESSION, WEEK 0-6 BODY WEIGHT.

	SS	d.f.	MS	F	Sig.
Regression about mean	4272026.04	18	237334.78	13.2908	<.0005
Error	7178530.26	402	17857.04		
Total about mean	11450556.29	420			

[a]See in Table D-1.

TABLE D-10. ANOVA FOR OVERALL REGRESSION, WEEK 0-6 ADG.

	SS	d.f.	MS	F	Sig.
Regression about mean	2464.43	18	136.91	12.8196	<.0005
Error	4378.77	410	10.68		
Total about mean	6843.20	428			

TABLE D-11. ANOVA FOR OVERALL REGRESSION, WEEK 0-6 ADFI.

	SS	d.f.	MS	F	Sig.
Regression about mean	621.69	8	77.71	16.3335	<.0005
Error	42.82	9	4.76		
Total about mean	664.51	17			

TABLE D-12. ANOVA FOR OVERALL REGRESSION, WEEK 0-6 F/G.

	SS	d.f.	MS	F	Sig.
Regression about mean	2.5786	8	.3223	7.7058	<.003
Error	.3764	9	.0418		
Total about mean	2.9550	17			

TABLE D-13. ANOVA FOR OVERALL REGRESSION, WEEK 6-8 BODY WEIGHT.

	SS	d.f.	MS	F	Sig.
Regression about mean	11869881.98	18	659437.89	22.916	<.0005
Error	11568254.84	402	28776.75		
Total about mean	23438136.82				

TABLE D-14. ANOVA FOR OVERALL REGRESSION, WEEK 6-8 ADG.

	SS	d.f.	MS	F	Sig.
Regression about mean	15944.09	18	885.78	11.2322	<.0005
Error	31702.25	402	78.86		
Total about mean	47646.34	420			

TABLE D-15. ANOVA FOR OVERALL REGRESSION, WEEK 6-8 ADFI.

	SS	d.f.	MS	F	Sig.
Regression about mean	340.88	8	42.61	.7516	.651
Error	510.24	9	56.69		
Total about mean	851.12	17			

TABLE D-16. ANOVA FOR OVERALL REGRESSION, WEEK 6-8 F/G.

	SS	d.f.	MS	F	Sig.
Regression about mean	.5995	8	.0749	1.1059	.438
Error	.60986	9	.0677		
Total about mean	1.2094	17			

TABLE D-17[a]. ANOVA FOR OVERALL REGRESSION, WEEK 0-8 (FINAL) BODY WEIGHT.

[a]See in Table D-13.

TABLE D-18. ANOVA FOR OVERALL REGRESSION, WEEK 0-8 ADG.

	SS	d.f.	MS	F	Sig.
Regression about mean	3747.35	18	208.19	22.6875	<.0005
Error	3688.86	402	9.18		
Total about mean	7436.20				

TABLE D-19. ANOVA FOR OVERALL REGRESSION, WEEK 0-8 ADFI.

	SS	d.f.	MS	F	Sig.
Regression about mean	224.19	8	28.02	2.3084	.117
Error	109.26	9	12.14		
Total about mean	333.44	17			

TABLE D-20. ANOVA FOR OVERALL REGRESSION, WEEK 0-8 F/G.

	SS	d.f.	MS	F	Sig.
Regression about mean	.93708	8	.1171	7.485	<.003
Error	.1408	9	.0156		
Total about mean	1.0779	17			

TABLE D-21. ANOVA FOR OVERALL REGRESSION, FINAL (WEEK 8) BODY WEIGHT OF SELECTED BIRDS.

	SS	d.f.	MS	F	Sig.
Regression about mean	2899221.03	18	161067.83	6.5357	<.0005
Error	2119403.73	86	24644.23		
Total about mean	5018624.76	104			

TABLE D-22. ANOVA FOR OVERALL REGRESSION, DRESSED WEIGHT OF THE SELECTED BIRDS.

	SS	d.f.	MS	F	Sig.
Regression about mean	1420752.25	18	78930.68	6.9702	
Error	973872.52	86	11324.10		
Total about mean	2394624.76	104			

TABLE D-23. ANOVA FOR OVERALL REGRESSION, DRESSING PERCENTAGE OF THE SELECTED BIRDS.

	SS	d.f.	MS	F	Sig.
Regression about mean	266.0281	18	14.779	1.2224	<.262
Error	1039.7385	86	12.090		
Total about mean	1305.7667	104			

LIST OF REFERENCES

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Acasio, U. A., S. C. Andales and M. R. Valdez. 1973. Factors affecting the efficient burning of rice hulls for grain drying. Phil. Agri. 56(9/10):324-334. Feb./March.

Adair, C. R. 1972. Production and Utilization of Rice. pp. 1-13. RICE: Chemistry and Technology. Published by American Association of Cereal Chemists. Inc. St. Paul, Minnesota.

Aizono, Y., M. Funatsu, K. Hayashi, M. Inamasu and M. Yamaguchi. 1971. Biochemical studies on rice bran lipase. Part II. Chemical properties. Agr. Biol. Chem. 35(12):1973-1979.

Aizono, Y., M. Funatsu, M. Sugano, K. Hayashi and Y. Fujiki. 1973. Enzymetic properties of rice bran lipase. Agr. Biol. Chem. 39(9):2031-2036.

Aizono, Y., M. Funatsu, Y. Fujiki and M. Watanabe. 1976. Purification and characterization of rice bran lipase II Agr. Biol. Chem. 40(2):317-324.

