INFLUENCE OF PARTICLE SIZE OF FEED AND PLANE OF FEEDING ON GROWTH, PHYSIOLOGICAL REACTIONS AND CARCASS CHARACTERISTICS OF GROWING-FINISHING PIGS

By

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CERTIFICATE - I

This is to certify that this dissertation entitled," Influence of particle size of feed and plane of feeding on growth, physiological reactions and carcass characteristics of growing-finishing pigs", submitted for the degree of Ph.D., in the subject of Livestock Production and Management of the Haryana Agricultural University, is a bonafide research work carried out by Sri. Kurien Thomas, under my supervision and that no part of this dissertation has been submitted for any other degree.

The assistance and help received during the course of investigation have been fully acknowledged.

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CERTIFICATE - II

This is to certify that the dissertation entitled, "Influence of particle size of feed and plane of feeding on growth, physiological reactions and carcass characteristics of growing-finishing pigs", submitted by Sri. Kurien Thomas to the Haryana Agricultural University in partial fulfilment of the requirements for the degree of Ph.D., in the subject of Livestock Production and Management has been approved by the Student's Advisory Committee after an oral examination on the same, in collaboration with an External Examiner.

Major Advisor

4.1.1982

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Dated: Hissar,
21 9 81

D E D I C A T E D

TO MY

MOTHER, BROTHERS AND SISTERS.

C O N T E N T S

1. INTRODUCTION

The primary purpose of pig farming all over the world is the production of meat; secondary considerations are the production of pig skin, bristles and manure. The F.A.O. estimation (Anon, 1981) of pig population in India for 1980 was 10 millions and the total pork production was of the order of 70,000 tonnes. Pork constituted 7.4 % of the total meat production of the country during the three calender years 1970-73 (Anon, 1976). Pig farming fits ver well in mixed farming and can also be complimentary to intensive crop production operations. In India, pig farming has a special significance as it can play an important role in improving the socio-economic status of a sizeable section of the weaker rural community. Pig rearing, by and large remains in the hands of these people. They do not possess the technical know-how of pig production on modern lines. With the adoption of improved rearing practices applicable under rural conditions, there will be significant increase in the income of some of the poorest people in the country who traditionally rear pigs.

Before the advent of Second Five Year Plan, virtually no attempt was made to popularise pig rearing on scientific lines. The pig population remained more or less stationery from 1951-66 (4.5 - 5 million). The pig population has increased to 6.5 millions in 1972 which constituted a growth of 28% over that of 1966.

There is scanty data on economics of pig farming in India. The major expense is on the feed and it accounts for 70-80% of the total cost of pig production. A good balanced pig ration contains 70-75% grains, mainly yellow maize. Grains, rice polish or bran, oil cake and fish meal constitute almost 95% of good pig ration in India at presen Maize is the chief source of energy in pig rations. Researc on utilization of agro-industrial by-products for pig feeding has not received adequate attention so far in this country. Protein requirement in pig rations is mostly met by various oil cakes and fish meal. Scarcity of good quali fish meal is being felt for the past few years.

The pig farming can be made remunerative mainly by keeping feed cost low, rearing pigs having high feed conversion efficiency and by ensuring remunerative price for the products. Under the prevailing shortage of grains, attempts should be made to use more of agricultural and industrial by-products in place of grains to the extent possible in pig rations without adversely affecting performance.

The nutritional requirements of various classes of pigs under temperate climate have been extensively studied and documented in developed countries. The feeding standards thus evolved like the ARC feeding standards, are relatively accurate under conditions available in those countries. But they may not hold good under hot tropics where ideal management conditions are hard to find.

The baby piglet at birth does not appear to posses a very efficient temperature regulating mechanism. It is incapable of protecting itself against either excessive heat or cold. As the pig grows the optimal air temperature for maximum live weight gain and efficiency of food conversion changes. Mean annual ambient temperature in most area of the tropics are only a few degrees above 26°C so that pigs weighing 30-65 kg are probably being reared under almost optimal environmental conditions, but as the pigs grow older and heavier, normal tropical temperatures would be too high for maximum productivity. Thus in the tropics the aim should be to raise a porker weighing approximately 55-65 kg and not bacon or lard pigs weighing 90-110 kg. During the day time particularly in the summer, tropical air temperatures are usually well above 26°C and large fatteners as well as sows and gilts may require some amelio-rations from hot or humid environment if they are to produc at an optimum. Under such conditions, relief from adverse effect of the hot days can be obtained by the provision of adequate shade and water sprays or wallows. More over, it is natural to expect differences in nutrient requirements of various classes of swine under tropical climatic conditions considering the inherent weaknesses of the species in homeothermic mechanisms.

The nutritional requirements of different classes of pigs of different age groups viz., sucklers, growers, adults etc. for rearing under various climatic conditions in this country have not been adequately studied. The optimum protein-energy ratio in the rations is likely to vary in different environmental conditions.

There is variation among pigs in the amount of lean meat produced per unit of feed consumption. The effect of restricted feeding practices on meat production have to be explored under the conditions prevailing in India. Restriction of feeding can be done by controlling the energy content of feed or by limiting the total quantity of feed intake or time allowed for eating etc. Various feeding practices may markedly influence the carcass composition.

With the foregoing resume as background the present investigation was set with the following objective

i) to find the effect of particle size of feed on growth and feed conversion efficiency,

ii) to determine the effect of three levels of energy intake in growing pigs on growth, feed efficiency and carcass characteristics.

iii) to assess the variation in physiological reactions under different feed treatments.

iv) to determine the feed cost of body weight gains in pigs fed different levels of energy and diet of varying particle size, and

v) to determine whether the nature of feed has any influence on the incidence of gastric lesions in growing pigs.

2. REVIEW OF LITERATURE

The very fact that swine enjoy a world wide distribution show that it can thrive in extremes of climatic conditions. However, the agro-climate, the plane and method of feeding, breed and management can profoundly influence the growth, feed utilisation, meat quality and eventually the net returns from them.

Plane of feeding

Protein level of feed :

It is well established that when the animal grows, it gains weight (Seymer et al., 1964; Walker et al., 1972; Frlond, 1977). Concomitant with the weight increase, lean tissues are also synthesised by the animal; but the proportion of muscle in weight gain tends to decrease and that of adipose tissue increase.

The increase in rate of deposition of energy in the form of lipids is rapid, whereas the deposition of nitrogen is relatively constant. The energy value of protein deposited in these conditions as percentage of metabolizable energy consumed decreases rapidly between 20-60 kg live weight (17.7 to 10.5%), then more slowly from 60-100 kg live weight (10.5 to 6.7%) and finally very slightly between 100 and 170 kg live weight (6.7 to 5%). According to Robinson (1964) and Holme et al. (1965) the efficiency of nitrogen retention is about 52 per cent in pigs weighing 35 kg. It decreases to about 35 per cent at 100 kg and 22 per cent at 160 kg. Hale and McCornick (197 have observed that the growth, feed efficiency and carcass of pigs fed on a diet with 16 per cent crude protein to about 50 kg and 13 per cent from there to slaughter at 97 kg were similar to those given 15 per cent throughout the finishing period. Jollie et al. (1973) reported a significantly higher growth rate in pigs on 16 per cent crude protein throughout than when reducing the protein level successively from 16 through 14 to 12 per cent.

The influence of sex on body composition is clear and well established. It is seen at a given weight, femal are leaner than castrated males (Lucas and Calder, 1956; Wallace et al., 1959; Robinson and Lewis 1964; Bell, 1965) This may be due to the difference in the hormonal balance and lower volume of feed intake in the female (Blair et al 1969 b). Bayley and Summers (1968) reported that the males had a higher growth rate. But they observed that the feed conversion is less efficient in males. Proportion of edible tissue is higher in the male than in the female and higher in the female than in the castrated male. The females deposit more nitrogen per day than castrated males by about 5 per cent between 24 and 50 kg and 10 per cent between 50 and 80 kg body weight (Kerat, 1972; Seerley et al., 1978). With diets to pigs varying from 12 to 20 per cent protein and metabolizable energy 2900 to 3700 kcal per kg, Cromwell et al. (1978); Seerley et al. (1964) have observed a faster gain, larger eye muscle area and a higher percentage of lean cuts as the protein percentage is increased. The protein supply should also be optimum in relations to the energy supply, the growth and the body composition characteristics becoming poorer if the supply is lower or higher than this optimum. Many research workers are still interested in the influence of protein in the diet on the performance of pigs. Most of these studies concern in particular the growing finishing period and an analysis have been made not only of growth but also of body composition (Robinson et al., 1964 b; Seymour et al. 1964; Smith et al., 1967; Blair et al., 1969 a, b). Widely varying conclusions were drawn by these authors in estimates of the neccesary nitrogen level.

Young et al.(1968) showed that during the growth period there was a linear increase in growth rate and a curvilinear reduction in feed efficiency when protein content of the diet was increased from 15.5 to 19.2 per cen protein level during the finishing period varying from 17.4 to 14 per cent did not affect the growth rate but feed efficiency decreased with the fall in the protein level. Replacement of the diet for the finishing period according to Robinson et al. (1964 a) must not be made too early. The reason is that even though weight gain is not affected by change in the diet at 36 kg live weight, the feed efficiency may not be as good as in the pigs having changed diet at higher live weight. Studies carried out by Blister and Wahlstrom (1973) indicated that dietary protein levels of 16 and 12 per cent fed during periods of 20-45; 45-113 kg body weight respectively were adequate for daily gains. However, they suggested 18, 14 and 12 per cent protein levels for maximum efficiency during the above periods.

Energy and protein relationship :

Energy and protein or amino acid content relationships have been the subject of study in the growing and finishing pigs (Robinson and Lewis 1964; Robinson et al., 1964 a). Increase in the energy content in the diet reduces the feed intake (Waldern, 1964; Seerley et al., 1964). This can cause a deficiency in protein intake if the energy protein ratio is not properly maintained. According to Clawson (1967) decrease in feed intake occurs only when the protein supply is inadequate both in quality and quantity. The level of amino acids in the diet should increase with a higher lipid content because of the accompanying reaction in feed intake (Anderson and Bowland, 1967). Inclusion of 9 per cent fat in the diet had been found to increase the feed efficiency by 8 per cent (Seerley et al., 1978).

In contrast to the lipid level, the level of cellulose affects the performance of growing pigs. It increases the dry matter intake but it is insignificant to compensate the decrease in energy value of the diet. Altho there is a higher intake of protein, the growth is a littl slower. This may be due to less lipid being deposited (Beacom 1963). Addition of cellulose or lipids to cause small variations in the energy content of the diet have not been found to affect nitrogen retention (Anderson and Bowland, 1967).

Ashton et al. (1955) and Bowland and Berg (1959) reported deleterious effects on carcass quality of high energy rations and supplemental fat. Clawson and coworkers (1962) and Seerley et al. (1964) were unable to demonstrate that addition of animal fat in diets of growing pigs significantly affected carcass leanness.

In order to reduce the fatness of hogs at slaughter, feed is often restricted during all or part of the finishing period. This does not, however, change the daily nitrogen retention. On isonitrogenous rations containing N.R.C. standards 10 or 20 per cent less of digestible energy during an experimental period of 23 weeks Mallikarjuna et al. (1978) concluded that rations having 10 per cent lesser energy than N.R.C. standards proved most effective in pigs in terms of feed efficiency and economy of feed conversions. The relation between feed restriction and protein supply for optimum growth need further study since it is still a controversial subject and it has not been possible to draw a definite and valid conclusion.

Limited feeding :

The method of feeding to be used in feeding growing finishing pigs is one of the important decisions that a swine producer must make. If the pigs are to be marketed early, self-feeding or full-feeding is generally more profitable than limited or restricted feeding. Without serious consequences, in limited feeding the ration can be reduced to about 80 per cent of the full-feed. Reducing feed intake to this extent from the time the pigs weigh about 55 kg will postpone the time they reach 90 kg by about 10 days (Krider and Carroll, 1971). Limiting the ration to some extent produces carcasses that carry som what less fat than full-fed hogs do, which is highly desirable. Restriction of energy in the diet during growing finishing period Sharda et al.(1977) observed a reduction in the average daily gain of market pigs.

When the feed of pigs in dry lot is restricted to only one-half to two-third of a full feed, they generally make slow gains and require larger amount of feed to attai market weight. In experiments where the feed of pigs has been only slightly restricted and they have been fed about three-fourth of a full ration until ready for market, the rate of gain has been about three-fourths as rapid as full feeding (Morrison, 1951).

Crude fibre content of the feed :

Except on some occasions where there is a delibe-rate introduction of large quantities of fibrous materials in an attempt to improve the carcass quality, the diet of the growing pigs normally does not contain more than 5-6 per cent crude fibre. The physical characteristics of the fibrous constituents in both cases can vary. Depending on the level of crude fibre in the diet, the availability of digestible energy per unit weight of material can vary. The higher the crude fibre level, the lower the available digestible energy per unit weight of the diet. Lower inclusion levels which gives an energy dilution effect did not always produce reduced growth rate (Becker et al., 1965)

It is still clearly not demonstrated that the diet with fibrous materials with the sole purpose to reduce the available energy per unit weight of diet will lower the energy intake, reduce growth rate and carcass quality. Bell and Cigyk (1954) reported that increasing the cellulose inclusion level of the diet caused an enhanced growth rate rather than decrease. This is because the lower caloric density diet has caused stimulation of appetite there by an increase in energy intake (Dohman et al., 1955). On the other hand Cole et al. (1967 a) were unable to show that increasing the fibrous level of the diet affected the intak of energy and Cole et al. (1967 b) could not find any effec on feed intake from isocaloric diets varying in crude fibre content.

Fibre ingredients such as rice bran and grass meal are normally used as fibrous rich materials. Their quality is widely varying. The type of fibrous material used may be important also in affecting the animal responses. Troelsen and Bell (1962) compared alfalfa meal, ground corn cobs, cellulose, wheat bran and oat husk as fibrous diluents and found that daily food intakes were very much dependent on the source of fibrous materials used. In all cases the digestible energy intake was decreased as the crude fibre level increased. Barley hulls modified the intake more than the wood cellulose (Larson and Oldfield, 1960). In order to determine the effect of high density fibrous diluents Baker et al. (1968) compared high density diluents such as sand with low density diluents such as cellulose and found that sand dilution upto a level of 40 per cent gave a compensatory feed intake. The rate of growth was not depressed until sand level had reached 20 per cent of the diet, whereas a 40 per cent gave a compensatory feed intake. The rate of growth was not depressed until sand level had reached 20 per cent of the diet, whereas a 40 per cent level of cellulose dilution gave a linear reduction in growth rate and carcass quality (Baird et al., 1970). These observations lead to the conclusion that fibrous materials can improve the carcass quality provided it results in a reduction in the energy intake

The fibrous constituents may actually affect the availability of other nutrients (Cunningham et al., 1962). Neither fat deposition nor the muscle development is altered significantly as digestible energy intake are held constant (Baird et al., 1970). The pig develops a compensatory increase in feed intake response to diets containing increasing levels of fibre (Owen and Ridgman, 1967; 1968). Besides according to Cole et al. (196u) this is markedly affected by the previous nutritional status of the animal.

Physical form of feed

Processing of cereals :

Cereals constitute a high percentage about 50-∞ per cent of most pig rations and therefore the nature of processing of this component can influence the physical form of the diet.

The rate of intake in restricted feeding or total intake in ad lib feeding can be affected by the physical form of the diet. Whole barley based diets have been found to be less a acceptable than finely ground (Lawrence 1972). In maize based diet Maxwell et al. (1970) have found that smaller particles were more acceptable to pigs than larger ones. When sorghum forms the base of the diet in some cases whole sorghum has been reported as having be eaten more readily than sorghum in either coarsely or finely ground forms. Wheat becomes pasty and stick to the mouth of the pig, when it predominates in ground form (Lawrence 1972) and to overcome this Cunha (1957) suggeste that wheat grains should be fed whole. According to Pelli (1962) coarsely ground or rolled wheat is more palatable.

Feed intake, digestion and digestibility :

In several animal species, the appetite is regulated by the action of the 'satiety' and 'appetite' centres situated in the hypothalamus. This has been verified in the pig also (Khalaf and Robinson, 1969).

By means of duodenal re-entrant fistulae the digestive transit and especially emptying of the stomach has been studied (Furuya and Takahashi 1980). About 45 per cent of the dry matter as emptied of the stomach within two hours of feeding (Rerat 1972). The emptying process is discontinuous. The movement of liquids precede solids. The amount of feed ingested is partly regulated by the degree of filling of certain segments of the small intestine and the rate of emptying varies with the nature of feed. The crude fibre is digested mainly in the large intestine (Slivitskii, 1979; Furuya and Takahashi, 1980). Cole et al. (1967 b) reported that rations containing 12.9 per cent crude fibre produced no reduction in the energy of pigs while Cole et al. (1968) observed that increasing the level to 13.5 per cent had caused a reduction in voluntary intake Oat feed was the diluent in both studies. It appears that source and level of crude fibre has a direct bearing on the digestibility of its own as well as on other components.