Aizono, Y. and M. Funatsu. 1978. Studies on active groups of rice bran lipase. Agr. Biol. Chem. 42(4): 757-762.

AOAC. 1975. Official Methods of Analysis (12th Ed.). Association of Official Analytical Chemists, Washington, D. C.

Arnott, G. W. and H. K. Lim. 1966. Animal feeding stuffs in Malaya. 2. Quality of rice bran and polishings. Malaysian Agr. J. 45:387.

Barber, S. 1980. Rice bran: Chemistry and technology <u>In</u> Rice Production and Utilization, pp. 790-847. <u>Ed.</u> Bor S. Luh. Westport, Conn. AVI Pub. Co.

Bayley, H. S. and R. G. Thomson. 1969. Phosphorus requirements of growing pigs and effect of steam pelleting on phosphorus availability. J. Anim. Sci. 28:484.

Bayley, H. S., J. Pos and R. G. Thomson. 1975. Influence of steam pelleting and dietary calcium level on utilization of phosphorus by the pig. J. Anim. Sci. 40:859.

Beagle, E. C. 1970. Rice Hulls: The largest agricultural opportunity item in the world. Address at Rice Technical Working group Meetings. Beaumont, Texas, Feb. 23.

Beagle, E. C. and C. A. Beagle. 1971. Paddy husk utilization. Paper presented at UNIDO Conference on Rice Processing, Madras, India.

Bergen, W. G., H. A. Henneman and W. T. Magee. 1973. Effect of dietary protein level and protein source on plasma and tissue free amino acids in growing sheep. J. Nutr. 103:575.

Binder, S. F., E. R. Skoch, G. L. Allee, K. C. Behnke and C. W. Deyoe. 1978. Evaluation of feeding a hydrthermally processed liquid feed to pigs weaned at three weeks of age. Abstr. 7th Ann. Meet. ASAS, p. 296.

Bird, H. R. 1978, 1980. Personal communication. Possibilities and problems of various heat treatments of rice by-product. University of Wisconsin, Madison, Wisconsin, 53706.

Bistoyong, A. G., J. A. Eusebio, P. F. Alcantara and R. R. Gonzales. 1968. Rice bran-fish meal combination with varying protein levels for growing pig rations. Phil. Agr. 52(4):287-296.

Bray, C. I. 1943. Rice and rice by-products for fattening swine. Louisiana Agr. Expt. Sta. Bull. No. 368, pp. 50.

Brooks, C. C. and I. G. Lumanta, Jr. 1975a. Rice bran composition and digestibility by the pig. Proceedings Western Sect., Am. Society of Anim. Sci. Vol. 26. J. Series No. 1879. Hawaii Agr. Exp. Sta.

Brooks, C. C. and I. G. Lumanta, Jr. 1975b. Effect of rice bran on pig performance and carcass. Proceedings, Western Sect., Am. Society of Anim. Sci. 26:115-117.

Browne, C. A., Jr. 1904. The chemical composition and feeding value of rice products. Louisiana Agr. Expt. Sta. Bull. 77:430.

Buvanendran, V. 1961. Effect of different levels of rice bran on growth and egg production in poultry. Ceylon Vet. J. Colombo: 9:107-113.

Campabadal, C., D. Creswell, H. D. Wallace and G. M. Camps. 1976. Nutritional value of rice bran for pigs. Trop. Agr. (Trinidad) 53(2):141-149.

Cann, J. R. 1966. Multiple electrophoretic zones arising from protein-buffer interaction. Biochemistry 5(3):1108.

Chaturvedi, D. K. and R. Mukherjee. 1966. Studies on cereal-free rations based on rice polishings and groundnut cake for growing chicks. Indian J. Poultry Sci. 2(2):36-51.

Chen, L. and D. F. Houston. 1969. Solubilization and recovery of protein from deffatted rice bran. Cereal Chem. 47(1):72-79.

Chernick, S. S., S. Lepkovsky and I. L. Chaikoff. 1948. A dietary factor regulating the enzyme content of the pancreas: Changes induced in size and proteolytic activity of the chick pancreas by the ingestion of raw soybean meal. Am. J. Physiol. 155:31-41.

Chicco, C. F., J. T. Perdomo, S. T. Garbati and T. A. Schultz. 1976. Sustitucion de maiz por pulitura de arroz para cerdes de engorde. Agronomica Tropical. 24(6):477-481.

Combs, G. F. and H. Nott. 1967. Improved nutrient composition data of feed ingredients, amino acid and other nutrient specifications for linear programming of broiler rations. Feedstuffs. 39(42):36-43.

Corley, J. R., D. H. Baker and R. A. Easter. 1980. Biological availability of phosphorus in rice bran and wheat bran as affected by pelleting. J. Anim. Sci. 50(2):286-292.

Dalrymple, W. H. 1910. Rough rice as feed for horses and mules. Louisiana Agr. Expt. Sta. Bull. No. 122, pp. 8.

Desai, R. T., N. D. Bhave and E. N. Moore. 1961. Utilization of by-product feedstuffs for chicken. Indian J. Vet. Sci. 31:65-74.

Din, M. G., M. L. Sunde and H. R. Bird. 1979. Effect of autoclaving, soaking and enzyme supplementation on the nutritive value of rice bran for chicks. Research note. University of Wisconsin, Madison, WI, 53706.

Emasiri, S. 1940. A comparative study of corn and rice bran as constituents of rations for growing market pigs. Phil. Agr. 28:848-855.

FAO. 1957. Rice Trade Glossary, pp. 65. Food and Agricultural Organization of the U. N., Rome, Italy.