The pig is a poor masticator of food and therefore, the whole grains are more poorly digested than those which have been rolled or ground to varying degrees of fineness (Young 1970) and a high percentage of grains pass through the alimantary tract undigested. The differences in particle size such as coarse and fine would impart a difference in the digestibility but of a small magnitude (Pickett et al., 1969). Simonsson (1978) could not find significant effect in daily gain and feed conversion efficiency in pigs fed with barley based meals varying in particle size from 1.25 to 5.25 mm. Similar observations were made by Dobson et al. (1978) in pigs maintained on wheat and barley based diets finely ground or pelleted. This is in contrast to Ehrensperger et al. (1976) who reported that the use of meals of less than one millimeter particle size produced significant increase in weight gain The literature documented on the subject is mainly on meals based on grains. It is not known whether variations in particle size of meals based on tuber materials like tapioca (Cassava) would produce any pronounced effect in growing finishing pigs.

Gastric lesions and nature of feed :

Since the specific reference to an esophagogastric ulcer by Bullard (1951) there have been several reports of the high incidence of this condition ranging from hyper-keratinisation through erosion to ulcers in swine mainly on maize based pellet feeds (Gamble et al., 1967; Blackshaw and Kelly, 1980). In other comparable trials such as pelleting of mixed feed with 80 per cent barley, Reese et al. (1966) could not establish stomach lesions. According to Pickett et al. (1969) it is not pelleting but fine grinding of maize that causes ulcers. Results of certain trials (Mahan et al., 1966; Huwer et al., 1967; Reimann et al., 1968) show that fine grinding by itself favours ulcer. According to Fugate et al. (1965) there is a definite connection between amount of lying space for animal, time of year and occurrence of stomach ulcers. It must be emphasized that stomach lesions in question had no adverse effect on weight gain or on feed utilisation. On the contrary only seldom was there an increased mortality (Dobson et al., 1978).

pH of the stomach :

The differential effects on pH changes at pyloric/fundic junction of the stomach on feeding barley of varying particle sizes have been observed by Lawrence (1972). In pigs fed with coarser particles, the digesta was less fluid than with finer particles, induced an acid environment at the pyloric/fundic region. Moreover, the particles produce stools of a higher dry matter content. These indicate that the gut environment could be affected markedly by the physical form of barley in the diet. Lawrence (1972) found that the pH of pyloric/fundic junction of the stomach was significantly lowered when bran was added to the diet. Soether et al. (1971) found that the polar (alcohol) extracts of oat husks significantly affected the gastric acid secretion. Lawrence (1970) has shown that the pH of the stomach depends on the frequency of meals and on the degree of grinding of the food. On wheat based diets Cuperlovic et al. (1975) reported that the pH of the digesta in stomach was slightly higher with pellets, 4.7 and 4.9 for soft and hard pellets and 4.1 for loose diet while on barley based diets Simonsson and Bjorklund (1978) observed that the pH ranged from 3.0 to 4.3.

Physiological reactions

Like all animals the pig is a homeotherm. The actual range over which the individual pig can maintain its temperature over long periods depends on factors like age and size. First attempt to relate weight gain in swine to air temperature over a range of temperature under controlled conditions were reported by Heitman and Hughes (1949) and shows the relationship of air temperature and live weight and average daily gain. Studies have shown that when the environmental temperature decreases from the level of thermal comfort and passes below a threshold, the animal has to resort to the chemical regulation of its central temperature, that is, the animal produces more heat to maintain the body temperature. To satisfy its supplementary expenditures, the animal must increase its feed intake, an increase which is sometimes very high (Heitman et al., 1958). This reaction could be utilised in countries with cold climate, An increased intake of cereals would allow the nitrogen requirement to be satisfied in the finishing animals without any supplementary protein concentrate. For the same intake of nitrogen, nitrogen deposition is high in pigs at temperatures of 15 or 23°C, it decreases considerably when the temperature is low or high (Stahly et al., 1979). When the air temperature is low, nitrogen deposition is reduced more than the growth rate resulting in an increase in lipid deposition. Such results were found by Fuller and Boyne (1971) at different feed intakes imposed at different temperatures. Although when the values were adjusted to the same feed intakes per unit body weight, there was no significant effect of temperature on nitrogen or fat content of the body. Martin and Leboute (1979) observed that barrows ate more in the hot season and gained less weight daily and reached 100 kg weight at an older age. According to Close and Mount(1978) the critical temperature of the pigs depend on the feed intake and decreases from 23.1°C in the morning to 20.7°C in the afternoon. The extra feed required to meet the extra thermoregulatory heat production was 0.65 g per kg body weight daily. According to Seymur et al. (1964) there is a significant interaction between the effects of protein and temperature on feed required per unit gain during the early growing period in summer and on the per cent yield of lean cuts in winter. Joshi et al. (1977) observed a two fold increase in body weight gain when high ambient temperature stress of hot dry season was ameliorated by keeping the pigs in artificially cooled chamber environment (18.5°C with the vapour pressure 10 mm Hg) for 8 hours daily for 7 weeks. Unprotected pigs consumed significantly more feed than the protected. Joshi et al.(1976) studied the seasonal variations in feed consumption, water intake, rectal temperature and respiration rate on sows during summer, rainy and winter seasons. They have found that feed consumption was significantly higher during winter than during summer or rainy and there was no significant diference in intake between summer and rainy, but it was negatively correlated with air and body temperature. They have observed further that the rectal temperature and respiration rate followed a trend similar to seasonal fluctuation in ambient temperature.

It is generally accepted that pigs eat to satisfy their requirement, however, temperature can influence energy intake and rate of gain (Bond et al., 1952; Mangold et al., 1960). High ambient temperature decreases feed consumption with minimal effect on feed efficiency, whereas low temperature increases feed consumption and decreases efficiency due to expense of heat production for maintenance of body temperature.

Investigations by Forbes and Swift (1944), Forbes et al. (1946 b) and Swift and Black (1949) showed that heat increment is variable for nutrients and generally increases from fat, carbohydrate to a high value with protein. Since nutrient is seldom metabolised alone, the heat increment of specific dynamic effect of a feed is directly affected by the combination in which the nutrients are fed. The resulting values are less than for an individual nutrient. A proper nutrient combination should decrease the cost of metabolism. Of the combinations studied, the heat increment was lowest with protein and fat mixtures according to Seerley et al. (1978).

Mount et al. (1980) observed that variations in air temperature within the ambient temperature range of

8-20°C had no significant effect on gain but increase of wind speed to 0.8 m/s at 12°C resulted in reduced gain.

Haemoglobin content of blood :

Milk is exceedingly low in iron and also in copper and it is not possible to increase the amount of these minerals by feeding the sow. When suckling farm animals are not allowed to other feed as soon as they will take it, these generally suffer from anaemia. This condition is often serious in piglets. It can be prevented by parenteral administration of iron preparations or supplemented through feed (Morrison, 1951). Barber (1956) observed a haemoglobin decline in indoor reared pigs than those reared outdoor. Updike (1960) reported a normal value as 9 g/100 ml upward.

Carcass characteristics

The pork quality has been understood in many ways by people related with the meat industry. Meat quality in general conveys a degree of excellence in a product. 'Quality indicators' are being used to evaluate degree of quality. Each segment of the livestock and meat industry has its own quality indicators. For a packer, meat quality is meant as maturity, marbling, texture, colour and firmness while a consumer thinks quality as tenderness, juiciness and flavour of cooked product. Health officials and nutritionists view it as clean, wholesome nutritious meat item for consumption and pork producer considers quality in terms of hair colour, bone refinement, hide thickness and head size (Hendrickson, 1972).

The consumer demand for pork is dependent on its quality. The consumer depends to evaluate the quality on visual indicators such as marbling, colour and firmness. Since these are associated with the processing characteristics of the cured product, they are important to the processor as well.

Feed and pork quality :

Cuts from hogs slaughtered at weights ranging fro 90-100 kg is preferred by the average consumer in the west Light weight hogs under 80 kg would yield only small cuts and lack the desired quality, texture, substance and firmness. Firmness is one of the most important factors in determining quality of pork products. Oily and soft carcasses are unattractive and difficult to merchandise and they are bought at a discount (Krider and Carroll,197

Feeds that are rich in unsaturated fats such as those in groundnut, if fed liberally produce soft carcasse because the soft fat reappear largely unchanged in the fatty tissues of the pig (Maynard et al., 1979). Garbage, rice bran and polish, buck wheat and unmilled oil seeds also have a softening effect in the carcass (Morrison,1951)

The different parts of the pig's body develop at different rates during different periods in its life. It is possible to vary these rates by raising or lowering the level or plane of nutrition, producing pigs with quite different carcass characteristics. By modifying the plane of nutrition, it is possible to produce bacon type and lard type hogs from swine having the same genetic make up. Experiments of McMeekan (1940, 1941) show the effects of different rates of feeding during different segments of the pigs development on the carcass characteristics of hogs fed to a final weight of 90 kg.

Dressing percentage :

Ensminger (1960) defined dressing percentage as the percentage yield of chilled carcass in relation to the weight of the animal on foot. Because the hogs have a small capacity for the alimentary tract, fill is less important in determining dressing percentage than is the case with cattle. The degree of fatness and the style of dressing are the important factors affecting dressing percentage in hogs. U.S.No.1 hogs dressed in packer style (with head, leaf fat and kidneys removed) dress about 69 per cent whereas hogs dressed shipper style (head left on, leaf fat and kidneys in) dress 4 - 8% higher(Ensminger,196

According to Glister and Wahlstrom (1973) carcass length and dressing percentage were unaffected by dietary protein level.

Shrinkage :

Shrinkage in live animal seems to be more a factor of distance than of mode of transportation. It is heaviest during the first 160 km or so. The great majority of hogs these days go between farm and market by truck. Extremes in temperature and humidity affect shrinkage. Shrink increase with increasing humidity and time in transit (Krider and Carroll, 1971). According to Maynard et al. (1979) there exists a fat-water relationship in adipose tissue which may have bearing on the amount of shrink in animals rapidly fattened. Besides shrink of live animal, a further shrink may be expected in carcass which may vary from 1-4 per cent depending on the duration the pigs were fasted prior to slaughter (Bowland and Standish, 1966).

Carcass length :

The extent or lean contents is of prime importance in these days and the length of carcass at any given body weight is regarded as an indication to it. At any given weight, the longer carcass on an average yields better cuts than short and deep. The carcass length of acceptable meat type swine slaughtered at 100 kg should be from 73.7 to 78.7 cm (29-31 inches). Studies carried out at Indiana Swine Evaluation Station showed that average carcass length has remained between 74.9 and 76.2 cm (29.5-30 inches) and 80 per cent of the carcass have measured 73.7 cm (29 inches) or more in length. A correlation has been established between carcass length and backfat thickness (Rice and Carroll, 1971).

Back fat thickness :

Hankins and Ellis (1934) were first to report the relationship between backfat measurements of a split carcass at different points and total body fat content. The actual fatness of a pig carcass can be estimated in different ways and the order of the methods in decreasing accuracy according to Warner et al. (1934) is chemical analysis of the entire carcass, chemical analysis of certain representative cuts, yield of particularly fat or lean cuts and measurements of certain parts of carcass such as thickness of back fat at rump, midback or shoulder. The thickness of back fat has long been recognised as an important measure of carcass quality. In the carcass, the back fat thickness is usually measured at several points such as the first rib, last rib and last lumber vertebra.

Hazel and Kline (1952) described a method of measuring back fat thickness in the live animal. There are several other methods for the determination of back fact thickness on the live hog. These mechanical tools are probe, lean meter and sonoray. The official U.S. standards for grades of barrows and their corresponding carcass show the relationship between average thickness of backfat, carcass length or weight and grade for carcasses with muscling typical of their degree of fatness (Krider and Caroll,1971

Eye muscle area :

Investigations were carried out long back by Mc Meekan (1941) to establish a relationship between loin area and total weight of muscle in the carcass. Hankins and Hiner (1937) first proposed that loin eye area measurements be made at the last rib. It is one of the better indicators of muscling presently in wide use and is critically evaluated by informed consumers in the selection of chops or loin roasts. At slaughter the outline of the eye muscle in between the tenth and eleventh rib is traced on a transparent paper and the area is then calculated by placing it over a graph paper or measured more accurately by means of a planimeter. Certification programme adopted by various Swine breed associations use a minimum loin eye area between tenth and eleventh rib as one of the requirements for certification. It has been observed by

Glister and Wahlstrom (1973) that pigs maintained on diets containing 10-20 per cent protein levels during the growth phases 20-45; 45-77 and 77-113 kg that the eye muscle area was decreased and fat content increased on 12 per cent protein level from 20-45 kg or on 10 per cent level from 45-113 kg.

Marbling :

It has been shown that colour and firmness of the carcass are associated with some important traits in the live hog. Examination of certain market weight hogs which were poorly adapted to stress, their carcass were found to be soft, watery and pale or very dark (Rust and Topel, 1969). Marbling, colour and texture are heritable. The degree of marbling is associated with juiceness and tenderness of pork. But an abundant marbling is undesirabl The extent of marbling can be influenced by the level of protein in the ration - the higher the level of protein the lower the degree of marbling and quantity of marbling in one muscle does not necessarily reflect the quantity in other muscles in the carcass (Henrickson, 1972).

Colour and firmness :

The reaction of the pig to preslaughter stress and its ability to adapt to stress influence the colour and firmness of pork. Pigs which have poorly adapted to stress show a high muscle acid content as an end product from rapid breakdown of muscle glycogen. Prolonged stress depletes the muscle glycogen to produce little acid after slaughter and the carcass will be dark and firm (Henricksen, 1972). On the other hand, pale soft muscle has a high acid content which also is undesirable in regard to its palatability, acceptability and keeping quality. Consumers seem to prefer an intermediate colour between dark and pale (Rust and Topel, 1969). The colour of lean adds little to the availability of meat, but it is important to promote sales since attractive well coloured meat cut appeals to consumers. Young animals have less pigment in their meat and hence less colour than older ones. The meat colour is associated with the amount of iron pigments, myoglobin, hemoglobin and Cytochrome C present in the muscle (Henricksen, 1972).

The fat and red muscle tissue are supported by the connective tissue frame work. The muscle and connective tissue are proteins but react differently to heat treatment. The kind and amount of amino acids contained in the proteins influence the tenderness of meat. In this respect according to Tokarev (1978) the meat of hybrid pigs has a high content of protein and lower content of fat. Further, the amount of amino acid composition in the meat of hybrid pig is better than Large White pigs.

Texture is an indicator of tenderness and influenced by the size of muscle bundles. Finer texture is imparted by smaller bundles and, therefore, the finer the texture the more tender the meat. The diameter of the muscle fibres is increased with increasing age but within an age group the diameter has little influence on tenderness (Henricksen, 1972).

Soft pork :

Certain feeds especially soybeans, peanuts, rice bran and rice polish tend to produce soft pork when fed to pigs in considerable amounts. The products from hog carcasses that are soft are undesirable from the standpoint of both the processor and the consumer and, therefore, sell at a decided discount (Morrison, 1951).

Lean cuts :

The yield of primal cuts viz., ham, loin, shoulder, side/bacon and particularly the per cent ham (Hazel and Kline, 1959) or per cent ham, loin and shoulder (Clawson et al., 1962) have been considered a good measure of carcass value.

It is well established as concluded in the review by Morgan and Robinson (1962), Hoye et al. (1963), Hays

(1968) and Moser (1977) that dietary protein and energy levels affect performance of pigs and ratio lean: fat in carcass and hence the yield of edible tissues. However, there is less evidence as to whether these changes actuall influence the eating quality of the meat. Research by Wagner et al. (1963), Wyllie et al. (1969), Brows et al. (1971) and Cromwell et al. (1971) indicated that the muscl longissimus dorsi is markedly influenced by the level of dietary protein. Intramuscular fat content, again a factor influenced by the feed has been reported to affect the physical and sensory scores of pork (Batcher and Dawso 1960; Henry et al., 1963; Kaufman et al., 1964; Miner et a 1966).

Economics

In raising fattener pigs, cost of feed is found t be the major item in the total cost of production. In a study of several hundred farms in U.S.A. it has been foun that feed cost works out to about 72-74 per cent of the total cost from weaning to market and labour constituted about 7 per cent (Krider and Carroll, 1971).

The feed cost of raising 1 kg live weight of growing-finishing Middle White pigs, Ranjhan et al.(1971) reported as Rs.2.57 and 2.01 when the rations contained digestible energy levels of 3234 and 2838 kcal, respectively, at a constant crude protein level of 20 per cent. The cost of feed per quintal was Rs. 63.20 and Rs.49.00, respectively. Dhudapker et al. (1971) reported from the same station, the cost of feed per quintal was Rs.62.00, Rs.60.00 and Rs.58.00 when the digestible energy levels in the rations for growing finishing pigs were 100 per cent, 90 per cent and 85 per cent of NRC standards, respectively at a crude protein level of 18 per cent.

The generation of profit to the extent possible in raising pigs depends on several factors such as the pig itself, feed, market, management etc. working in harmony.

3. MATERIALS AND METHODS

Feeding trials on pigs was carried out at the University Pig Breeding Farm, Kerala Agricultural University, Mannuthy, Kerala. The meteorological observations recorded at the pig farm are given in Table 3.1.

Male piglets of Large White Yorkshire breed born during the month of April/May 1980 formed the experimental subject for the study. The age difference between the youngest and the oldest piglet was only 15 days (Table 3.2). They were raised till weaning (8 weeks of age) on routine management practices. The piglets were castrated by open method and a week there-after they were dewormed and sprayed against ectoparasites. The barrows were weighed individually at an average age of 67 days. Based on nearness in their body weight 36 barrows were randomly divided into six groups. Six diet treatments replicated six times were randomly assigned to each of the groups. The animals were housed individually in farrowing pens; each pen having a dimension of 2.4 m x 4.4 m and having concrete flooring and adequate drainage. After an adjustment period of three days, during which the initial values of observations were recorded, the barrows were put on experimental diets.

Feeding :

All the ingredients required for the feeding of

Table 3.1. Meteorological observation.

Location : University pig breeding farm, MANNUTHY, Kerala.

Elevation : 22.5 meters above sea level.

Latitude : 10^{o} 32' N

Longitude : 76^{o} 16' E

Fortnightly values from July 1980

Fort-night	Max. tem. °C Range	Mini. temp. °C Range	Mean vapour pressure mm of Hg	Temperature Humidity Ind (McDowell,19
1	25.0-29.9	23.3-22.0	22	75.9
2	25.0-30.4	22.8-21.8	24	77.0
3	24.5-30.8	23.6-22.4	24	77.1
4	24.5-30.4	23.7-22.1	22	76.7
5	29.5-30.4	23.9-23.6	24	77.7
6	30.4-31.5	25.5-22.1	24	78.5
7	29.6-31.5	23.0-22.7	25	79.3
8	30.4-32.6	24.7-22.4	22	77.5
9	31.8-32.1	23.7-22.6	23	78.3
10	30.5-32.8	24.4-22.6	21	77.6
11	31.4-32.5	25.2-20.4	21	77.6
12	30.0-32.8	24.9-20.4	21	77.4

[1] THI = 0.72 (Cdb + Cwb) + 40.6

db = drybulb reading

wb = wetbulb reading.

Table 3.2. Experimental details

Code	Treatments					
	1	2	3	4	5	6
Level of digestible energy (DE), NRC,%	100	90	85	100	90	85
Particle size of feed, mm	2 - 3	2 - 3	2 - 3	<1	<1	<1
Number of barrows/replications	6	6	6	6	6	6
Average age, days	71±3.5	73±2.3	66±2.6	66±2.7	73±3.5	70±3.9
Average body weight, kg	11.1±1.5	11.5±1	11.3±0.9	11.5±0.9	11.0±1	11.0±1.2

pigs during the experimental period were procured in one consignment and stored in a damp proof building. The proximate composition of ingredients were determined as per methods described by A.O.A.C. (Anon, 1970) and rations for pigs of different weight classes of the treatments were formulated (Table 3.3) and analysed (Table 3.4).

The feed ingredients, such as dried tapioca (*Manihot utilisema*) chips, groundnut cake and maize were ground seperately in a mill using 3 mm screens. The ground material containing particles upto a maximum of 3 mm size was seived manually through a 2 mm screen partitioning the material into two categories, viz. (a) having 2-3 mm size, and (b) having less than 2 mm size and the latter was again ground to less than 1 mm by changing the screen in the mill. The rice bran was procured as coarse and fine grades with respect to the particle size. The dried unsalted sardine fish was crushed at first to smaller sizes and then was further ground along with rice bran to the desired particle size. Experimental feeds were compounded and mixed in a batch of 1.3 to 2.0 quintals at a time.

The pigs were fed twice a day individually i.e., in the morning at 7 AM and in the evening at 3 PM. The feed was moistend with water keeping feed: water ratio as 3:1 in order to facilitate consumption. The pigs were allowed

Table 3.3 Composition of rations (kg/100 kg)

Body weight range (kg)	10-20			20-35			35-60			Above 60		
Ration	I			II			III			IV		
Ingredients	A[1]	B[1]	C[1]	A	B	C	A	B	C	A	B	C
Maize	36	18	-	36	-	-	-	-	-	-	-	-
Tapioca	24	24	12.5	30.05	35.25	12.5	61	40	18.5	63.55	43	21
Groundnut cake	18	18	15.5	13	13.5	15.5	21	13.5	10.5	18.85	12.5	9.5
Dried fish	17.5	17.2	17.2	17.2	17.25	10.5	9.25	12	10.5	8.8	10.5	9
Rice bran	-	22.3	58	-	33.5	61	6.5	33.75	60	6.55	33.5	60
Rendered beef fat	4	-	-	3	-	-	1.75	-	-	1.75	-	-
Mineral mixture[2]	0.5	0.5	0.5	0.75	0.5	0.5	0.5	0.75	0.5	0.5	0.5	0.5
Total	100	100	100	100	100	100	100	100	100	100	100	100
Vita blend[2] (g/100 kg)	20	20	20	20	20	20	20	20	20	20	20	20
Cost/100 kg (Rs)	209.36	157.35	116.15	184.30	131.20	104.46	163.77	120.25	102.81	162.36	126.02	101.2

1. A, B, C represent diets containing 100, 90 and 85% of digestible energy of NRC standards respectively. These diets were processed in two mesh sizes:- less than 1 and 2-3 mm.
2. Containing: moisture-3%; Calcium-32%; Phosphorus-6%; Zinc -0.2%; Iron-1000 ppm; Copper-100 ppm.
3. Containing per g: Vitamin _ - 40000 I.U.; Vitamin D_3-6000 I.U.; Vitamin B_2- 25 mg.

Table 3.4. Per cent chemical composition of rations (dry matter)

Body weight range (kg)	10-20			20-35			35-60			Above 60		
Ration	I			II			III			IV		
Contents	A[1]	B[1]	C[1]	A	B	C	A	B	C	A	B	C
Dry matter	92.3	92.0	91.8	92.2	91.8	91.5	92.3	92.2	91.8	92.8	92.7	[illegible]
Crude protein	18.03	18.00	18.03	16.04	16.03	16.04	14.03	14.06	14.05	13.03	13.05	[illegible]
Ether extract	8.75	5.04	5.43	7.41	4.45	5.31	4.61	3.97	4.94	4.46	3.77	
Crude fibre	2.2	5.31	10.26	2.09	6.56	10.77	2.85	6.65	10.47	2.81	6.61	[illegible]
Ash	9.15	12.23	15.14	9.08	13.7	15.05	8.07	12.28	15.15	7.83	11.46	[illegible]
NFE	61.87	59.46	51.14	65.38	59.26	52.85	70.44	63.04	55.39	71.87	65.11	[illegible]
Digestible energy kcal/kg	3360	3026	2833	3300	2990	2810	3290	3000	2810	3290	3010	[illegible]

1. A,B,C. represent diets containing 100, 90 and 80% of NRC standards respectively.

to eat whatever they could within a period of one hour. The left over was collected, air dried and weighed. Total daily intake was measured.

Diets were changed as per the recommendations of N.R.C. (Anon, 1968) at the attainment of 20, 35 and 60 kg body weight by the barrows.

Observations recorded :

i) Meteorological :

Dry and wet bulb readings were recorded daily at 7 AM and 3 PM and maximum and minimum temperature daily at 7 AM.

ii) Physiological reactions :

The observations were recorded at fortnightly intervals both at 7 AM and at 3 PM.

a) Rectal temperature:

The rectal temperature was recorded using a clinical thermometer. Young pigs were restrained by holding them tightly on ears and tail while older pigs were controlled by applying a snare at the snout.

b) Respiration rate:

Respiration rate per minute was recorded while the pigs lay relaxed and undisturbed. The upward and downward movement of the abdomen was noticeable to count the respiration rate.

c) Heart rate:

Heart rate per minute was recorded using a stethoscope, the site being immediately posterior to the left fore leg on the lateral thorax.

iii) Body measurements :

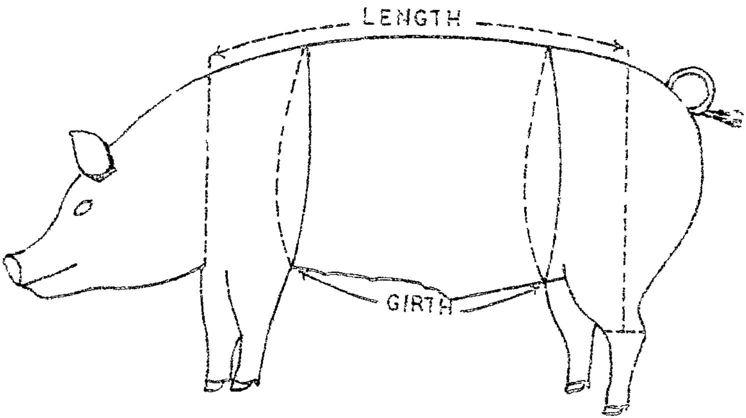
The measurements were recorded weekly as described below:

a) Body length:

The pig was allowed to stand on legs squarely. An imaginery line was drawn prependicularly upwards from the central point of a similar line drawn across the later aspect of the hock joint (see figure). The perpendicular line where it joined the mid dorsal line was considered to be the posterior land mark to measure the length of body.

A line upwards along the anterior border of the shoulder joint of one side to the other was drawn. The poi this line joined the mid doral line was considered to be the anterior land mark. The distance between the anterior and posterior marks along the mid dorsal line was measured with a steel tape to record as length of body.

FIGURE SHOWING METHOD OF MEASURING THE BODY LENGTH AND GIRTH.



b) Girth:

The circumference just behind the shoulder was recorded as the heart girth. The posterior girth was similarly measured immediately in front of the pelvis. The girth was the average values of the heart girth and posterior girth.

c) Body weight:

When the pigs were smaller enough to contain in a wooden box, it was easier to record the live body weight on a portable platform scale. As they grew larger, the pigs were driven to a fixed platform scale with a built-in cage. It was recorded at fortnightly intervals.

iv) Determination of haemoglobin:

The haemoglobin concentration, g/100 ml of blood drawn from ear vein was determined monthly by the Acid hematin method (Oser, 1965).

v) Digestibility of nutrients :

Two feeding trials, each having five days duratio to determine the digestibility of nutrients were carried out in all the treatments simultaneously when the pigs attained on an average of 5 and 7 months of age.

The daily left over of feed during the trial period was dried, weighed and stored in closed containers.

At the end of the trial all the left over feed was mixed and representative sample drawn for proximate analysis. Feces from individual pigs was collected every day in metal containers having lid. At the end of each 24 hours, it was weighed mixed thoroughly and representative samples drawn for proximate analysis. Samples of feces for crude protein determination were preserved in 25% sulphuric acid in wide mouthed bottles having air-tight lids. Samples of feces for determination of other components were dried in an oven at 100°C for 24 hours.

At the end of the trial period, the samples of feces from the respective treatments were analysed for proximate composition as per standard methods (Anon,1970).

vi) Slaughtering and dressing of hogs:

The pigs, on attaining 8 months of age, were transported to the bacon factory situated about 120 km away during the evening hours for slaughter next morning. Their last meal before slaughter was on the previous day in the Farm.

The chain method of slaughtering was used in killing and dressing of hogs. The hogs were stunned electrically, slaughtered and dressed. The split hot carcass was weighed and pushed into the chilling room maintained at $2^{o}C$ for rapid cooling and fabrication of cuts the next day.

a) Fabrication of cuts:

The whole carcass from the chilling room was weighed to determine the dressing percentage, seperated into halves on the cutting table and prepared each half into four main cuts viz., the shoulder, ham, side and loin as described by Anderson (1950). The cuts were weighed individually.

b) Melting point of body fat:

A sample of leaf fat was removed from individual carcass and melting point was determined as per method described by A.O.A.C. (Anon, 1970).

c) Carcass length:

The length of the carcass was measured in the split carcass from the anterior border of the pelvic bone (aitch bone) to the base of the first rib (Krider and Carroll, 1971).

d) Back fat thickness:

The thickness of back fat was measured at three sites viz., at the first rib; last rib and last lumbar (Krider and Carroll, 1971).

e) Area of eye muscle:

Over an even transverse section of the eye muscle (*longissimus dorsi* muscle) at the region between the tenth and eleventh rib, a transparent paper was placed and the outline of the muscle was traced on it (Krider and Carroll 1971). To find the area of the outline, it was placed over a graph paper marked in square centimeters and the area was calculated.

f) Examination of the stomach:

The stomach was opened within an hour after slaughter. The pH of the stomach contents in the viscinity of esophagogastric region was determined by using pH indicator paper (BDH). The stomach was washed and examined for lesions if any, on the gastric mucosa. The gastric mucosa was scored for lesions as described by Chamberlain *et al.* (1966).

g) Internal organs:

The wet weights of alimentary tract, liver, pancreas, spleen, kidneys, adrenals, heart and lungs were recorded.

h) Quality score of eye muscle:

The transverse section of the eye muscle at the region between 10th and 11th rib was scored for marbling, colour and firmness as per standards of Iowa State University described by Rust and Topel (1969).

vii) Statistical analysis of the data :

The data obtained for growth, physiological reaction and carcass characteristics were statistically analysed for Analysis of Covariance and Analysis Variance using technique suggested by Snedecor and Cochran (1967).

The pairwise comparison of means which were statistically significant, were made using t-test.

4. RESULTS AND DISCUSSION

Body weight

The data pertaining to body weight and average daily gain at various ages are given in Tables 4.1 and 4.2. There was an increase in body weight under all the treatments at all ages. But as expected the relative increase was maximum under treatments 1 and 4 (100 per cent DE of NRC standards) followed by treatments 2 and 5 (90 per cent) and minimum under treatments 3 and 6 (80 per cent DE). This observation is in agreement with the findings of Sharda *et al.* (1977) and Merkel *et al.* (1958), but is contrary to those of Mallikarjuna *et al.* (1978) who reported a significantly higher growth rate in pigs maintained for 23 weeks from weaning on rations containing 20 per cent less digestible energy than NRC standards. Ranjhan *et al.* (1971) and Bhudapker *et al.* (1971) reported no depression in growth rate on diets containing 3234 and 3056 kcal digestible energy respectively at 70 kg body weight.

At 8 months of age, pigs under treatment 5 receiving 90 per cent DE of the NRC standard had slightly higher, though statistically non-significant body weight than that of pigs under treatment 2.

Table 4.1. Adjusted mean and standard error of body weight at 5, 7 and 9 months of age as affected by dietary treatments.

Treatments			Body weight(kg) at		
Code	MCM% of DB	Particle size mm	5 months of age	7 months of age	9 months of age
1	100	2-3	$43.2^{a}\pm2.064$	$81.2^{a}\pm3.424$	$102^{a}.9\pm3.736$
2	90	2-3	$39.6^{a}\pm2.066$	$67.9^{b}\pm3.427$	$86.3^{b}\pm3.739$
3	85	2-3	$29.5^{b}\pm2.064$	$50.0^{c}\pm3.424$	$67.1^{c}\pm3.735$
4	100	$\angle 1$	$42.7^{a}\pm2.066$	$77.7^{a}\pm3.427$	$99.4^{a}\pm3.739$
5	90	$\angle 1$	$40.6^{a}\pm2.065$	$70.5^{b}\pm3.424$	$92.3^{ab}\pm3.738$
6	85	$\angle 1$	$29.9^{b}\pm2.065$	$51.2^{c}\pm3.424$	$67.2^{c}\pm3.738$

Means having the same superscript in a column do not differ significantly ($P \angle 0.01$)

Analysis of variance for body weight

Source	df	Mean sum of squares		
		5 months	7 months	9 months
Treatment	5	226.42	904.97**	1459.31**
Error	29	29.57	70.35	84.65

** $P \angle 0.01$

Table 4.2. Mean and standard error of daily gains upto 5, 7 and 8 months of age of pigs as affected by dietary treatments.

Treatment			Daily gain (kg) upto		
Code	NRC% of DE	Particle size mm	5 months	7 months	8 months
1	100	2-3	0.429^{a} ± .023	0.483^{a} ± .022	0.545^{a} ± .019
2	90	2-3	0.390^{a} ± .038	0.397^{a} ± .037	0.448^{a} ± .031
3	85	2-3	0.252^{b} ± .040	0.282^{b} ± .028	0.329^{b} ± .025
4	100	< 1	0.431^{a} ± .041	0.466^{a} ± .035	0.524^{a} ± .035
5	90	< 1	0.392^{a} ± .026	0.408^{a} ± .025	0.473^{a} ± .022
6	85	< 1	0.248^{b} ± .027	0.276^{b} ± .023	0.326^{b} ± .022

Means having the same superscript in a column do not differ significantly ($P < 0.01$).