FAO. 1978. Production Year Book. Vol. 32. Food and Agricultural Organization of the U. N., Rome, Italy.

Fijiki, Y., Y. Aizono and M. Funatsu. 1978. Chemical properties of major subunit of rice bran lipase. Agr. Biol. Chem. 42(3):599-606.

Fraps, G. S. 1904. The composition of rice by-products. Texas Agr. Expt. Sta. Bull. 73, pp. 14.

Freivalds, J. 1975. Finding the best use for rice by-products. Rice J. 78(7):18-23.

Fujimaki, M., T. Tsugita and T. Kurata. 1977. Fractionation and identification of volatile acids and phenols in the steam distillation of rice bran. Agr. Biol. Chem. 41(9):1921-1725.

Funatsu, M., Y. Aizono, K. Hayashi, M. Watanabe and M. Eto. 1971. Biochemical studies on rice bran lipase. Part I. Purification and physical properties. Agr. Biol. Chem. 35(5):734-742.

GBII. 1918. Utilization of rice and its by-products. Great Britain Imperial Institute, Bull. No. 16(1):16.

Gill, J. L. 1978. Design and analysis of experiments in the animal and medical science. Vol. 1 and 2. Published by the Iowa State University Press, Ames, Iowa.

Gobert, L. 1921. Fleruage de riz. Ann. Fals. 14:226 (Chem. Abstr. 15:3346, 1921).

Goering, H. K. and P. J. Van Soest. 1970. Forage fiber analyses (apparatus, reagents, procedures and some applications(, Agr. Handbook No. 379, A. R. S., U. S. D. A.

Gomeri, G. 1942. A modification of the colorimetric phosphorus determination for use with the photoelectric colorimeter. J. Lab. Clin. Med. 27:955-960.

Grifo, Jr., A. P., H. S. Teague and W. L. Roller. 1974. Effectiveness of additives in paste feed. Swine Research. Ohio Agr. Res. and Dev. Center. Research summary, 1978.

Hamad, M. A., A. E. Al-Ashmawy, H. El-Saied and S. M. Soliman. 1976. Effects of dry treatment of rice hulls with alkali and steam on their nutritive value. Indian J. of Anim. Sci. 46(2):59-62, Feb.

Harvey, W. R. 1960. Least squares analysis of data with unequal subclass numbers. USDA, ARS, 20-8.

Hayes, D. 1977. Energy: The solar prospect. Worldwatch Paper, March 11.

Hill, F. W., D. L. Anderson, R. Renner and L. B. Carew, Jr. 1960. Studies of the metabolizable energy of grain and grain products for chickens. Poultry Sci. 39:573-579.

Hill, F. W. and R. Renner. 1960. The metabolizable energy of soybean oil meals, soybean mill feeds and soybean hulls for the growing chicks. 39:579-583.

Horiguchi, T. and K. Kitagishi. 1971. Studies on rice seed protease V. Protease inhibitor in rice seed. Plant and Cell Physiol. 12:907-915.

Horton, O. H. and C. Elynn. 1967. Feeding rice hulls as roughage component of high-energy rations. Feed Bag 43(8):3.

Hough, J. H. and H. T. Barr. 1966. Possible uses for waste rice hulls in building materials and other products. Louisiana State University Bull. No. 507.

Houston, D. F. 1972. RICE: Chemistry and Technology. Published by American Assoc. of Cereal Chemists. Inc. St. Paul, Minnesota.

Houston, D. F., M. E. Allis and G. O. Kohler. 1969. Amino acid composition of rice and rice by-products. Cereal Chem. 46:527-537.

Houston, D. F. and G. O. Kohler. 1970. Nutritional Properties of Rice. National Acad. of Sciences, Washington, D. C.

Hutanuwatr, N., F. C. Hinds and C. L. Davis. 1974. An evaluation of methods for improving the *in vitro* digestibility of rice hulls. J. Anim. Sci. 38(1): 140-148.

IRRI. 1963. International bibliography of rice research. 1951 to 1961. pp. 881. International Rice Research Institute, Leguna, The Phillipines. Scarecrow Press. Inc. New York, and Annual Supplements subsequently published by the Institute.

Jordan, E. L., A. F. Kidder, L. E. Long and R. C. Calloway. 1921. Feeding ground rough rice, etc., to horses, mules, hogs and dairy cattle. A preliminary report. Louisiana Agr. Expt. Sta. Bull. No. 197, pp. 8.

Juliano, B. O., G. M. Bautista, J. C. Lugay and A. C. Reyes. 1964. RICE QUALITY: Studies on the physiochemical properties of rice. J. Agr. Food Chem. 12(2):131-138. March/April.

Kakade, M. L., N. Simons and I. E. Liener. 1969. An evaluation of natural vs. synthetic substrates for measuring antitryptic activity of soybean samples. Cereal Chem. 46:518.

Keys, J. E., Jr., P. J. Van Soest and E. P. Young. 1969. Comparative study of the digestibility of forage cellulose and hemicellulose in ruminants and non-ruminants. J. Anim. Sci. 29:11-15.

Kik, M. C. 1956. Nutrients in rice bran and rice polish and improvement of protein quality with amino acids. Agr. and Food Chem. 4(2):170-172.

Kirsi, M., J. Mikola. 1971. Occurrence of proteolytic inhibitors in various tissues of barley. Planta (Berl.) 96:281-291.

Kohler, G. O. and R. Palter. 1967. Studies on methods for amino acid analysis of wheat products. Cereal Chem. 44:512-520.