Analysis of variance for daily gains

Source	df	Mean sum of squares		
		5 months	7 months	8 months
Treatment	5	0.0427**	0.0471**	0.0534**
Error	30	0.0068	0.0052	0.0043

** ($P < 0.01$)

pigs under treatments 3 and 6 receiving 85 per cent NRC levels of digestible energy had attained lowest body weight among the three levels studied. This observation is in agreement with that of Ranjhan et al. (1971), Friend (1977), Leibholz et al. (1974) and Otz et al. (19… but is at variance with Dhudapker et al. (1971) and Mallikarjuna et al. (1978).

Duration to attain various body weights :

The duration (in days) required to attain various body weights from start of the experiment to 100 kg weight is presented in Table 4.8.

It can be seen that the duration to attain higher body weights progressively increased as the body weight increased. To attain 90 kg weight from 20 kg, treatments 1 and 4 needed 114 and 119 days; 2 and 5 required 118 and 121 days, respectively, while the pigs under treatments 3 and 6 did not reach 90 kg weight even till 8 months of age. Alcantara and Arganosa (1975) noticed that pigs weighing 23 kg fed twice a day at 2.5 per cent of live weight required 140, 111 and 194 days to attain 85 kg. Jain et al. (1978) reported that Large White pigs maintained on fish silage meal or 11.12 per cent replaced with rice br… took 155 days to increase their body weight from 20 to 60 kg. Dhudapker et al. (1971) observed that pigs on 35…

Table 4.3 Average number of days required from the start of experiment (70 days) to attain the various body weights in different treatments.

Treatment			Body weight(kg) upto					
Code	NRC% of DE	Particle size mm	20	35	50	70*	90*	100*
1	100	2-3	35 ±6.42	68 ±6.04	96 ±5.09	126 ± 5.23	149 (5)	156 (3)
2	90	2-3	37 ±7.04	75 ±7.23	108 ±9.13	137 ±8.27	155 (3)	165 (2)
3	85	2-3	56 ±9.79	100 ±9.87	136 ±9.83	158 (3)	na	na
4	100	∠ 1	31 ±7.22	69 ±6.59	97 ±7.36	129 ±7.97	150 (5)	158 (4)
5	90	∠ 1	36 ±6.24	75 ±6.27	106 ±6.49	140 ±6.68	157 (4)	161 (2)
6	85	∠ 1	57 ±9.45	103 ±10.14	139 ±9.01	158 (3)	na	na

na : none attained the set weight.

* : All the animals did not attain the weight.

Figures in parenthesis indicate the number of animals which attained the set weight.

3200 or 3056 kcal digestible energy required 126 days from weaning (56 days) to attain 70 kg weight and that variation in the level of energy did not affect the duration.

Kirchgessner and Roth (1976) noticed that pigs previously undernourished by restricted feeding followed by full feeding reached 92 kg in 90.5 to 105 days from a starting weight of 25 kg. Raje *et al.* (1972) fed Large White pigs weighing 22 kg for 140.8 days to attain the slaughter weight of 100.9 kg. The variation reported by various workers might be due to the difference in the plane of feeding and the strain/breed of pigs.

Daily gain

The average daily gain of pigs under the different treatments at 6, 7 and 8 months of age is presented in Table 4.2 and that at different body weights during the course of the trial is depicted in Table 4.4

The average daily gain increased with the advancement of age and also with the increase in body weight. Lowering the level of digestible energy from 100 or 90 per cent of the standards to 80 per cent has significantly ($P < 0.01$) reduced the average daily gain at all ages. The apparent difference in average daily gain in treatments 2 and 3 with that of 1 and 4 was not significant. The

Table 4.6. Average daily gain and standard error (kg) of pigs at different body weights as affected by dietary treatments.

Treatment			Body weight (kg) upto					
Code	IRC % of DE	Particle size mm	20	35	50	70*	90*	100*
1	100	2-3	0.270 ±.024	0.358 ±.017	0.407 ±.009	0.469 ±.009	0.522 (3)	0.559 (3)
2	90	2-3	0.240 ±.031	0.321 ±.019	0.366 ±.024	0.431 ±.002	0.488 (3)	0.522 (2)
3	85	2-3	0.174 ±.023	0.221 ±.033	0.291 ±.018	0.368 (3)	na	na
4	100	< 1	0.321 ±.049	0.385 ±.029	0.404 ±.022	0.436 ±.039	0.524 (5)	0.554 (4)
5	90	< 1	0.265 ±.025	0.327 ±.017	0.368 ±.015	0.421 ±.013	0.492 (4)	0.519 (2)
6	85	< 1	0.159 ±.009	0.225 ±.022	0.284 ±.010	0.362 (3)	na	na

na = weight none attained till 8 months.

* Figures in parenthesis indicate the number of pigs which attained the set weight.

average daily gain at 70 kg body weight in the different treatments in their order was 0.467, 0.428, 0.371, 0.454, 0.420 and 0.373 kg respectively which is in agreement with that reported by Sharda *et al.* (1977) for Middle White pigs. A similar observation was made by Ranjhan *et al.* (19 on Middle White pigs on 3234, 3146, 2904 or 2838 kcal/kg digestible energy. This is at variance with Mallikarjuna *et al.* (1978) who have observed an average daily gain of 0.294, 0.303 and 0.339 kg at 60 kg live weight in pigs maintained on diets containing 100, 90 or 80 per cent of NRC levels of digestible energy, respectively.

Observations similar to the present study were made by Castell and Spurr (1976) in pigs fed twice daily restricting the time to 45 minutes, when the average daily gain in boars, barrows and gilts were found to be 0.521, 0.541 and 0.519 kg respectively from 25-92 kg weight. Gamko (1977) observed an average daily gain of 0.553, 0.635 and 0.598 kg, respectively in Large White pigs on 80, 100 or 120 per cent of USSR recommended allowance. Cheeke and Pennick (1970) reported that average daily gain was significantly higher in pigs receiving 3848 kcal/kg digestible energy when compared to 2820 kcal.

Live body measurements

The average girth and length of body at 70 days and 8 months of age are presented in Table 4.5.

It is evident that initial girth of pigs were uniform and not significantly different. But at 8 months of age the girth (circumference) was significantly ($P < 0.0$ different between treatments, the highest being in treatments 1 and 4 and lowest in 3 and 6. Treatments 2 and 5 stood in between. The average garth of 110.5 cm at 8 months of age at about 100 kg weight as observed in treatments 1 and 4 is in agreement with that of Hetzer et al. (1950) who reported 109 cm at 95 kg weight. Hetzer and Miller (1972) reported 93.1 cm girth at 79.4 kg weight in Large White pigs. This was comparable to the 91.2 and 92.2 cm recorded in treatments 3 and 6 at the weight of 67 kg.

The pigs fed at 85 per cent of NRC level of energ had significantly ($P < 0.01$) smaller body length compared to those on 90 or 100 per cent. Several workers have measured the length of body taking various points on the body as landmarks, such as from base of ear to base of tail (Hetzer et al., 1950; Hetzer and Miller, 1972) with a view to correlate the body measurements with carcass yield (Hetzer et al., 1950; Miller and Wheat, 1970; Lidvall et al., 1972) or to determine the specific gravity and volume or body (Svechin, 1971).

Table 4.5. Mean and standard error of body girth[1] and length of pigs at initial[2] and 8 months of age as affected by dietary treatments.

Treatment			Girth (cm)		Length (cm)	
Code	NSC % of DE	Particle size cm	Initial	8 months	Initial	8 months
1	100	2-3	52.2 ± 2.797	110.5^{a} ± 2.617	34.8 ± 2.039	88.2^{a} ± 2.959
2	90	2-3	49.3 ± 2.417	103.0^{b} ± 3.803	34.8 ± 1.302	85.8^{a} ± 0.792
3	85	2-3	51.2 ± 0.792	91.2^{c} ± 1.201	34.1 ± 1.6	76.1^{b} ± 3.208
4	100	< 1	52.0 ± 1.999	110.5^{a} ± 3.336	34.0 ± 1.483	86.4^{a} ± 1.745
5	90	< 1	51.8 ± 3.119	103.5^{b} ± 2.951	34.3 ± 1.406	86.2^{a} ± 1.195
6	85	< 1	50.6 ± 2.720	92.2^{c} ± 3.449	34.0 ± 1.751	76.0^{b} ± 2.476

[1] Average of anterior and posterior girth. [2] Initial age was 70 days.

Means having same superscript in a column do not differ significantly ($P < 0.01$)

Analysis of variance for body measurements at 8 months of age

Source	df	Mean sum of squares	
		Girth	Length
Treatment	5	401**	190.51**
Error	30	59.06	30.29

** $P < 0.01$

With a view to determine the live weight of pigs under conditions where a weighing scale is not available, an equation was evolved from the weekly measurements of girth and length of the experimental subjects involved in the present study. The equation $W = 5.16 + \frac{LG^2}{11568}$ was arrived at by fitting a regression line taking Y, (W) as the live body weight and X as πLG^2, where L is the length of body and G is the mean girth. The correlation coefficient of the above equation (r) was 0.98. With the help of this equation, the live weight of pigs was predicted and presented as conversion chart in Table 4.6. The variances within and between treatments were tested for homogeneity before the equation was compounded and found to be homogeneous. However, its value for use with other breeds and sex of pigs has not been tested. Since the pig changes its position frequently, the relative accuracy depends on the repeatability of the measurements.

Feed consumption

The cumulative feed consumption upto 8 months of age, feed required upto 100 kg weight and average daily consumption are presented in Tables 4.7, 4.8 and 4.9 respectively.

It can be seen from Table 4.7 that the total feed consumed by the pigs in all the treatments increased pro-

Table 4.6. Prediction equation and conversion chart of live weight of pigs (kg) from body measurements.

Girth cm	Conversion Chart Body length cm																
	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95	100
40	8	9	9	10	11	11	12	13	14	14	15	16	16	17	18	18	19
45	9	10	10	11	12	13	14	15	16	17	17	18	19	20	21	22	23
50	10	11	12	13	14	15	16	17	18	19	20	21	22	24	25	26	27
55	10	12	13	14	17	17	18	20	21	22	23	25	26	27	29	30	31
60	11	13	15	16	18	19	21	22	24	25	27	29	30	32	33	35	36
65	13	14	16	18	20	22	23	25	27	29	31	33	34	36	38	40	42
70	14	16	18	20	22	24	26	28	31	33	35	37	39	41	43	45	48
75	15	17	20	22	25	27	30	32	34	37	39	42	44	47	49	51	54
80	16	19	22	25	27	30	33	36	38	41	44	47	49	52	55	58	61
85	18	21	24	27	30	33	36	40	43	46	49	52	55	58	61	65	68
90	19	23	26	30	33	37	40	44	47	51	54	58	61	65	68	72	75
95	21	25	29	32	36	40	44	48	52	56	60	64	68	72	75	79	83
100	22	27	81	35	40	44	48	53	57	61	66	70	74	79	83	87	92
105	24	29	34	39	43	48	53	58	62	67	72	77	81	86	90	96	100
110	26	31	37	42	47	52	58	63	68	73	78	84	89	94	99	106	110
115	28	34	39	45	51	57	62	68	74	80	85	91	97	102	108	114	119
120	30	36	43	49	55	61	67	74	80	86	92	99	105	111	117	123	130
125	32	39	46	52	59	66	73	79	86	93	100	106	113	120	127	134	140
130	34	42	49	56	64	71	78	86	93	100	107	115	122	129	137	144	-

Table 4.7. Average cumulative feed consumption (kg) and standard error of pigs at various ages from start of experiment[1] as affected by dietary treatments.

Treatment			Months of age					
Code	NRC % of DE	Particle size mm	3	4	5	6	7	8
1	100	2-3	20.6 ±1.84	54.3 ±4.26	98.9 ±7.19	161.8 ±11.06	236.4 ±14.65	315.5 ±17.12
2	90	2-3	22.0 ±2.22	56.5 ±5.24	103.9 ±9.26	163.6 ±15.05	240.5 ±19.64	329.8 ±21.46
3	85	2-3	17.1 ±1.4	45.6 ±5.05	86.0 ±10.2	142.9 ±17.11	214.9 ±22.11	303.4 ±22.62
4	100	∠1	21.6 ±1.61	54.7 ±4.27	100.9 ±8.52	162.0 ±13.33	233.1 ±20.69	311.1 ±18.97
5	90	∠1	21.5 ±1.7	56.5 ±4.68	103.2 ±9.05	164.5 ±15.59	241.2 ±22.01	338.3 ±24.03
6	85	∠1	17.9 ±1.65	47.4 ±4.76	87.9 ±9.36	142.0 ±15.45	213.9 ±20.84	300.7 ±23.87

[1] Initial age was 70 days.

Analysis of variance for feed consumption

Source	df	Mean sum of squares		
		5 months	7 months	8 months
Treatment	5	369.2	1074.6	1306.8
Error	30	483.26	2263.6	2272.7

Table 4.8. Average feed consumption (kg) and standard error upto different body weights as affected by dietary treatments.

Treatment			Body weight (kg)					
Code	NRC % of DE	Particle size mm	20	35	50	70*	90*	100*
1	100	2-3	27±4.9	70.6±5.2	122±4.8	195±5.9	268(3)	307(3)
2	900	2-3	30±4.9	86±6.9	150±9.9	238±9.0	319(3)	371(2)
3	85	2-3	39±6.7	111±8.1	206±12.5	325(3)	na	na
4	100	∠ 1	26±4.8	73±4.4	128±7.7	202±8.2	266(5)	313(4)
5	90	∠ 1	29±4.9	84±6.2	147±5.9	244±7.3	327(4)	386(2)
6	85	∠ 1	46±6.1	120±8.2	207±7.8	313(3)	na	na

na = none attained the weight till 8 months of age.

* Figures in parenthesis indicate the number of pigs which attained the set weight.

Table 4.9. Average daily feed consumption of pigs (kg) and standard error at various body weights as affected by dietary treatments.

Treatment			Body weights (kg) upto					
Code	TKC% of DL	Particle size mm	20	35	50	70	90*	100*
1	100	2-3	0.78 ±.025	1.16 ±.062	1.28 ±.048	1.56 ±.058	1.8 (3)	1.98 (3)
2	90	2-3	0.83 ±.033	1.16 ±.63	1.32 ±.071	1.75 ±.063	2.06 (3)	2.25 (2)
3	35	2-3	0.71 ±.053	1.14 ±.057	1.52 ±.074	2.05 (3)	na	na
4	100	<1	0.87 ±.083	1.06 ±.047	1.43 ±.062	1.56 ±.059	1.79 (5)	1.98 (4)
5	90	<1	0.83 ±.042	1.13 ±.058	1.38 ±.084	1.75 ±.094	2.03 (4)	2.33 (2)
6	35	<1	0.85 ±.043	1.16 ±.049	1.51 ±.073	1.99 (3)	na	na

na : Weight none attained till 8 months of age.

* Figures in parenthesis indicate the number of pigs which attained the set weight.

gressively with age. The effect of treatments on feed consumption at different ages was statistically nonsignificant. The treatments 3 and 6, having low level of digestible energy, consistently increased the average daily consumption although there had been an initial set back due to higher proportion of rice bran in the ration. At 70 kg weight the pigs under treatments 3 and 6 were consuming 2.05 kg compared to 1.56 kg under 1 and 4 or 1.75 k under 2 and 5. However, pigs under treatments 3 and 6 consumed an almost same quantity of feed upto 8 months of age from the start despite their low body weight and gaine significantly (P ∠ 0.01) less weight when compared to treatments 1, 4, 2 or 5. Treatments 1 and 4 led to less feed consumption than 2 and 5 or 3 and 6. In general, the higher the energy concentration of the diet, lesser was the average daily consumption among the energy levels studied.

Seerley et al. (1964), Cole et al. (1967 a) and Tally et al. (1976) reported that on high levels of dietar energy, pigs required lesser feed than those on low energ diets. Pigs maintained on 112.5 per cent, 100 per cent or 87.5 per cent of N.R.C. standards of digestible energy consumed on an average 2.34, 2.5 and 2.55 kg feed per day respectively (Talley et al., 1976). Mallikarjuna et al.

(1978) have observed that pigs fed with 10 or 20 per cent less of NRC standards of digestible energy required more feed to attain 61.4 kg weight. The average daily consumption was 2.092 and 1.565 kg on 10 and 20 per cent less than NRC standards while it was 1.425 kg on 100 per cent NRC standards. Restricting to 75 per cent of the expected intake, diets containing 16 per cent crude protein and 3100 kcal/kg digestible energy, Desmoulin (1973) reported in castrated pigs a reduction of 10 per cent growth and pigs required 38 kg more feed to attain 100 kg body weight from initial 20 kg, when compared to entire males or fem. Cole et al. (1976 b) observed in pigs that isocaloric diet of 2770 kcal/kg dry matter containing 8.9 and 12.9 per cent crude fibre, when allowed for voluntary intake, resulted in no significant difference in the rate of gain and carcass quality. In the present study 10.47 per cent crude fibre in the rations of treatments 3 and 6 had possibly restricted the digestible energy intake resulting in poor growth when compared to the pigs on diets of treatments 2 and 5 containing about 6.5 per cent crude fibre. Merkel et al. (1958) found that, upto 12 per cent crude fibre in the rations pigs, could satisfy their requirements for TDN by increasing consumption, but increasing fibre content further, reduced the intake of TDN.

Individual housing and feeding reduces the exercise and competition at feed trough (Irape et al., 1960). The reduction in exercise may have profoundly reduced their energy requirement reflected in reduced the feed intake. The energy requirement for exercise is about 30-35 per cent of the basal level (Mitchell, 1962) which would account for about half the difference observed in the present study. This view is strengthened by the hypothesis put forward by Cole et al. (1967 a). Further, Sheeny (1955) suggested that exercise is a stimulus to increased appetite and this persists for some time after the exercise is reduced. These facts possibly explain the reduction in feed intake observed in the treatments with high level of dietary energy.

Feed conversion ratio

The feed conversion ratio from the start of the experiment to 8 months of age and at various body weights from 20 to 100 kg are presented in Tables 4.10 and 4.11.

It can be seen from Table 4.10 that the ratio at 3 months of age was wider than that at 4 months. From 5 months of age, the ratio gradually became wide in all the treatments. The feed conversion ratio at 5 months of age in treatments 1, 4, 2 and 5 were statistically of the same order but was significantly ($P < 0.01$) narrower than

Table 4.10. Average feed conversion ratio and standard error at various ages as affected by dietary treatments.

Treatment			Age in months upto				
Code	NRC % of DE	Particle size mm	3	4	5	7	8
1	100	2-3	3.36 ±.762	3.18 ±.315	3.1^{a} ±.167	3.4^{a} ±.079	3.4^{a} ±.095
2	90	2-3	4.61 ±.819	3.89 ±.343	3.6^{a} ±.229	4.2^{b} ±.086	4.3^{b} ±.063
3	85	2-3	5.39 ±.947	5.59 ±.326	4.9^{b} ±.396	5.3^{c} ±.066	5.6^{c} ±.166
4	100	∠ 1	3.49 ±.447	3.17 ±.303	3.2^{a} ±.091	3.5^{a} ±.088	3.5^{a} ±.076
5	90	∠ 1	3.3 ±.299	3.32 ±.181	3.5^{a} ±.106	4.2^{b} ±.159	4.2^{b} ±.108
6	85	∠ 1	6.43 ±.839	5.17 ±.272	4.8^{b} ±.073	5.3^{c} ±.112	5.4^{c} ±.098

Means having the same superscript in a column do not differ significantly (P ∠ 0.01)

Analysis of variance for feed conversion ratio

Source	df	Mean sum of squares		
		5 months	7 months	8 months
Treatment	5	3.592**	4.467**	5.114**
Error	30	0.45	0.064	0.0755

** (P ∠ 0.01)

in treatments 3 or 6. At 7 and 8 months of age the ratio was significantly ($P \angle 0.01$) smaller in treatments 1 and 4 than in 2 or 5, while in 3 and 6 it was significantly ($P \angle 0.1$) the widest. As the level of energy was lowered from NRC standards by 10 or 15 per cent there was a progressive widening of the ratio which meant that more feed was required per unit gain in body weight and hence the feed efficiency was poor. The feed conversion ratio was narrower at younger body weights in all the treatments as compared to higher weights.

Owen and Ridgman (1967) reported that pigs on restricted digestible energy intake from 27.2 to 50 kg weight had retarded growth than in unrestricted pigs but the difference was little on continuing the same diet from 50 to 118 kg allowing for voluntary intake. Besides, the conversion ratio was 3.42, 3.9, 4.11 and 4.48 for live weight ranges of 27-50, 50-72, 72-95 and 95-118 kg, respectively. The remarkable ability of pig, when allowed f voluntary intake, in its making good the deficiency of the previous dietary regime is further elucidated by the work of Cole et al. (1967 b). These workers observed tha in pigs between 45-91 kg on voluntary intake of isocalori feed varying in crude fibre content (8.9 and 12.9 per cen no significant difference was noticed in rate of gain, feed conversion ratio and average daily consumption. Sharma and Yadava (1977) reported the feed conversion ratio as 3 and 4.19 for growing and finishing pigs, respectively, and no appreciable change was observed on *ad libitum* feeding even when the digestible energy content was reduced to 3000 kcal/kg. Ranjhan *et al*. (1971) reported the feed conversion ratio in Middle White pigs as 3.78 when the diet contained 3234 kcal/kg digestible energy.

Talley *et al*. (1976) observed the feed conversion ratio as 3.12, 3.29 and 3.31 when the rations contained digestible energy levels of 112.5, 100 and 87.5 per cent NRC standards, respectively.

The significant differences in feed conversion ratio observed in the present study might be due to the restricted energy density and the restriction imposed on feeding time. Maynard *et al*. (1979) were of the view that the pigs grew faster at 45 kg. This stage is possibly the point of inflection in the growth gradient and seems to coincide with the stage of 5 months of age of the pigs in the present study. It is well known that feed conversion efficiency is maximum around the point of inflection. This was also evident from the narrow feed ratio observed at this age of pigs.

Digestibility experiments

The data pertaining to digestibility of nutrients at 5 and 7 months of age are presented in Tables 4.12 and 4.13 respectively.

It can be seen from the tables that the digestibility per cent of dry matter, organic matter, ether extractives and NFE at 7 months of age was significantly higher ($P < 0.01$) in treatments 1 and 4 than in 2, 5, 3 or 6. Apparent difference in the digestibility per cent of these nutrients in treatments 2, 5, 3 and 6, was statistically nonsignificant at 5 months of age. However, at 7 months of age it was significantly ($P < 0.01$) low in treatments 3 and 6. There was greater variation in the digestibility per cent of crude carbohydrate and protein at both the ages and NFE at 5 months of age. Significantly low ($P < 0.01$) digestibility of crude protein was observed at both ages under treatments 3 and 6 as compared to 1 and 4. Treatments 2 and 5 were statistically of the same order in respect of crude protein digestibility as 1 and 4 or with 3 and 6 at 5 months of age. At 7 months of age treatments 2 and 5 had significantly ($P < 0.01$) lower digestibility when compared to treatments 1 and 4, but the digestibility was of the same order as under treatments 3 and 6.

Table 4.11. Average feed conversion ratio and standard error at various body weights as affected by dietary treatments.

Treatment			Body weight (kg) upto					
Code	NRC % of DE	Particle size mm	20	35	50	70 *	90 *	100
1	100	2-3	2.9 ±.332	3.48 ±.286	3.41 ±.118	3.42 ±.097	3.44 (3)	3.5 (3
2	90	2-3	3.76 ±.48	3.62 ±.233	3.61 ±.093	4.09 ±.128	4.21 (3)	4.3 (2
3	85	2-3	4.28 ±.436	4.07 ±.282	5.29 ±.219	5.38 (3)	na	na
4	100	< 1	3.33 ±.364	2.96 ±.145	3.57 ±.283	3.72 ±.393	3.3[illegible] (5)	3.5 (4
5	90	< 1	3.47 ±.326	3.48 ±.193	3.74 ±.104	4.19 ±.137	4.22 (4)	4.4 (2
6	85	< 1	5.27 ±.192	5.46 ±.469	5.27 ±.153	5.48 (3)	na	na

na : Weight none attained till 8 months of age.

* Figures in parenthesis indicate the number of pigs which attained the set weight.

Table 4.12. Adjusted mean digestibility (%) and standard error of nutrients at 5 months of age as affected by dietary treatments.

Treatment			Ration	Digestibility of nutrients (%)						
Code	NMC % of DC	Particle size mm		DM	OM	CP	EE	Crude Carbo.	CF	NFE
1	100	2-3	III A	78.67^{a}± 1.6637	88.46^{a}± 0.8022	84.43^{a}± 1.3641	87.17^{a}± 2.475	89.41^{a}± 0.9757	5.68^{a}± 0.4021	92.08^{a}± 0.9832
2	90	2-3	III B	60.47^{b}± 1.6649	83.16^{b}± 0.8023	80.59^{ab}± 1.3651	62.58^{b}± 2.4768	85.15^{b}± 0.9764	9.03^{b}± 0.4024	94.3^{ab}± 0.9892
3	85	2-3	II C	57.31^{b}± 1.6634	84.07^{b}± 0.8021	79.46^{b}± 1.3639	56.1^{b}± 2.4747	87.51^{a}± 0.9756	11.07^{c}± 0.4021	96.2^{b}± 0.9833
4	100	$\angle$ 1	III A	80.36^{a}± 1.6649	90.45^{a}± 0.8028	86.26^{a}± 1.3651	89.15^{a}± 2.4768	91.53^{a}± 0.9764	5.86^{a}± 0.4024	94.39^{ab}± 0.9892
5	90	$\angle$ 1	III B	63.27^{b}± 1.6644	82.54^{b}± 0.8026	82.16^{ab}± 1.3647	63.06^{b}± 2.4762	84.67^{b}± 0.9762	8.6^{b}± 0.4023	91.85^{a}± 0.9889
6	85	$\angle$ 1	II C	62.46^{b}± 1.6644	83.9^{b}± 0.8026	77.94^{b}± 1.3647	52.64^{b}± 2.4762	88.34^{a}± 0.9762	10.9^{c}± 0.4023	96.42^{b}± 0.9889

Means having the same superscript in a column do not differ significantly ($P \angle 0.01$)

Analysis of variance for digestibility (%) at 5 months of age

Source	df	Mean sum of squares						
		DM	OM	CP	EE	Crude Carbo.	CF	NFE
Treatment	5	582.51**	62.45**	58.5**	1492.2**	40.37**	37.36**	22.74**
Error	29	16.6	3.86	11.16	36.74	5.71	0.97	5.86

** ($P \angle 0.01$).

Table 4.13. Adjusted mean digestibility (%) and standard error of nutrients at 7 months of age as affected by dietary treatments.

Treatment			Ration	Digestibility of nutrients (%)						
Code	NaC % of DE	Particle size mm		DM	OM	CP	EE	Crude carbo.	CF	NFE
1	100	2-3	IV A	80.93[a] ±1.6851	88.12[a] ±1.2743	78.32[a] ±1.8068	91.77[a] ±2.1757	89.83[a] ±1.7378	16.57[a] ±0.6298	91.74[a] ±1.8894
2	90	2-3	IV B	61.13[b] ±1.6863	73.90[b] ±1.2752	67.38[b] ±1.8081	77.46[b] ±2.1773	73.62[b] ±1.7369	17.82[a] ±0.6304	79.5[b] ±1.8912
3	85	2-3	III C	43.92[c] ±1.6843	59.24[c] ±1.2742	65.85[b] ±1.8365	52.39[c] ±2.1754	53.92[c] ±1.7374	22.73[b] ±0.6298	65.65[c] ±1.8395
4	100	∠ 1	IV A	81.16[a] ±1.6663	87.86[a] ±1.2702	81.84[a] ±1.8081	91.74[a] ±2.1773	88.78[a] ±1.7389	16.91[a] ±0.6304	91.6[a] ±1.8912
5	90	∠ 1	IV B	59.67[b] ±1.6658	71.36[b] ±1.2749	68.98[b] ±1.8076	76.37[b] ±2.1767	71.95[b] ±1.7385	20.26[b] ±0.6302	76.69[b] ±1.8905
6	85	∠ 1	III C	41.96[c] ±1.6858	57.18[c] ±1.2749	71.97[b] ±1.8076	57.32[c] ±2.1767	54.1[c] ±1.7385	21.74[b] ±0.6302	60.27[c] ±1.8905

Means having the same superscript in a column do not differ significantly (P ∠ 0.01)

Analysis of variance for digestibility (%) at 7 months of age

Source	df	Means sum of squares						
		DM	OM	CP	EE	Crude carbo.	CF	NFE
Treatment	5	1749.2**	1067.87**	257.72**	1637.4**	1305.57**	40.77**	1011.85**
Error	29	17.03	9.74	19.58	28.39	18.11	2.38	21.42

The digestibility per cent of NFE was significantly higher (P ∠ 0.01) under treatments 3 and 6 at 5 months of age as compared to treatments 1 and 5. Treatments 2 and 4 were of the same order.

The digestibility per cent of crude fibre was significantly higher (P ∠ 0.01) as the level of digestible energy in the diet was decreased to 90 or 85 per cent of NRC standards in both the experiments.

Dry matter :

The differences in digestibility per cent of dry matter observed in the present studies has also been recorded by Owen and Ridgman (1968) who reported 79, 66.9 and 61.5 per cent digestibility in pigs ranging in live weigh 29.5 to 59 kg and kept on diets containing 3.52, 2.92 and 2.71 kcal/kg digestible energy. Cole et al. (1967 a) observed the digestibility as 75.1 and 64.3 per cent with diets having 2970 and 3356 kcal/kg digestible energy at 38 kg weight.

Organic matter :

The digestibility of organic matter observed in the present experiments is close to the 80.5 per cent observed by Simonsson (1978) in pigs on barley based diet The low per cent observed in treatments 3 and 6 might be due to the high proportion of rice bran in these diets.

Crude protein :

There was variation in the digestibility per cent of crude protein. It increased as the level of digestible energy was increased and vice versa. Cole et al.(1967 a) observed that isocaloric diets (2820 kcal/kg digestible energy) differing in crude fibre content (6.9 and 12.9 per cent) significantly reduced the digestibility of nitrogen from 71 to 67.1 per cent. Lozdrin (1976) reported the crude protein digestibility in pigs as 80.2, 83.2 and 73.4 per cent at different levels of feeding with barley based diets having crude protein content of 20.5, 25.3 and 16.6 per cent. The results of the present study lend support to the findings of Soundstol et al. (1979), who observed that in larger pigs the digestibility of crude protein was higher. In contrast, Lal and Takkar (1976) reported that on isonitrogenous diets, the digestibility of crude protein was increased with age. Further Ozerova (1977) observed on identical plane of feeding, variation in the treatments of feed such as boiling, drying or pelleting caused the digestibility of dry matter, crude protein, crude fibre and NFE to profoundly differ. To add to the mystery, Clawson et al. (1962) reported the crude protein digestibility varied according to the protein-calorie ratio and it was 76 per cent when the ratio was 38. One or more factors discussed above, together with the source and nature of protein coupled with the varying energy density of the diets and restrictions imposed by way of feeding time, might have contributed to the significant variation observed in the digestibility of crude protein in the different dietary treatments.

Ether extracts :

On isocaloric diets (gross energy 4125 kcal/kg) varying in crude protein content (20.5, 20.3 and 16.6 per cent), Nozdrin (1976) reported the digestibility of ether extracts as 82.2, 92.1 and 64.3 per cent, respectively, but when the gross energy was reduced to 3298 kcal/kg the digestibility was reduced to 49 per cent. With conventional and unconventional milk substitute in pigs at 60 days of age Smekalov and Taivishevkii (1974) observed the digestibility of crude fat as 64.4 and 72.9 per cent. Maynard et al. (1979) have quoted the crude fat digestibility as 71 per cent. The digestibility values observed here on diets varying in energy and particle sizes ranged from 52.64 to 91.77 per cent. This range falls within the large range of variations reported by the various authors referred above.

Crude carbohydrate/crude fibre/NFE :

There was greater variation in the digestibility of crude carbohydrate at 5 months of age, which was of the order of 84.6 and 85.15 per cent on treatments 2 and 5. It was significantly higher on treatments 1, 4, 3 and 6. Simonsson (1978) reported values close to the ones observed on mid energy rations of the present study. It is interesting to observe that all treatments except those of 2 and 5 had high carbohydrate digestibility. But deeper analysis turns this aspect into a confusing one difficult to explain when it is observed that the varying energy levels in the ration did not produce any consistent trend in the level of digestibility. These observations contradict those of Furuya and Takahashi (1980) who indicated a relationship between the cellulose level and the crude carbohydrate digestibility of rations.

The digestibility of NFE observed in treatments 1 and 4 was in agreement with that of Kozdrin (1976) and Maynard et al. (1979). Shekalov and Faivishevskii (1974) reported the digestibility of NFE as 81.4 and 82.4 per cent in pigs at 65 days of age, while Lawrence (1970) reported it as 85.6 per cent at 39 kg live weight. Ozerova (1977) noticed there was a reduction in digestibility of NFE when the diets were dried or pelleted rather than boiled. Clawson et al. (1962) reported the digestibility of NFE as 93 per cent when the calorie-protein ratio was 53. The digestibility coefficient of crude fibre in the different treatments at 7 months of age was in agreement with that of Clawson et al. (1962) who reported it as 18 per cent when the caloric-protein ratio was 38. Smekalov and Faivishevskii (1974) observed the digestibility of crude fibre at 65 days of age as 24.1 and 29.5 per cent on conventional and unconventional milk substitutes, respectively, while Nozdrin (1976) noticed 29.6 per cent with rations containing gross energy of 4205 kcal/kg and crude protein content of 20.5 per cent. Furuya and Takahashi (1980) reported a decrease in crude fibre digestibility as the level of cellulose content in the rations were increased. At 39 kg live weight in pigs Lawrence (1970) noticed the digestibility as 18.3 per cent.