Kondo, K., M. Mitsuda and K. Iwai. 1949. Mechanism of thiamine formation in rice. Rept. Inst. Chem. Res. Kyoto Univ. 19:64. [Chem. Abstr. 45:5252 (1951)]

Kondo, K. and Y. Morita. 1954. Studies on protein 58. Nucleic acid in rice glutelin. Bull. Res. Inst. Food Sci., Kyoto Univ. 15:1.

Kratzer, F. H. 1980. Problems and possibilities of wet treatment of rice mill feed to use as a dietary ingredient for chickens. Personal communication. University of California, Davis, California.

Kratzer, F. H., L. Earl and C. Chiaravanont. 1974. Factors influencing the feeding value of rice bran for chickens. Poultry Sci. 53:1975-1800.

Kratzer, F. H. and C. G. Payne. 1977. Effects of autoclaving, hot water treating, parboiling and addition of ethoxyquin on the value of rice bran as a dietary ingredient for chickens. Br. Poult. Sci. 18:475-482.

Kuilman, L. W. 1979. Rice during and after the war. A bibliography of the literature on rice during the period 1940 to 1947. Mededel. Algem. Proefsta. Landbouw No. 87. pp. 244 (in English).

Laiń, E. R. and E. S. Rodríguiz. 1965. Subproductos del arroz. I. Contemido en principol immediates. II. Contenido en amino acidos. III. Calidad proteica--Indices de Mitchel Block y Oser. Rev. Nutr. Animal 3:92-98.

Lal, M., M. S. Kochar and G. S. Makkar. 1976. Energy utilization and growth performance of swine fed on the agro-industrial by-products. Indian J. Anim. Sci. 46(7):357-361.

Larson, N. G. 1957. Rice hulls and rice straw. 1907-1955, a list of references (Rev.). U. S. D. A., Library List No. 31, Washington, D. C., p. 24.

Lew, E. J-L., D. F. Houston and D. A. Fellers. 1975. A note on protein concentrate from full-fat rice bran. Cereal Chem. 52(5):748-750, Sept./Oct.

Liener, I. E. 1975. Effects of anti-nutritional and toxic factors on the quality and utilization of legume proteins. In Nutrition and Clinical Nutrition Part 2. Quality Factors--Plant Breeding, Composition, Processing and Anti-nutrients. Proc. Symposium, Atlantic City, N. J. Sept. 9-11. pp. 674. Marcel Dekken, Inc. New York.

Liener, I. E. and M. L. Kakade. 1969. Protease Inhibitors. In Toxic Constituents of Plant Foodstuffs. (I. E. Liener, Ed.) pp. 7-68. Acad. Press. New York.

Limcango-Lopez, P. D., F. S. Achacoso and L. S. Castilla. 1962. The chemical composition of rice and corn by-products. I. Proximate composition and minerals. Phil. Agr. 46:324.

Loosli, J. K., J. O. Pena, L. A. Ynalvez and V. Villagas. 1954. The digestibility by swine of rice bran, copra meal, coconut meat, coconut residue and two concentrate mixtures. Phil. Agr. 38:191-196.

Lyman, C. M., K. A. Kuiken and F. Hale. 1956. Essential amino acid content of farm feeds. J. Agr. Food Chem. 4:1008-1013.

Lyman, C. M., B. J. Camp and H. M. Tiller. 1958. The tyrosine content of farm feeds. J. Agr. Food Chem. 6:767-770.

Lynn, L., R. M. Anderson and D. C. Carpenter. 1967. New X-M Rice Bran: Entirely new basic raw materials now available to food processors. Cereal Sci. Today 12:221-222, 260.

Lynn, L. 1969. Edible rice bran foods. pp. 154-172. Protein-Enriched Cereal Foods for World Needs. Edited by Dr. Max Milnex. Published by the American Association of Cereal Chemists.

Mahadevan, P., D. G. Pandittesekera, J. S. L. White and V. Arumugam. 1957. The effects of tropical feeding-stuffs on growth and first year egg production. Poultry Sci. 36:286-295.

Makdami, D. D., J. T. Huber and W. G. Bergen. 1971. Effect of histidine and Methionine supplementation on the nutritional quality of commercially prepared fish protein concentrates in rat diets. J. Nutr. 101:367.

Majun, G. K. and C. G. Payne. 1977. Autoclaved rice bran in layers' diets. Br. Poult. Sci. 18:201-203.

Mandal, L., G. L. Banerjee and S. K. Sankar. 1974. Metabolizable energy value of deoiled rice polish in chicks. Indian Vet. J. 51:527-533.

Matsushima, K. 1955. On the naturally occurring inhibitors of *Aspergillus*-prolease I. Occurrence and distribution of inhibitors in natural products. J. Agr. Chem. Soc. Japan 29:883-887.

Maust, L. E., M. L. Scott and W. G. Pond. 1972. The metabolizable energy of rice bran, cassava-flour and blackeye cowpeas for growing chickens. Poultry Sci. 51:1397-1401.

McDowell, L. R., H. C. Joe, J. E. Thomas and L. E. Harris. 1974. Latin American Tables of Feed composition. University of Florida, Gainesville, Florida.

Morrison, F. B. 1956. Feeds and Feedings, a handbook for the student and stockman (22nd ed.). Morrison Pub. Co., Ithaca, N. Y.

National Research Council. 1977. Nutrient Requirements of Domestic Animals, No. 1. Nutrient Requirements of Poultry. National Academy of Sciences, Washington, D. C.

National Research Council. 1979. Nutrient Requirements of Domestic Animals, No. 2. Nutrient Requirements of Swine. National Academy of Sciences, Washington, D. C.

Nelson, T. D., L. W. Ferrata and N. L. Storer. 1968. Phytate phosphorus content of feed ingredients derived from plants. Poultry Sci. 47:1372.

Noland, P. R. and J. H. Gainer. 1953. The use of rice hulls as a roughage for wintering steer calves and for gestating-lactating ewes. Ark. Agr. Expt. Sta. Bull. No. 538.

Nonaland, P. R. and B. F. Ford. 1954. For wintering steers. . .rice hulls and rice mill feed. Ark. Farm Res. 3(3):34.

O'Dell, B. L., A. R. de Baland and S. R. Koirtyhann. 1972. Distribution of phytate and nutritionally important elements among the morphological components of cereal grains. J. Agr. Food Chem. 20:718.

Pino, J. A. 1962. Sources of energy for poultry in the Pacific area. World's Poult. Sci. J. 18:406-418.

Platt, R. B. and J. F. Griffiths. 1972. Environmental measurement and interpretation. Robert E. Krieger Publishing Company, Huntington, N. Y., pp. 56-82.

Rackis, J. J. and R. L. Anderson. 1964. Isolation of four soybean trypsin inhibitors by DEAE-cellulose chromatography. Biochem. Biophysics Res. Communication. 15:230.

Ranjhan, S. K., S. B. Chabra and S. B. Gupta. 1972. Nutritional evaluation of rice bran via-a-vis the wheat bran in growing chick ration. Indian J. Poultry Sci. 7(3):8-11.

Rao, B. S., R. P. Raghava and B. V. Reddy. 1974. Biological evaluation of heat treated soybean. Indian J. of Poultry Sci. 9(1):3-6.

Ray, M. L. and R. D. Child. 1963. Rice hulls in wintering rations. Ark. Farm Res. 12:2.

Reddy, V. R., C. V. Reddy and S. M. Siddique. 1972. Influence of deoiled rice bran with and without supplemental tallow on the performance of chicks. Indian Vet. J. 49(1):76-81.

Rothman, S. S. and H. Wells. 1967. Enhancement of pancreatic enzymes synthesis of pancreozymin. Am. J. Physiol. 213:215.

Ryan, C. A. 1973. Proteolytic enzymes and their inhibitors in plants. Annual Rev. Plant Physiol. 24: 173-196.

Ryan, C. A. and R. W. van Denburgh. 1968. Transitory aspects of a single protein in tissues of Solanum tuberosum and its coincidence with the establishment of new growth. Plant Physiol. 43:589-596.

Sagar, V. and I. S. Yadava. 1968. The development of a meal mixture with little or no grain for growing pigs. I. Replacement of maize with rice polish and molasses. J. of Res. 3(1):86-92.

Schweigert, B. S. 1947. Amino acid of feeds. J. of Nutr. 33:553-559.

Schweigert, B. S. 1948. The value of various feeds as sources of arginine, histidine, lysine and threomine for poultry. Poultry Sci. 27(1): 223-227.

Scott, M. L., M. C. Nesheim and R. J. Young. 1969. Nutrition of the chicken. M. L. Scott and Associates, Ithaca, N. Y.

Shastry, B. S. and M. R. R. Rao. 1971. Studies on rice bran lipase. Indian J. Biochem. Biophy. 8:327-332. Dec.

Shastry, B. S. and M. R. R. Rao. 1972. Phosphatases from rice bran. Indian J. Biochem. Biophy. 9:227-303. Dec.

Shastry, B. S. and M. R. R. Rao. 1975. Chemical studies on rice bran lipase. Cereal Chem. 53(2):190-201. March/April.

Shastry, B. S. and M. R. R. Rao. 1975. Studies on lipoxygenase from rice bran. Cereal Chem. 52(2):597-603. Sept./Oct.

Smith, R. M. 1934. Rice by-products in the poultry ration for egg production and growth. Ark. Expt. Sta. Bull. No. 304.

Smith, R. M. 1948. The use of rice and rice by-products in the laying ration. Ark. Agr. Expt. Sta. Bull. No. 478.

Snook, J. T. and J. A. Meyer. 1964. Response of digestive enzymes to dietary protein. J. Nutr. 82:409.

Summers, J. D., D. J. Slinger and G. Cisneros. 1967. Some factors affecting the biological availability of phosphorus in wheat by-products. Cereal Chem. 44:318.

Summers, J. D., W. F. Pepper, H. S. Bayley and S. J. Slinger. 1968. The effect of steam pelleting on the utilization of phosphorus in wheat bran. Poultry Sci. 47:1397.

Sycip, G., Velayo and Co. 1965. Swine Project Feasibility Study. Paniqui Sugar Mills Inc. pp. 25.

Tamura, S. and K. Kenmochi. 1963. Studies on amino acid content of rice III. Distribution of amino acid in rice grain (English translation). Nippon Nogeikagaku Kaishi 37:753-756.

Tashiro, M. and Z. Maki. 1978. Partial purification and some properties of a trypsin inhibitor from rice bran. Agr. Biol. Chem. 42(6):1119-1124.

Thrasher, D. M. and A. M. Mullins. 1965a. Using rice bran in pig rations. A. S. Mimeo Cir. 65-2. Animal Sci. Dept., LSU. January.

Thrasher, D. M., A. M. Mullins and V. B. Scott. 1965b. Replacing corn in pig rations with rice bran. A. S. Mimeo Cir. 65-15. Anim. Sci. Dept., LSU. November.

Thrasher, D. M., A. M. Mullins and V. B. Scott. 1966. Re-evaluation of rice bran in modern pig ration. J. Anim. Sci. 25:258 (Abstr.).