It is of interest to note here that the diets offered to the pigs of varying live weight in the various treatments differed in energy concentration, chemical composition and source and level of nutrients. Coupled with these the time limit imposed on the pigs in regard to the feeding which is known to influence rate of passage of food through gut (Castle and Castle, 1957), might have also affected the digestibility of various nutrients.

Seerley et al. (1962) reported that diets eaten ad libitum had faster rate of passage than those offered at a lower scale when they were pelleted but not when they were given as meal. This suggests that the crude fibre digestibility is considerably affected due to several contributory factors.

The quality of rice bran used in the present study might have greatly influenced the digestibility of nutrients.

A partial explanation for the differing apparent coefficients of digestibility of nutrients may rest in the rates of passage of the digesta throughout the gut. The results indicated that the source and level of fibrous constituents in the diet were of greater importance in affecting crude carbohydrate digestibility in particular and that of other nutrients in general.

Rectal temperature

The average rectal temperature at 70 days and 8 months of age in the morning and in the afternoon in all the treatments are presented in Table 4.14. Analysis of variance revealed no treatment effect on the rectal temperature, although diurnal variation did exist, the difference being of the order of 0.35°C at 70 days of age and 0.5°C at 8 months of age.

Andersson (1977) reported the normal rectal temperature range of the pig as 38.7-39.8°C, a difference of 1.1°C, but stated further that depending on the depth of

Table 4.14. Mean and standard error of rectal temperature(°C) at initial[1] and 3 months of age as affected by dietary treatments.

Treatment			Morning		Afternoon	
Code	M.C % of DL	Particle size mm	Initial	8 months	Initial	8 mont
1	100	2-3	37.5±.02	37.4±.02	37.8±.05	38.0±.0
2	90	2-3	37.5±.02	37.5±.03	37.9±.05	38.0±.0
3	85	2-3	37.5±.03	37.5±.02	37.9±.04	37.9±.0
4	100	∠1	37.5±.03	37.5±.03	37.8±.05	38.1±.0
5	90	∠1	37.5±.04	37.5±.03	38.0±.02	38.0±.0
6	85	∠1	37.5±.02	37.5±.02	37.[illegible]±.05	37.9±.0

[1]Initial age was 70 days.

Analysis of variance for rectal temperature at 3 months of age

Source	df	Means sum of squares	
		Morning	Afternoon
Treatment	5	7.61	.006
Error	30	7.67	.004

insertion of thermometer into the rectum, there will be variation in the reading. The variation in rectal temperature observed in the present study lies within the range reported by Pullar (1949) viz., 36.2-39.2°C.

In animals which are active during day time, temperature maxima are usually found in the afternoon and minima in the morning and the rectal temperature of the pig begins to rise above normal at an environmental temperature of 30-32°C (Anderson, 1977). The maximum ambient temperature during the course of the present study was not more than 33°C at any time. This small increase in ambient temperature (beyond 32°C) was probably just sufficient to initiate a small rise in rectal temperature (0.35 to 0.5°C).

Talley *et al.* (1976) reported that the body temperature was not affected by diets containing 112.5, 100 or 87.5 per cent of NRC standards of digestible energy for pigs. The evidence gathered here also shows that the levels of dietary energy did not have any influence on the rectal temperature. Whatever variation the rectal temperature exhibited was due to normal diurnal rhythm.

Heart rate

The average heart rate of 70 days and 8 months of age in all the treatments in the morning and afternoon is presented in Table 4.15. Analysis of variance showed that treatments had no significant effect on the heart rate of pigs involved in the present study. The age also appeared to have no significant effect. The heart rate was higher in the afternoon by about 30% than in the morning.

According to Miller and Robertson (1959) the pulse rate of pigs is 70-80 per minute. Dukes (1955) states that the heart rate of the resting pig varies from 60-80 beats per minute. Luisada et al. (1944) in a study of pigs of various weights recorded heart rates of 120-135 per minute. Pond and Maner (1974) reported the heart rate as 120 beats per minute . In the present study the heart rate in the morning was recorded before feeding and in the afternoon while feeding and hence activity of eating might have had some effect on heart rate.

Respiration rate

The average respiration rate at 70 days and 8 months of age recorded in the morning and afternoon in all the treatments is presented in Table 4.16. Analysis of variance has shown that the diets had no significant effect on the respiration rate. The respiration rate in the afternoon was higher than that in the morning at both the stages - initial as well as at 8 months of age.

Table 4.15. Mean and standard error of heart rate per minute at initial[1] and 8 months of age as affected by dietary treatments.

Treatment			Heart rate/minute			
			Morning		Afternoon	
Code	NRC % of DE	Particle size mm	Initial	8 months	Initial	8 months
1	100	2-3	97.7±.61	106.3±.80	129.3±2.04	136.3±1.08
2	90	2-3	97.7±.61	104.3±1.08	127.7±3.59	136.7±2.17
3	85	2-3	100.7±2.04	104.3±.95	129.0±3.17	134.7±1.61
4	100	< 1	99.7±1.2	105.3±.90	128.[illegible]±3.73	136.7±1.11
5	90	< 1	96.6±.42	104.7±.66	130.7±3.91	136.[illegible]±2.73
6	85	< 1	98.0±.73	106.6±.84	126.0±2.[illegible]2	134.6±1.60
	Average		98.4	105.25	128.55	135.38

[1] Initial age was 70 days.

Analysis of variance for heart rate at 8 months of age

Source	df	Means sum of squares	
		Morning	Afternoon
Treatment	5	1.78	27.11
Error	30	4.62	16.27

Table 4.16. Mean and standard error of respiration rate per minute at initial[1] and 8 months of age as affected by dietary treatments.

Treatment			Respiration rate/minute				Aver
			Morning		Afternoon		
Code	N(C)% of DE	Particle size mm	Initial	8 months	Initial	8 months	
1	100	2-3	24.3±1.08	22.0±.61	43.6±1.49	60.6±.42	37.[illegible]
2	90	2-3	24.3±1.08	22.3±.61	4[illegible].6±1.11	54.0±1.36	36.[illegible]
3	85	2-3	24.0±.73	21.6±.80	45.0±1.34	52.0±.51	35.[illegible]
4	100	∠ 1	25.0±.85	22.3±.61	44.0±1.15	62.6±.84	33.[illegible]
5	90	∠ 1	24.6±.84	22.3±.61	43.6±1.48	55.0±1.23	36.[illegible]
6	85	∠ 1	24.6±.84	22.3±.61	44.0±1.46	51.6±.61	35.[illegible]
	Average		24.46	22.13	44.13	55.96	

[1] Initial age was 70 days.

Analysis of variance for respiration rate of 8 months of age.

Source	df	Means sum of squares	
		Morning	Afternoon
Treatment	5	2.33	4.53
Error	30	2.11	25.37

The breathing rate in pigs has been reported to vary from 8-18 per minute (Martin, 1964). Steinbach(1971) observed in Nigeria during January and February a respiration rate of 20-112 per minute in adult pigs. The thermoneutral zone in pigs is 20-26°C (Maynard *et al.*, 1979) above which the circulatory adjustments are no longer enough for the maintenance of heat balance and hence they must be supplemented by an increase of evaporative heat loss by panting (Andersson, 1977). The ambient temperature during the course of the present study (Table 3.1) was higher than the upper critical temperature and hence the discomfort has been reflected in the higher respiration rate in the evening. The variation in respiration rate at the start of the experiment and at 8 months of age is also explainable in the light of the fact that the minimum ambient temperature remained almost constant (22.3 - 23.8°C) while the maximum at the commencement of the experiment was around 27.5°C and at termination 31.4°C.

<u>Haemoglobin content</u>

The haemoglobin content (g/100 ml) of blood at 70 days and 8 months of age in all the treatments is presented in Table 4.17. Updike (1960) reported a normal concentration of haemoglobin from 9.0 g/100 ml upward. Miller *et al.* (1961) made haemoglobin determination in a large number of

Table 4.17. Adjusted mean and standard error of haemoglobin concentration (g/100 ml) of blood at initial[1] and 8 months of age as affected by dietary treatments.

Treatment			Haemoglobin (g/100 ml)	
Code	NRC% of DL	Particle mm size	Initial	8 months
1	100	2-3	9.87±.166	10.68±.234
2	90	2-3	9.76±.244	10.28±.411
3	85	2-3	9.97±.257	9.86±.145
4	100	∠ 1	9.88±.272	10.47±.409
5	90	∠ 1	9.78±.272	10.07±.277
6	85	∠ 1	9.88±.398	9.82±.315

[1] Initial age was 70 days.

Analysis of variance for haemoglobin at 8 months of age

Source	df	Means sum of squares
Treatment	5	0.71
Error	29	0.61

pigs and reported a range of 9.2-13.9 g/100 ml of blood. Analysis of variance has shown that the treatment has not produced significant effect on this parameter even though there was slight decrease in haemoglobin content in pigs reared on low energy diet. This might be due to the inclusion of high level of rice bran in the diet which contained higher levels of phytids and other chelates. These might be interfering with the metabolism of haemoglobin related minerals (Maynard et al., 1979). Moreover, the experiment pigs were on a concrete floor all along which also might have influenced the haemoglobin level. Pigs raised on concrete floor would generally have slightly lower content of haemoglobin at weaning due to deficiency of iron, but impr as they start feeding on balanced diet subsequently (Morrison, 1951).

Yield of cuts

The yield of dressed carcass and choice cuts from pigs in all the treatments and the Analysis of Variance are presented in Table 4.18.

Shrinkage :

It can be seen from Table 4.18 that the per cent shrinkage was least in treatments 1 and 4 and maximum in 3 and 6 while treatments 2 and 5 are in between.

Table 4.18. Effect of treatment on the per cent yield of lean cuts from cold carcass at 8 months of age.

Traits	Treatment Code					
	1	2	3	4	5	6
Kill weight, kg	99.2±4.84	83.5±5.51	63.7±4.94	97.0±6.13	86.0±4.6	62.3±4.37
Shrinkage, %	3.3	4.7	5.3	3.4	5.5	6.3
Dressing, %	72.1[a]	68.8[ab]	64.7[b]	72.5[a]	68.8[ab]	64.7[b]
Carcass shrink, %	2	1.7	1.2	2.4	2.2	1
Ham, %	21.3[a]	22.6[ab]	24[b]	21.4[a]	22.5[ab]	23.8[b]
Loin, %	17.3	17.1	15.9	17.5	17	16.2
Bacon, %	16.7	17.1	17.2	16.4	17	17
Shoulder, %	19.7	18.9	18.8	19.4	19.6	18.6
Ham + loin, %	38.6	39.7	39.9	38.6	39.5	39.9
Ham + shoulder, %	41	41.4	43	40.8	42.1	42.4
Total of cuts as % of kill wt[1]	55.31[a]	52.8[ab]	49.70[b]	55.38[a]	53.76[ab]	50.07[b]

1- Adjusted mean

Means having same superscript in a row do not differ significantly ($P < 0.01$)

continued....

Table 4.18 (continued) ...

Analysis of variance for carcass traits

Source	df	Means sum of squares							
		Dressing	Ham	Loin	Bacon	Shoulder	Ham+ Loin	Ham+ Shoulder	Total of lean[2] cu
Treatment	5	65.39**	11.65**	2.65	0.62	1.26	2.38	4.38	37.15**
Error	30	7.14	2.68	1.81	1.96	3.21	3.19	4.40	7.02

** $(P < 0.01)$

2 df: 29

According to Krider and Carroll (1971) shrinkage in transit is more of a factor of distance than the mode of transportation and that it is heaviest during the first 160 km Anderson and Kiser (1963) reported the shrinkage by truck for 30 kg (50 miles) was 2.3 per cent and 160 km (100 miles) was 4.6 per cent in barrows and gilts. Bowland and Standish (1966) observed fasting in pigs prior to slaughter for 24 hours resulted in a 5-5.7 per cent live weight shrink and 48 hours fasting resulted in 7.9 per cent and gilts shrank 5.6 per cent while barrows 6.2 per cent.

Carcass shrink :

It can be seen from Table 4.18 that there was no uniformity in the carcass shrink and that it varied from 1-2.4 per cent. This observation is in agreement with that of Bowland and Standish (1966) who reported 1-2.8 per cent carcass shrink and 3.1 per cent on fasting the pigs weighing 90 kg for 48 hours. However, this is at variance with Malmfors and Nilsson (1978) who observed a drip loss of 2.01, 3.92 and 4.46 in boars, weighing 100 kg and barrows and gilts weighing 90 kg, respectively.

Dressing per cent :

It is apparent from Table 4.18 the dressing per cent was significantly higher ($P < 0.01$) under treatments 1 and 4 than under 3 or 6 and treatments 2, 5, 3 and 6 were statistically of the same order.

The per cent yield of dressed carcass from pigs in the present study is in agreement with that of Cole et al. (1967 b) who reported 69.7 and 70.6 per cent in pigs weighing 57 and 80 kg, respectively. Tawley, et al.(1976) observed that pigs maintained on low level of digestible energy (87.5 per cent of NRC) had low dressing than those on high levels of energy. Sharda et al. (1977) observed on Middle White pigs maintained on restricted energy levels, the dressing percentage at 70 kg body weight was 69 per cent. Kumar et al. (1976) noticed in pigs weighing 50, 70 and 90 kg, a dressing per cent of 67.2, 69.3 and 69.8 per cent, respectively. In pigs weighing 82-84 kg, Wanko(1977) observed the dressed carcass yield was 62.7 to 65.4 per cent.

Desmoulin (1973) reported the killing out per cent increased by 1.6 per cent after castration and 2.2 per cent under restricted feeding which lends support to the higher dressed yield observed under treatments 1 and 4. Bohman et al. (1955) observed that feeding pigs with diets containing bulky materials increased the size of stomach and large intestine and had affected the dressing percentage.

Ham :

From Table 4.18 it is evident that the yield of ham as per cent of cold carcass was significantly lower

(P ∠ 0.01) under treatments 1 and 4 than under 3 or 6 and that treatments 2 and 5 were statistically of the same order with 1, 4, 3 and 6. This observation is in agreement with that of Sharda et al. (1977) who reported 23.3 and 24.5 per cent ham as percent of hot carcass in pigs slaughtered at 73 kg and maintained on 3370 and 3060 kcal digestible energy/kg. The difference in yield was reported to be significant (P ∠ 0.05). Kumar et al. (1976) observed in pigs weighing 50, 70 and 90 kg the yield of ham was 15, 13.4 and 13 per cent, respectively, with respect to the slaughter weight. Lidvall et al. (1972) reported the ham in carcass of pigs weighing 94.8 kg as 21.9 per cent.

Loin, shoulder and bacon (side) :

It may be seen from Table 4.18 that the yield of these cuts from the cold carcass was not statistically different under the various treatments. This observation is in agreement with that of Lidvall et al. (1972) who reported the shoulder cut from carcass of pigs weighing 94.8 kg was 18 per cent and loin 16.8 per cent. Sharda et al. (1977) noticed significant (P ∠ 0.05) difference in the yield of shoulder cut in pigs maintained on 3370 and 3060 kcal digestible energy/kg at 70 kg live weight and the yield of loin, belly and sparo rib between treatments were nonsignificant. This variation may be due to differen in procedure adopted for the preparation of cuts.

Ham + Loin and Ham + Shoulder :

It can be seen from Table 4.18 that there was no significant difference between treatments when those cuts were considered together to assess the yield of lean cuts.

According to Adams et al. (1972), the weight of ham was the most valuable single measurement in predicting differences in lean cuts as a percentage of live weight and the loin weight accounted for the largest amount of variation on a carcass weight basis. Shoulder weight was the least variable.

The observations reported in the present study in regard to combined yield of these cuts are in agreement with that of Lidvall et al.(1972) who noticed the combined yield of ham plus loin was 38.7 per cent and ham plus loin plus shoulder, 56.7 per cent while loin alone was 16.8 per cent. Sharda et al. (1977) reported significant ($P < 0.05$) difference in the yield of ham plus loin in pigs weighing 73 kg maintained on 3370 and 3060 kcal digestible energy/kg.

The per cent ham, Hazel and Kline (1959) and per cent ham, loin and shoulder, Clawson et al.(1962) have sugg to be considered a good measure of carcass value.

Cuts per cent :

It is evident from Table 4.18 that the total per cent yield of primal cuts was significantly higher ($P < 0.0$ under treatments 1 and 4 than under 3 or 6 while treatmen 2 and 5 were statistically of the same order with 1, 4, and 6.

This observation is almost in agreement with that of Cromwell et al. (1978) who reported in pigs that were maintained on diets containing 2900 and 3240 kcal digest. ble energy/kg upto 95 kg, the lean cut yield was 57.7 and 58 per cent, respectively. Petrova (1979) observed the per cent yield of lean in carcass was 57.4 and 58 per cen when the dressing per cent varied from 74.2 to 75 per cen Sharda et al. (1977) did not observe significant differen in the yield of total lean cuts with respect to hot carc. from pigs weighing 73 kg maintained on 3370 and 3060 kcal digestible energy/kg.

Carcass characteristics

The mean values of carcass characteristics are shown in Table 4.19.

Back fat thickness :

The overall backfat thickness of three measurements (first rib, last rib and last lumbar) is shown in

Table 4.19. The backfat thickness was significantly highe under treatments 1, 4, 2 and 5 than under 3 or 6, the high est was under treatments 1 and 4. This observation is in agreement with that of Sharda et al. (1977) and Talley et (1976). According to Kumar et al. (1976) the average back thickness of pigs slaughtered at 50, 70 and 90 kg varied from 2.4, 2.8 and 3.6 cm, respectively, indicating that th backfat thickness in pigs increased with the weight of animals. The observations of Neely et al. (1979) that as slaughter weight increased there was a corresponding incre in backfat thickness lends support to those in the present study.

Desmoulin (1973) reported that castration resulted in a 21 per cent increase in backfat thickness but restric tion in feeding reduced it by 14.5 per cent.

Reddy and Agarwala (1975) did not observe any sign ficant difference in back fat measurement in pigs fed with diets varying in energy-protein ratio.

Carcass length :

It is clear from Table 4.19 that the carcass leng was significantly higher under treatments 1, 4, 2 and 5 t under 3 or 6 and the highest length was observed under treatments 1 and 4. This observation is compatible with

Table 4.19. Mean and standard error of carcass characteristics of pigs at 8 months of age as affected by dietary treatments.

Characteristics	Treatment Code					
	1	2	3	4	5	6
Overall back fat thickness, mm	$45.4^{a} \pm 3.21$	$38.3^{a} \pm 2.31$	$28.5^{b} \pm 0.76$	$43.8^{a} \pm 2.35$	$37.9^{a} \pm 2.37$	$27.2^{b} \pm 1.$
Carcass length, cm	$72.5^{a} \pm 1.18$	$70.2^{a} \pm 1.60$	$64.4^{b} \pm 2.18$	$71.3^{a} \pm 0.70$	$69.9^{a} \pm 1.33$	$63.7^{b} \pm 1.$
Eye muscle area, cm^2	$30.9^{a} \pm 0.59$	$29.6^{ab} \pm 0.93$	$28.0^{b} \pm 0.83$	$31.5^{a} \pm 1.07$	$29.3^{ab} \pm 0.56$	$27.1^{b} \pm 1$
Melting point of body fat °C	$45.2^{a} \pm 0.31$	$39.8^{b} \pm 0.31$	$38.8^{b} \pm 0.31$	$44.8^{a} \pm 0.70$	$39.7^{b} \pm 0.21$	$38.5^{b} \pm 0$
Fat in eye muscle, % (dry matter basis)	24.7	24.6	22.5	24.9	24.6	22.3
Lean-fat ratio in eye muscle	3.09 ± 0.21	3.1 ± 0.17	3.45 ± 0.08	3.1 ± 0.27	3.1 ± 0.16	$3.55 \pm 0.$
Quality score:						
Marbling	$3.8^{a} \pm 0.16$	$3.3^{a} \pm 0.21$	$2.3^{b} \pm 0.21$	$3.8^{a} \pm 0.16$	$3.2^{a} \pm 0.16$	$2.5^{b} \pm 0.2$
Colour	$3.3^{a} \pm 0.21$	$3.2^{a} \pm 0.16$	$2.5^{b} \pm 0.22$	$3.2^{a} \pm 0.16$	$3.2^{a} \pm 0.21$	$2.5^{b} \pm 0.2$
Firmness	$3.3^{a} \pm 0.21$	$3.0^{a} \pm 0$	$2.0^{b} \pm 0$	$3.3^{a} \pm 0.21$	$3.0^{a} \pm 0$	$2.0^{b} \pm 0$

Means having same superscript in a row do not differ significantly (p / 0.01).

continued...

Table 4.19 (continued).....

Source	df	Means sum of squares								
		Back fat thickness	Carcass length	Eye muscle area	% of fat	Fat in eye muscle	Lean: fat	Marb-ling	Colour	Firm-ness
Treatment	5	343.12**	82.42**	19.65**	55.22**	8.74	0.2604	2.47**	0.93**	2.31**
Error	30	29.86	12.68	5.20	1.21	8.65	0.2448	0.22	0.23	0.09

** $P < 0.01$.

Kumar et al. (1976) who reported in pigs raised to 50, 70 and 90 kg, the carcass length was 61.7, 68.3 and 71.2 cm. Lidvall et al. (1972) observed 75.3 cm as carcass length in pigs weighing 94.8 kg whereas Bowland and Standish (1966) reported as 77.2 cm. At 73 kg weight, the carcass length, Sharda et al. (1977) reported as 71.9 and 74 cm in Middle White pigs raised on rations containing 3370 and 3060 kcal digestible energy/kg, respectively, which is at variance with the findings of the present study.

Eye muscle area:

The eye muscle area measured at the region between 10th and 11th rib was significantly ($P < 0.01$) higher under treatments 1 and 4 than under 3 or 6 and that 2, 5, 3 or 6 were statistically of the same order. This observation is in agreement with that of Talley et al. (1976) who reported 31, 33.2 and 29.5 cm^2 in pigs maintained on 112.5 per cent 100 per cent and 87.5 per cent digestible energy of NRC recommended standards, respectively, and slaughtered at 94.8 kg, while Kumar et al. (1976) measured an eye muscle area of 19.8, 26 and 32.1 cm^2 at 50, 70 and 90 kg slaughter weight, respectively. However, the eye muscle area observed in the present study is at variance with that of Bowland and Standish (1966) who reported 25.9 cm^2 at 90 kg slaughter weight, which is smaller than the values here.

At a slaughter weight of 94.8 kg Lidvall et al. (1972) observed 29.8 cm^2 while Petrova (1979) reported in pigs maintained on 17-20 per cent less than the USSR recommended allowance and slaughtered at 6.5 months of age the eye muscle area varied from 31.4 to 31.8 cm^2.

Melting point of body fat :

The melting point was significantly ($P < 0.01$) higher under treatments 1 and 4 than under 2, 5, 3 or 6 and the latter treatments were of the same order.

The melting point of lard varied from 35-45°C (Maynard et al., 1979).

The rations for pigs in the present study from 60 kg weight contained (Table 3.3) 63.55 per cent tapioca (cassava) under treatments 1 and 4, 60 per cent rice bran under treatments 3 and 6 and 43 per cent tapioca and 33.5 per cent rice bran under treatments 2 and 5. Maynard et al. (1979) have indicated that feeds containing high proportion of carbohydrate (tapioca) produced body fat having higher melting point and unsaturated fatty acid (rice bran) produced body fat having lower melting point. This may probably explain the variation in melting point of body fat in the present study.

Fat in eye muscle and lean fat ratio :

It can be seen from Table 4.19 that between treatments the apparent difference was nonsignificant, although the fat per cent under treatments 3 and 6 was slightly lower. This observation is in agreement with that of Cromwell et al.(1978) who reported that the intra muscular fat in eye muscle between 3rd and 7th rib was 24.4 per cent and the level of energy in the diet did not affect the muscle composition although the fat content was decreased with a corresponding increase in protein content in this muscle by feeding higher level of protein. In contrast, Sharda et al. (1977) reported significantly higher fat percentage of 7.2 and 8.3 per cent in eye muscles having 71.6 and 70.6 per cent moisture, respectively, where the dietary energy for these pigs varied from 3370 and 3060 kcal/kg.

Prost et al. (1975) reported that the muscles longissimus dorsi and biceps femoris had highest fat content among muscles. The fat content in these muscles increased with the advancement of age. Petrova (1979) noticed when pigs maintained till 6.5 months of age on 17-20 per cent less than USSR recommended allowance, the carcass fat was 30.3 per cent.

The lean fat ratio in the eye muscle between treatments was not consistently different and the apparent difference was nonsignificant. The ratio was slightly larger under treatments 3 and 6.

Quality score of eye muscle :

It may be noticed from Table 4.19 that the marbling, colour and firmness scores were significantly ($P < 0.01$) higher under treatments 1, 4, 2 and 5 than under 3 and 6 and the former treatments were statistically of the same order suggestive of better quality of carcass. This observation is in agreement with that of Sharda et al.(1977). Talley et al. (1976) observed the marbling scores of eye muscle as per Wisconsin Quality Score methods in pigs maintained on 112.5 per cent, 100 per cent and 8.75 per cent of NRC recommended levels of digestible energy were 1.92, 1.5 and 2.25, respectively.

Internal organs

The wet weight of internal organs of pigs within an hour after slaughter as per cent of kill weight, under all the treatments, is presented in Table 4.20.

It can be seen that per cent organ weights were not consistently different between treatments and the weights were within the normal range characteristic of the breed (Getty, 1975; Pond and Maner, 1974). Apparently, the treatment effect was not sufficient enough to produce a measurable variation in the organs studied.

Table 4.20. Effect of dietary treatments on internal organs at 8 months of age.

Treatment			Internal organs (% of body weight)						
Code	NRC% of DE	Particle size mm	Liver	Pan-creas	Kid-neys	Adre-nals	Spleen	Heart	Lungs
1	100	2-3	1.6	0.11	0.22	0.005	0.1	0.25	0.60
2	90	2-3	1.79	0.13	0.25	0.006	0.11	0.26	0.66
3	85	2-3	2.0	0.13	0.28	0.006	0.11	0.24	0.66
4	100	< 1	1.64	0.12	0.21	0.005	0.1	0.23	0.6[illegible]
5	90	< 1	1.83	0.13	0.24	0.006	0.11	0.28	0.6[illegible]
6	85	< 1	1.98	0.14	0.27	0.006	0.1	0.25	0.6[illegible]

Alimentary tract :

The weight of alimentary tract with the contents after the pigs were fasted for 24 hours prior to slaughter is shown in Table 4.21. Significantly higher ($P < 0.05$) weight was observed under treatments 3 and 6 when compared to 1 or 4.

Kass et al. (1980) reported the weight of empty gut including all segments was increased with increasing fibre content in the diet. Further, Owen and Ridgman (1967, 1968) observed an increased intake response in pigs when caloric density of the diet was reduced.

In as much as there was an increased feed intake as the caloric density of the diet was reduced added with the residual material in the gut might be some of the contributory factors for the higher weight of alimentary tract observed under treatment 3 and 6 and probably under 2 and 5 when compared to treatments 1 or 4. The trend was the same when the weight was expressed as per cent of body weight or of metabolic body size ($W_{kg}^{.75}$). Bohman et al. (1955) reported that on feeding pigs with bulky materials there was an increase in size of stomach and intestine and this had affected the dressing percentage also.

Table 4.21. Adjusted mean and standard error of weight of alimentary tract[1] of pigs slaughtered at 8 months of age as affected by dietary treatments.

Treatment			Weight (kg)	% of body weight	% of metabolic body size ($W_{kg}^{0.75}$)
Code	NC% of DE	Particle size mm			
1	100	2-3	7.18[a] ± 0.4082	8.3	22.22
2	90	2-3	8.4[ab] ± 0.4086	9.8	29.53
3	85	2-3	9.68[b] ± 0.4082	12.29	41.29
4	100	∠ 1	6.99[a] ± 0.4086	8.18	22.44
5	90	∠ 1	8.34[ab] ± 0.4085	9.53	28.0
6	85	∠ 1	9.72 ± 0.4085	12.38	41.41

[1]Weight of alimentary tract plus contents after the animal was fasted for 24 hours before slaughter.

Means having the same superscript do not differ significantly ($P \angle 0.05$).

Analysis of variance for weight of alimentary tract

Source	df	Means sum of squares
Treatment	5	8.29*
Error	29	1

* ($P \angle 0.05$)

pH and ulcer score of stomach

The pH and ulcer score of stomach of pigs in all the treatments are shown in Table 4.22. Analysis of variance has shown that the differences between treatments in regard to pH of the stomach were statistically nonsignificant.

This observation is in agreement with that of Cuperlovic et al. (1975) who reported on barrows fed with mash the pH of the stomach contents after 24 hours of fasting was 4.1. Simonsson and Bjorklund (1978) reported in pigs on barley based meal varying in particle size from 1 to 5.2 mm, the pH of the stomach varied from 3 to 4.3.

Gross examination of the empty stomach did not show any specific lesion suggestive of gastric ulcer.

Since the specific reference to an oesophagogastirc ulcer in pigs by Bullard (1951), there have been several reports of the incidence of this condition (Ephrensperger et al., 1976; Blackshaw and Kelly, 1980) mainly on maize based diets. In comparable trials such as mixed feed with 80 per cent barley, Reese et al. (1966) could not establish such lesions. According to Fugate et al. (1965) there is definite connection other than the nature of feed, between the amount of lying space for animal, time of year and

Table 4.22. Mean and standard error of ulcer score and pH of stomach of pigs at slaughter as affected by dietary treatments.

Treatment			pH	Ulcer score
Code	NHC % of DE	Particle size mm		
1	100	2-3	$4.2 \pm .166$	0
2	90	2-3	$4.3 \pm .247$	0
3	85	2-3	$3.9 \pm .30$	0
4	100	$\angle$ 1	$4.2 \pm .281$	0
5	90	$\angle$ 1	$4.0 \pm .233$	0
6	85	$\angle$ 1	$4.2 + .166$	0

Analysis of variance for pH

Source	df	Means sum of squares
Treatment	5	0.1426
Error	30	0.3364

occurrence of stomach ulcers. Curtin *et al.* (1963) found that even piglets had developed gastric lesions. Kowalczyk *et al.* (1966) described the sudden appearance of ulcers in gilts about to farrow. Seasonality in occurrence of ulcers has been found, with more ulcers appearing during winter than the summer (Boenker, 1967). This agrees with the cyclic occurrence of ulcers in man (Kowalczyk, 1968). Breed differences have also been recognised (Curtin *et al.*, 1963; Mahan *et al.*, 1966). Derruccos and Robison (1972) reported that Durocs were having a higher incidence than Yorkshires. The etiology and development mechanism of the condition are still insufficiently understood.

Particle size of meal

It is evident on perusal of the foregoing tables that particle size had no significant effect on any of the parameters studied. There is paucity of information to support or contradict the effect of particle size of tapioca meal for pigs in relation to digestable energy. It is difficult to forsee any interaction of these two treatments and hence while partitioning the effect of treatments it was presumed that the interaction did not exist and pairwise comparison was made for the six treatments studied. It is pertinent to point out that the major energy source in this study was tapioca which was ground to different particle sizes. The general observation shows that it easily gets dissolved and the particle size as such looses its entity to manifest any effect. Further, Simonsson (1976) could not find significant effect in daily gain and feed conversion efficiency in pigs fed with barley based meals varying in particle sizes from 1.25 to 5.25 millimeter. Similar observation was made by Dobson et al. (1978) in pigs maintained on wheat and barley based diets finely ground or pelleted. In contrast, Ehrensperger et al. (1976) reported that the use of less than one millimetor meal produced a significant increase in body weight gain.

Economics

Cost per kg gain :

It is evident from Table 4.23 that the feed cost per kg gain in body weight was almost progressively increased till the pigs were slaughtered at 8 months of age. Although there was no uniformity in the increase in cost per kg gain under the respective treatments, it was lower under treatments 2 and 5. None of the pigs under treatment 3 and 6 attained 90 kg till 8 months of age. Treatment 2 having 90 per cent NRC levels of digestible energy costed less per kg gain at 90 kg body weight.

Table 4.23. Feed cost[1] per kg gain (Rs) in pigs at various body weight as affected by dietary treatments.

Treatment			Body weights, kg						
Code	ISC % of DE	Particle size mm	50	60	70*	80*	90*	100*	at 8 months of age
1	100	2-3	5.17	5.33	5.46	5.51	5.49 (3)	5.59 (3)	5.90
2	90	2-3	5.00	5.13	5.14	5.14 (4)	5.12 (3)	5.28 (2)	5.69
3	85	2-3	5.48	5.44	5.59 (3)	5.16 (1)	na	na	6.10
4	100	< 1	5.44	5.59	5.61	5.52 (5)	5.54 (5)	5.73 (4)	5.94
5	90	< 1	4.84	5.09	5.20	5.17 (5)	5.15 (4)	5.36 (2)	5.51
6	85	< 1	5.48	5.33	5.36 (3)	5.19 (1)	na	na	5.87

[1] Details of feed cost is shown in Table 3.3.

na: weight not attained till 8 months of age

* Figures in parenthesis indicate the number of pigs which attained the set weight.

Cost of labour :

The cost of labour in raising the pigs to higher weights was concomitantly increased with the body weight in all the treatments (Table 4.24). It was lowest under treatments 1 and 4 and highest under 3 and 6. Since the duration to attain higher body weights was much more under treatments 3 and 6 than under 2 and 5 or 1 and 4, the cost of labour was correspondingly the highest as might be expected.