Tillman, A. D., J. F. Kidwell and C. B. Singletary. 1951. The value of solvent extracted rice bran in the rations of growing swine. J. Anim. Sci. 10:837.

Tirol, R. H. 1933. Comparative feeding value of coarse and standard rice bran for growing pigs. Phil. Agr. 21:628-638.

Tsai, Yeh-Chi. 1976. Contribution of protease inhibitors to the deleterious effects of fractions and heat-treated rice bran fed to chicken. J. Chinese Agr. Chem. Society 14(3-4):187-194.

Tucker, W. P. 1944. A study of the physical and chemical properties of rice hulls. Masters Thesis, William Jowel College, U. S. A.

Ullrey, D. E., E. R. Miller, B. E. Brent, B. L. Bradley and J. A. Hoefer. 1967. Swine hematology from birth to maturity. IV. Serum calcium, magnecium, sodium, potassium, copper, zinc and inorganic phosphorus. J. Anim. Sci. 26:1024-1029.

Univ. Phil. 1958-1962. Abstract bibliography of rice. Vol. 4. University of the Philippines, College of Agr., Laguna, Philippines.

Upp, C. W. 1933. Rice and rice by-products as feeds for laying hens. Louisiana Agr. Expt. Sta. Bull. No. 248.

USDA. 1966. United States Dept. of Agr., Washington, D. C.

Van Soest, P. J. 1963. Use of detergents in the analysis of fibrous feeds. II. A rapid method for the determinations of fiber and lignin. J. Ass. Official Anal. Chem. 46:829.

Van Soest, P. J. 1963. Use of detergents in the analysis of fibrous feeds. I. Preparation of fiber residues of low nitrogen content. J. Ass. Official Anal. Chem. 46:825.

Van Soest, P. J. 1965. Use of detergents in the analysis of fibrous feeds. III. Study of effects of heating and drying on yield of fiber and lignin in forages. J. Ass. Official Anal. Chem. 48:785.

Vogel, R., I. Trautschold and E. Werle. 1969. Natural Protease Inhibitors. Acad. Press., N. Y.

Wang, C. C. and M. I. Grossman. 1951. Physiological determinations of release of secretion and pancreozymin from intestines of dogs with transplanted pancreas. Am. J. Physiol. 164:527.

White, T. W. 1966. Utilization of ammoniated rice hulls by beef cattle. J. Anim. Sci. 25:25-28.

White, T. W., W. L. Reynolds and R. H. Klett. 1969. Roughage sources and levels in steer rations. J. Anim. Sci. 29:1001.

Yasumoto, K., K. Iwani, H. Tsuji, J. Okada and H. Mitsuda. 1976. Cited by Yasumoto et al., 1977, Vitamins 50:327.

Yasumoto, K., H. Tsuji, K. Iwani and H. Mitsuda. 1977. Isolation from rice bran of a bound form of vitamin B_6 and its identification as 5'-0-(B-D-Glucopyranosyl) Pyridoxin. Agr. Biol. Chem. 41(6): 1061-1067.

Zablan, T. A., M. Griffith, M. C. Nesheism, R. J. Young and M. L. Scott. Metabolizable energy of some oil seed meals and some unusual feedstuffs. Poultry Sci. 42:619-625.

GENERAL REFERENCES

Alamanza, R. and S. Lopez. 1978. Total solar radiation in Mexico using sunshine hours and meteorological data. Solar Energy, 21(4).

Allas, T. P. 1924. Rice bran, corn and copra meals as supplement to camote vines for growing pigs. Phil. Agr. 13:253-259.

Anonymous. 1973. Solar heating and cooling demonstration Act. No. 24. Nov. 13, 14, 15.

Anonymous. 1973. Research development and the energy crisis. No. 22. November 20.

Anonymous. 1976. The economics of solar energy. Hearing before the joint economic committee congress of the U. S., 94th Congress, 2nd session, April.

Babatunde, G. M., B. L. Fetuga and Y. A. Oyenuga. 1971. The effects of varying the dietary calorie:protein ratios on the performance characteristics and carcass quality of growing pigs in the tropics. Anim. Prod. 13:695-702.

Babatunde, G. M., M. J. Olomu and V. A. Oyenuga. 1972. Determination of the optimum crude protein requirements of pigs in a tropical environment. Anim. Prod. 14:57-67.

Ballard, S. S. 1959. Infrared Physics and Technology. Proc. Inst. Radio Eng. 47:1417-1649.

Becker, C. F. and J. S. Boyd. 1957. The solar radiation availability on surfaces in the U. S. as affected by season orientation, latitude, altitude and cloudiness. J. of Applied Solar Energy. Sco. and Eng. 1:1, pp. 13-21.

Blaga, A. 1973. Plastics. Nat. Res. Coun. Canada, Div. Bldg. Res. Can. Bldg. Digest 154, Ottawa.

Bond, T. E., C. E. Kelly and Hubert Heitman, Jr. 1952. Heat and moisture loss from swine. Agri. Eng. 33(3): 148-152, 154.

Brodie, H. W. 1962. Instruments for measuring solar radiation. The Hawaiian Planters Record, 57(2): 159-197.

Buelow, F. H. 1957. Grain drying with solar heat. Paper No. 57-602. Presented at the winter meeting of the Am. Society of Engineers, Chicago, Ill. December.

Buelow, F. H. 1962. Solar energy collector design. ASAE Transactions 5(1).

Buelow, F. H. 1967. Solar energy received by inclined surfaces. Quarterly Bull. M. S. U. 49(3).

Buelow, F. H. and J. S. Boyd. 1957. Heating air by solar energy. ASAE Journal. 38(1):38.

Butli, Ken and John Perlin. 1978. The middle age of solar energy use. Solar Age, p. 74. November.

Calderwood, D. L. 1977. Rice drying with solar heat. ASAE Paper No. 77-3003.

Chaprin, D. M., C. S. Fuller and G. L. Pearson. 1954. J. of Applied Physics. 25(5):676.

Chancellor, W. J. 1965. An experiment on sun drying of paddy. The Malaysian Agricultural Journal 45(1): 65-70.

Chen, Mao-Chiang. 1977. The utilization of agricultural by-products for livestock. Ag. Assoc. of China, N. S. J. No. 97-100.

Coulson, K. L. 1975. Solar and Terrestrial Radiation. Academic Press, New York.

Davis, P. A. 1957. Eppley phyrheliometers. Exploring the atmosphere's first mile. 1:83-86.

Dore, W. G. 1958. A simple chemical light meter. Ecology 39:151.

Esmay, M. L., C. J. Flegal, J. B. Gerrish, J. E. Dixon, C. C. Sheppard, H. C. Zindel and T. S. Chang. 1975. In-house handling and dehydration of poultry manure from a caged layer operation: A project overview ASAE. Third International Symposium on livestock wastes. Paper No. 29-191 and Mich. Agric. Exp. Station J. Article No. 7202.

Esmay, M. L. and C. F. Flegal, H. Zindel, F. Hall and M. Maples. 1978. Solar energy use in livestock shelters. Annual report, M. S. U. Agric. Engineering Dept.

Esmay, M. L., Fred Hall, Charles Sheppard, C. Flegal and H. Zindel. Solar heating research project. Agric. Eng. Dept. M. S. U., East Lansing, MI 48824.

Esmay, M. L. and J. M. Moore. 1958. A mechanized poultry house for more densely populated laying flocks. M. S. U. Agric. Exp. Station Quarterly Bull. pp. 40-57.

Esmay, Merle L., B. A. Stout and H. C. Zindel. 1976. Solar energy utilization in livestock production systems. Solar energy utilization for supplemental heating of laying house in the northern states and excreta dehydration. M. S. U., East Lansing, MI 48824.

Fetuga, B. L., G. M. Babatunde and V. A. Oyehuga. 1975. Protein levels in diets for European pigs in the tropics. Anim. Prod. 20:133-146.

Forrest, J. C., J. A. Will, G. R. Schmidt, M. D. Judge and E. J. Briskey. 1968. Homeostatis in animals (Sus domesticus) during exposure to a warm environment. J. Appl. Physiol. 24:33.

Fritschen, L. J. 1963. Construction and evaluation of a miniature net radiometer. J. App. Met. 2:165-172.

Friend, M. T. 1959. Shade measurement by a chemical radiation meter. E. African Agr. J. 25:110.

Funk, J. P. 1959. Improved polythene-shield net radiometer. J. Sci. Instr. 36:267.

Geiger, R. 1959. The climate near the ground. 2nd ed., Chap. 2, Trans. M. N. Stewart et al., Harvard University Press, Cambridge, Massachusetts.

Geiger, R. 1966. The climate near the ground. 4th ed., Chap. 1, Trans. Scripta Technica, Inc. Harvard University Press, Cambridge, Massachusetts.

Giles, G. W. 1975. The orientation of agricultural mechanization for the developing countries. Part I. Published by Shinnorinsha Co. Ltd., Tokyo, Japan.

Hafez, E. S. E. 1968. Environmental effects on animal productivity. In Adaptation of Domestic Animals, Ed. E. S. E. Hafez. Lea and Febiger, Philadelphia.

Hall, Fred, M. L. Esmay, C. Sheppard and C. J. Flegal. 1977. Summer utilization of solar energy for drying poultry excreta. ASAE Paper No. 77-4536.

Hall, F. W., M. L. Esmay, C. J. Flegal, C. C. Sheppard and H. C. Zindel. 1977. A supplemental solar heater for egg production. ASAE Paper No. 77-4015.

Hall, F. W., M. L. Esmay, C. J. Flegal, C. C. Sheppard and H. C. Zindel. 1978. ASAE Paper No. 78-4558.

Harter, Leslie H. 1975. Energy Reporter. August/September.

Harrenstein, H. P. 1977. A solar world and a solar market. Annual meeting, exhibition. American Section/ international solar energy society, June 6-10 at the Hyatt House, Orlando, Florida.

Henry, Z. A. 1975. Instrumentation and measurement for environmental sciences. ASAE.

Holmes, C. W. 1973. The energy and protein metabolism of pigs growing at a high ambient temperature. Anim. Prod. 16:117-133.

Husseini, Ihsan, T. H. Short and P. C. Badger. 1977. Radiation on a solar pond with polyethylene covers and reflectors. ASAE Paper No. 77-4010.

Idso, S. B. and R. D. Jackson. 1969. Thermal radiation from the atmosphere. J. Geophys. Res. 74, 5397-5403.

Idso, S. B. and R. D. Jackson. 1972. Systematic deviations of clear sky atmospheric thermal radiation from predictions of empirical formulae. Quart. J. Roy. Soc. 98:399-401.

Jeerananda, Reddy, S. 1971. An empirical method of the estimation of total solar radiation. Solar Energy 13:289.

Kimball, H. H. 1928. Amount of solar radiation that reaches the surface of the earth on the land and on the sea, and methods by which it is measured. Monthly Weather Rev. 56:393.