The labour component when expressed as per cent of the total cost of feed and labour it was found to be lowest under treatment 1 and 4 (Table 4.25) and highest under 3 and 6. There was a progressive decrease in cost of labour as the pigs were carried to higher weights. At 70 kg, it was about 13.5 per cent under treatments 1 and 4; 15.7 per cent under 2 and 5 and 16.5 per cent under 3 and 6, respectively.

Cost of feed and labour :

The cost of feed and labour was progressively increased as the pigs were carried to higher body weights. It was lowest under treatments 2 and 5; highest under 3 and 6 (Table 4.26) and 1 and 4 remained in between.

Table 4.24. Average cost of labour[1] (Rs) per pig at various body weights as affected by dietary treatments.

Treatment			Body weights (kg)						
Code	NRC % of DE	Particle size mm	50	60	70*	80*	90*	100*	At 3 months
1	100	2-3	41.45	48.19	54.27	60.73	64.51 (3)	67.33 (3)	73.44
2	90	2-3	46.60	55.63	59.08	62.99 (4)	66.89 (3)	71.11 (2)	73.44
3	85	2-3	58.67	61.59	68.24 (3)	73.44 (1)	na	na	73.44
4	100	∠ 1	42.01	49.22	55.61	58.88 (5)	64.69 (5)	68.25 (4)	73.44
5	90	∠ 1	45.95	53.88	60.57	64.28 (5)	68.02 (4)	71.78 (2)	73.44
6	85	∠ 1	60.08	62.84	68.24 (3)	7[illegible].14 (1)	na	na	73.44

na : Not attained till 3 months of age

1 : Total cost of labour was Rs. 2645.28

Total number of pig days - 6120. Cost of labour/pig/day - Rs. 0.432

* Figures in parenthesis indicate the number of pigs which attained the set weight.

Table 4.25. Cost of labour as % of cost of feed and labour[1] at various body weights in pigs as affected by dietary treatments.

Treatment			Body weights (kg)							
Code	NRC % of DE	Particle size mm	20	35	50	60	70*	80*	90*	100*
1	100	2-3	21	17.6	15.7	14.6	13.7	13.1	12.4 (3)	11.4 (3)
2	90	2-3	24.2	20.7	18.4	17.4	15.7	14.2 (4)	13.8 (3)	12.9 (2)
3	85	2-3	31.1	25	20.6	18.2	16.5 (3)	16.6 (1)	na	na
4	100	< 1	19.7	17.5	15.4	14.4	13.6	12.8 (5)	12.4 (5)	11.2 (4)
5	90	< 1	25.5	21.1	18.5	17	15.7	14.7 (5)	12.7 (4)	12.5 (2)
6	85	< 1	27.8	24.1	19.5	18.5	16.9 (3)	16.2 (1)	na	na

na: Not attained

1 : Cost of feed and labour at 3 months was taken as 100%

* Figures in parenthesis indicate the number of pigs which attained the set weight.

Table 4.26. Feed and labour cost per pig at various body weights from start of experiment as affected by dietary treatments and prevailing market value of pigs (Rs.)

Treatment			Body weights (kg)					
Code	MAC % of DE	Particle size mm	50	60	70*	80*	90*	100*
1	100	2-3	264.48	330.06	395.12	464.70	521.64 (3)	588.31 (3)
2	90	2-3	253.39	318.95	375.93	430.83 (4)	483.76 (3)	573.51 (2)
3	85	2-3	285.29	337.46	412.65 (3)	499.75 (1)	na	na
4	100	< 1	273.16	341.88	407.97	458.28 (5)	520.27 (5)	607.11 (4)
5	90	< 1	248.06	316.87	384.68	436.52 (5)	498.51 (4)	556.28 (2)
6	85	< 1	307.56	339.36	404.39 (3)	480.95 (1)	na	na
Market value[1]			325.00	390.00	490.00	560.00	630.00	550.00

na : Not attained till 8 months of age

1 : 50-less than 70 kg live weight @ Rs. 6.50/kg
70-less than 90 kg live weight @ Rs. 7.00/kg
Above 90 kg live weight @ Rs. 5.50/kg

*Figures in parenthesis indicate the number of pigs which attained the set weight

Receipts :

The net surplus receipts over cost of feed and labour at 8 months of age were negative under treatments 1 and 4 and marginal under other treatments (Table 4.27). The pigs involved in the present study were marketed on termination of the experiment at 8 months of age. Pigs above 90 kg and below 70 kg were discriminated in the prevailing market to fetch a lower price per kg live weight (Table 4.28) and hence the receipts did not show the correct picture as of an enterprise motivated on profits. On the other hand, if the sales had been effected between 70 and 90 kg, maximum receipts would have had obtained.

It may be seen from Table 4.29 that the maximum profit that might be derived at 70, 80 or 90 kg live weight would be from pigs in treatment 2.

Although the prevailing market has favoured with a higher price for pigs between 70 and 90 kg, consumer preference based on quality of carcass has not been weighted.

Besides accomplishing the highest profit (30.34 per cent) for pigs under treatment 2, and an overall favourable assessment of the carcass together with the attraction of an early return on investments, the present study reveals that the performance of Large White barrows reared on feeds with 2-3 mm particle size and 90 per cent NRC levels of digestible energy was much better than under any other treatments studied

Table 4.27. Cost of feed and labour and receipt per pig by sale(Rs.) at 8 months of age as affected by dietary treatments.

Treatment			Cost of feed and labour	Receipt by sale of pig	Surplus	Deficit
Code	NRC % of DE	Particle size mm				
1	100	2-3	612.23	585.04	-	27.19
2	90	2-3	506.78	533.54	26.76	-
3	85	2-3	411.52	455.25	43.73	-
4	100	< 1	602.59	571.50	-	31.09
5	90	< 1	517.17	542.00	24.83	-
6	85	< 1	399.59	450.83	51.24	-

Table 4.28. Receipt per pig on sale (Rs) at different body weights over cost of feed and labour as affected by dietary treatments.

Treatment			Body weight (kg)					
Code	MC % of DM	Particle size mm	50	60	70	80	90	100
1	100	2-3	60.52	59.94	94.83	95.30	108.36	(-)38.31
2	90	2-3	71.61	71.05	114.07	129.17	146.24	(-)23.51
3	85	2-3	39.71	52.54	77.35	60.25	na	na
4	100	∠ 1	51.34	49.12	82.03	101.72	109.73	(-)57.11
5	90	∠ 1	76.69	71.13	105.32	123.43	134.49	(-) 6.28
6	85	∠ 1	17.44	50.64	85.61	79.05	na	na

na: Not attained till 8 months of age.

Table 4.29. Per cent profit over cost of food and labour at different body weights as affected by dietary treatments.

Treatment			Body weights (kg)		
Code	NRC % of DE	Particle size mm	70*	80*	90*
1	100	2-3	24.01	20.50	20.77 (3)
2	90	2-3	30.34	29.98 (4)	30.23 (3)
3	85	2-3	13.74 (3)	12.06 (1)	na
4	100	∠ 1	20.10	22.19 (5)	21.09 (5)
5	90	∠ 1	27.38	28.28 (5)	27.14 (4)
6	85	∠ 1	21.17 (3)	16.43 (1)	na

na : Weight not attained till 8 months of age.

* Figures in parenthesis indicate the number of pigs which attained the set weight.

5. SUMMARY AND CONCLUSION

A study was undertaken to investigate the effect of different levels of digestible energy and the influence of feed particle size on the performance and physiological reaction of growing-finishing Large White Yorkshire weaned pigs. The experiment was conducted under controlled conditions of feeding, housing and other management at the Pig Breeding Farm, Kerala Agricultural University, Mannuthy, where the ambient temperature ranged from 22° to 33°C and vapour pressure from 21 to 25 mm of Hg during the course of investigation.

2. Thirtysix barrows averaging 70 days of age and 11.2 kg weight were assigned at random to six treatments. They were individually housed and maintained on the experimental diets compounded mainly of dried sardines, dried tapioca, groundnut cake and rice bran till they attained 8 months of age. The pigs were provided with the experimental diets having 100%, 90% or 80% of NRC standards of DE with feed particle size of less than one or two to three millimeter.

3. It was observed that variations in particle size of feed did not produce any statistically significant effect on growth, physiological reactions and carcass characteristics of pigs under any of the treatments studied.

4. At 8 months of age the pigs under treatments 1 and 4 (100% DE of NRC); 2 and 5 (90 % DE of NRC); and 3 and 6 (85 % DE of NRC) had,

(i) a final weight of 102.9; 99.4; 86.8; 92.3; 67.1 and 67.2 kg,

(ii) an average daily gain of 0.545; 0.524; 0.448; 0.473; 0.329 and 0.326 kg,

(iii) consumed feed on an average of 315.5; 311.1; 329.9; 338.3; 303.4 and 300.7 kg, and

(iv) feed conversion ratio of 3.4; 3.5; 4.3; 4.2; 5.6 and 5.4, respectively.

5. The pigs reached a market weight of 70 kg at a comparatively younger age of 197.5 days on an average under treatments 1 and 4. The pigs under treatments 2 and 5 reached the same weight by 208.5 days and under treatments 3 and 6 by 228 days.

6. The digestibility of dry matter, organic matter, ether extractives and crude carbohydrate in pigs under all the treatments was significantly ($P < 0.01$) lower with the decreasing levels of DE at 5 and 7 months of age. Although the digestibility of crude protein was significantly higher ($P < 0.01$) in pigs that received 100% levels of DE than 85% level at 5 and 7 months of

age, it was found to be of the same order with that of 90% level at 5 months of age.

7. Dietary treatments had no significant effect on the rectal temperature, heart rate and respiration rate either in the morning or in the afternoon; but these were higher in the evening than in the afternoon.

8. The dietary treatments did not exert any significant influence on haemoglobin concentration in pigs involved in the present study.

9. The live weight shrinkage on transportation of pigs to a distance of 120 km by truck was found to be slightly increasing with decrease in energy concentration of diets and the shrinkage in the different treatments ranged from 3.3-6.3%.

10. There was no uniformity in the carcass shrink of pigs under different treatments and that it varied from 1-2.4 per cent.

11. As the dietary level of DE was decreased from 100% to 90 or 85%, there was a corresponding decrease in the yield of dressed carcass from 72.3 to 68.8 or 64.7% respectively. Higher dressing percentage was observed in pigs having higher body weights. The per cent yield of ham was increased from 21.35 in pigs under 100% NRC levels

of DE to 22.56 or 23.9 in 90 or 85% DE, respectively.

12. The per cent yield of other choice cuts such as loin, shoulder and bacon, or combined yield of ham plus loin, and ham plus shoulder was not significantly different between treatments indicating that among the choice cuts studied, the yield of ham was subject to variations.

13. The total yield of the four lean cuts as per cent of kill weight was significantly (P ∠ 0.01) higher in treatments having 100 per cent NRC levels of energy (55.3%) than 85 per cent (49.85%) while 90 per cent stood in between (53.1%).

14. The overall back fat thickness at 8 months of age was significantly low (P ∠ 0.01) in pigs on diets that contained 85 per cent NRC levels of energy (28.5 and 27.2 mm in treatments 3 and 6) than 90% (38.3 and 37.9 mm in 2 and 5) or 100 per cent (45.4 and 43.8 mm in 1 and 4).

15. The carcass length, area of eye muscle and melting point of body fat had manifested the same trend as that of backfat thickness. The carcass length varied from 71.9 cm in pigs under treatments having 100% DE, 70.05 cm on 90%, and 64.05 cm on 85% DE. The area of eye muscle was 31.2 cm^2 in pigs on 100% DE; 29.3 cm^2 on 90% DE and 28.4 cm^2 on 85% DE. The melting point of body fat was

45°C, 39.7°C and 38.6°C in pigs on diets containing 100, 90 and 85% DE, respectively.

16. The per cent fat in eye muscle on dry matter basis was not significantly different between treatments (22.3 to 24.9%) although it was slightly lower in low energy diets.

17. Quality score, for marbling, colour and firmness was significantly ($P < 0.01$) in favour of diets that contained higher levels of digestible energy.

18. The pH of the stomach contents on slaughter of pigs, after fasting for 24 hours, was almost uniform in all the treatments (3.9 to 4.3).

19. There was no evidence of lesions suggestive of gastric ulcer on gross examination of stomach in pigs under any of the treatments.

20. The weight of alimentary tract with the contents after the pigs were fasted for 24 hours prior to slaughter was found to be significantly higher ($P < 0.05$) on diets having 85 per cent NRC levels of energy (9.7 kg) than on 100 per cent (7.0 kg) while the treatments having 90 per cent NRC level of energy stood in between (8.35 kg).

21. The per cent weight of internal organs such as liver, pancreas, kidneys, adrenals, spleen, heart and

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lungs was within the normal range.

22. An equation $W = 5.16 + \frac{LG^2}{11568}$ was evolved from live body measurements of grith and body length predicting the live weight of pigs ranging from 8 to 144 kg, and a conversion chart to arrive at the live weights from these measurements were also worked out.

23. The feed cost per kg gain in body weight of pigs under different dietary treatments or total cost of feed and labour at different market weights of 70, 80 and 90 kg were determined. The cost of raising pigs from weaning to early market weight of 70 kg, on rations containing 90 per cent NRC levels of digestible energy was found to be most economic.

24. Maximum return and profit per cent over cost of feed and labour in pigs under the different dietary treatments were estimated and the profit was found to be 30.34 per cent at 70 kg weight in pigs under treatment 2 having 90% NRC level of DE.

25. It can be concluded that under the conditions existing in this country and Kerala in particular, pigs can be profitably raised to market weights of 70 to 90 kg on rations containing 90% of NRC standards of DE. However, it would be worthy to investigate further that how far the variation in the levels of both crude protein and DE of the diet would affect the performance of piglets, fatteners and breeding stock and the cost factor involved.

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INFLUENCE OF PARTICLE SIZE OF FEED AND PLANE OF FEEDING ON GROWTH, PHYSIOLOGICAL REACTIONS AND CARCASS CHARACTERISTICS OF GROWING-FINISHING PIGS

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Thirtysix Large White Yorkshire barrows averaging 70 days of age and 11.2 kg weight were assigned at random to six dietary treatments in order to study the influence of feed particle size and level of digestible energy on the performance, physiological reactions and carcass characteristics. They were individually housed and maintained on diets compounded mainly of dried sardines, dried tapioca, groundnut cake and rice bran till they were 8 months of age. The barrows were provided with the experimental diets having 100%, 90% or 85% of NRC standards of DE with feed particle size of less than one or two to three millimeter.

It was observed that variations in feed particle size did not produce any significant effect on growth, physiological reactions and carcass characteristics of pigs under any of the treatments.

At 8 months of age, the pigs under treatments 1 and 4 (100% DE of NRC; 2 and 5 (90 % DE of NRC) and 3 and 6 (85% DE of NRC) had, (i) a final weight of 102.9; 99.4; 86.8; 92.3; 67.1 and 67.2; (ii) an average daily gain of 0.545; 0.524; 0.448; 0.473; 0.329 and 0.326 kg, and (iii) feed conversion ratio of 3.4; 3.5; 4.3; 4.2; 5.6 and 5.4, respectively. The pigs under treatments 1 and 4 reached 70 kg weight at an age of 197.5 days on an average, while pigs under treatments 2 and 5 reached the same weight by 208.5 days, and under 3 and 6 by 228 days.

The digestibility of dry matter, organic matter, ether extract and crude carbohydrate in pigs under all the treatments was significantly ($P < 0.01$) lower with decreasing levels of DE at 5 and 7 months of age. Although the digestibility of crude protein was significantly higher ($P < 0.01$) in pigs that received 100% DE of NRC than 85% at 5 and 7 months of age, it was statistically of the same order with that of 90% at 5 months of age.

Dietary treatments had no significant effect on the rectal temperature, heart rate, respiration rate and haemoglobin concentration of blood of the experimental pigs.

The yield of dressed carcass was decreased from 72.3% to 68.8% or 64.7% with the decreasing body weight of pigs on 100%, 90% or 85% DE of NRC standards, respectively. The yield of ham was increased from 21.3% to 22.5% or 23.5% with the decreasing levels of DE, respectively. The length of carcass, eye muscle area and overall backfat thickness were significantly ($P \angle 0.01$) lower as the level of DE was decreased. The fat percentage in dried eye muscle was almost uniform (22.3 to 24.9%) in pigs under different dietary treatments. The quality score for marbling, colour and firmness was significantly ($P \angle 0.01$) in favour of diets that contained higher of DE.

The feed cost per kg body weight gain of pigs under different dietary treatments or total cost of feed and labour at market weights of 70, 80 and 90 kg were determined. The cost of raising pigs from weaning to these weights on rations containing 90% DE of NRC standards and two to three millimeter feed particle size was found to be most economic.

An equation $W = 5.16 + \frac{LG^2}{11568}$ was evolved predicting live weight of barrows ranging from 8 to 144 kg, where W, is the weight in kg, L, is the length of body in cm, and G, is the girth in cm.