Leibholz, J., J. A. Eusebio, V. A. Momongan, R. Mendoza and E. Eusebio. 1972. The protein and energy requirements of pigs under tropical conditions. Phil. Agri. 22:93-101.

Lof, G. O. G. 1962. Solar energy for the drying of solids. Solar Energy 6:122-128.

Male-Kayongo, H., D. E. Ullrey, E. R. Miller and K. K. Keahey. 1977. Manganese, calcium and phosphorus interactions in the diet of the growing pig. Ghana J. Agri. Sci. 10:39-46.

Mason, Mary A. 1979. Raising the roof on solar. Solar Age, pp. 7-9. March.

McDow, J. J. 1957. Factors affecting the design of a solar energy storage unit. Ph. D. thesis M. S. U., East Lansing, MI 48824.

McDow, J. J. and J. S. Boyd. 1958. The storage of solar energy. ASAE Paper 58-206.

McLaughlin, M. M. 1978. Agricultural technology transfer and value conflicts in developing nations. A paper presented in panel discussion. Developing and marketing equipment for small farms in developing nations. Illinois.

Morrison, S. R., T. E. Bond and Hubert Heitman, Jr. 1967. Skin and lung moisture loss from swine. Transactions of the ASAE 10:691-692, 696.

Noland, P. R., K. W. Scott and A. W. North. 1961. Rice bran studies for swine rations. Rice J. 64(1):19.

Notaridou, V. A. and D. P. Lalas. 1979. The distribution of global and net radiation over Greece. Solar Energy, 22(6).

Ogawa, M., K. Tanaka and Z. Kasai. 1975. Isolation of high phytin containing particles from rice grains using an aqueous polymer two phase system. Agr. Biol. Chem. 39(3):695-700.

Page, J. K. 1964. The estimation of monthly mean values of daily total shortwave radiation on vertical and inclined surfaces from sunshine records for latitudes 40°North 40°South. Proc. UN Conf. on New Sources of Energy, 4:378.

Palafose, A. L. and M. M. Rosenberg. 1952. A comparison of corn, brown rice and wheat in chick rations. World's Poultry Sci. J. 8:6-12.

Panda, B. and S. M. Guple. 1965. Utilization of rice by-products in animal industry. J. Food Sci. Technol. 11:120-123.

Peck, E. C. 1962. Drying lumber by solar energy. Sun at Work 3d:4-6.

Pierce, Norton T. 1978. Low cost concentrating collectors. Solar Age. February.

Pond, W. G. and J. H. Maner. 1974. Swine Production in Temperate and Tropical Environments. W. H. Freeman and Co., San Francisco.

Proceedings of symposium on use of solar energy for poultry and livestock production. Auburn University, Auburn, Alabama. Jovonn Inn, November 9-10, 1978.

Sanderson, R. D. 1979. A Michigan Builder Goes Solar. Solar Age, p. 21. January.

Saunders, R. M., H. G. Walker, Jr. and G. O. Kohler. 1968. The digestibility of stem-pelleted wheat bran. Poultry Sci. 47:1636-1637.

Schulze, W. D., S. B. David, J. D. Balcomb, Katson, S. Noll, F. Roach and M. Thayer. 1977. The economics of solar home heating. January.

Sobel, A. T. and F. H. Buelow. 1963. Galvanized steel roof construction for solar heating. ASAE Journal, 44(6).

Solar Age Catalog. Copyright 1977 by Solar Vision Inc. First printing, September 1977.

Stephen, J. and N. C. Ganguli. 1976. A note on effect of heat treatments on casein micelles in relation to rennet action. Indian J. Anim. Sci. 46(8):450-451.

Summers, J. D. 1973. Feed wastage: Some ways to control it. Shaver Focus, 2(3).

Susmi, V. E., M. Franssila and N. F. Islitzer. 1954. An infrared net radiation instrument. J. Meteorol. Quart. J. Roy. Met. Soc. 89, 339-348.

Tanner, C. B. 1963. Radiation. Basic instrumentation and measurements for plant environment and micrometeorology. Soils Bulletin 6, November.

Thekaekara, M. P. 1973. Solar electromagnetic radiation. NASA space vehicle design criteria monograph. SP8005, rev. 1973, pp. 37.

Toit, J. de V. du and P. A. Boyazoglu. 1975. Amino acid composition of some South African feedstuffs. S. Afr. J. Anim. Sci. 5:1-6.

Trice, James B. 1979. Industrial process heat. Solar Age, pp. 22, March.

Turner, L. W., A. C. Dale and B. A. McKenzie. 1977. Solar heating for home, farm and small business. AE 88. Cooperative extension service. Purdue University, West Lafayette, Indiana.

Weather Measure Corporation. Solar Radiation, Instruments and Services for Environmental Sciences and Industry. Catalog 975.

Weiss, Charles and Simon Pak. 1976. Developing country applications of photovoltaic cells. Paper presented to the ERDA National Solar Photovoltaic Program Review Meeting, San Diego, California, January.

Wilson, B. W. 1961. The role of solar energy in the drying of vine fruits in U. N. Conference on New Source of Energy E 35-S4, Rome.

Woodwell, G. M. 1970. The energy cycle of bisphere. Scientific American 223(3):64-97. September.

World Meteorological Organization. 1962. Guide to meteorological instruments and observing practices. Ch. 9 (Revised).

Yellott, J. I. 1978. Solar radiation and its uses on earth. Energy Primer, pp. 30-87. Published by Dell Publishing Co. Inc., Dag Hammarjold Plaza, New York, NY 10017. 2d edition.