EFFECT OF PARTICLE SIZE OF MAIZE ON THE GROWTH PERFORMANCE AND DIGESTIBILITY OF NUTRIENTS IN CROSSBRED (LARGE WHITE YORKSHIRE x DESI) PIGS

By

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THESIS

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DEPARTMENT OF ANIMAL NUTRITION
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DECLARATION

I hereby declare that this thesis entitled **"EFFECT OF PARTICLE SIZE OF MAIZE ON THE GROWTH PERFORMANCE AND DIGESTIBILITY OF NUTRIENTS IN CROSSBRED (LARGE WHITE YORKSHIRE x DESI) PIGS"** is a bonafide record of research work done by me during the course of research and that the thesis has not previously formed the basis for the award to me of any degree, diploma, fellowship or other similar title, of any other University or Society.

Mannuthy
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CERTIFICATE I

This is to certify that this thesis, entitled **"EFFECT OF PARTICLE SIZE OF MAIZE ON THE GROWTH PERFORMANCE AND DIGESTIBILITY OF NUTRIENTS IN CROSSBRED (LARGE WHITE YORKSHIRE x DESI) PIGS"** submitted for the degree of M.V.Sc. in the subject of Animal Nutrition of the Kerala Agricultural University, is a bonafide research work carried out by **Shri.Vasudevan, G.,** under my supervision and that no part of this thesis 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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We, the undersigned members of the Advisory Committee of **Shri.Vasudevan, G.,** a candidate for the degree of Master of Veterinary Science in Animal Nutrition, agree that the thesis entitled **"EFFECT OF PARTICLE SIZE OF MAIZE ON THE GROWTH PERFORMANCE AND DIGESTIBILITY OF NUTRIENTS IN CROSSBRED (LARGE WHITE YORKSHIRE x DESI) PIGS"** may be submitted by Shri.Vasudevan, G., in partial fulfilment of the requirement for the degree.

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Vasudevan, G.

To

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INTRODUCTION

INTRODUCTION

At the dawn of the new millennium, nearly 30 per cent of Indian population continues to remain below the poverty line. The avowed objective of providing balanced diet to the entire population remains a distant dream due to inadequate edible protein supply. The availability of animal protein with high biological value to an average Indian is only 7.6 g against the World average of 24.7 g and Indian Council of Medical Research recommended level of 34 g (Shanmugasundaram, 1997).

The prejudice against beef and slow multiplication of sheep and goat to keep pace with the ever increasing demand for animal protein had precipitated the need to find other sources to satisfy human requirements. Thus, pig production has an important role to play as an effective instrument of social change in India.

Pigs are the most accommodative and the most prolific among domestic animals. They are quick growers, use cereal by products efficiently and give higher dressing percentage at younger ages. Considering the acute shortage of animal protein on the one hand and the high production potentials of a well organized pig industry on the other, it is evident that the improvement of pig production in the poorer rural parts of our country has greater promise. But *Desi* pigs having no definite characteristics do not provide any tangible financial benefit. Hence the Indian Council of Agricultural Research has taken up the crossbreeding (Large White Yorkshire x *Desi*) programme under the All India Co-ordinated Research Project (AICRP).

Supply of nutritionally balanced economical ration is a matter of paramount importance. Several processing techniques have been developed to improve the usefulness of wide variety of feedstuffs. They are mainly processed to alter the physical form or particle size to preserve, improve palatability, digestibility, alter nutrient composition and to detoxify the feedstuffs before feeding the swine. Improving production efficiencies driven by new feed processing technologies are pushing pork production costs lower.

Grinding improves the digestibility of feed ingredients by increasing the surface area for enzyme action. Since reduction of particle size does not impose much labour and cost, a higher profit on diet with reduced particle size offers greater scope in swine feeding.

But only sketchy information is available regarding the effect of grinding on the performance of crossbred pigs in India. Hence, the present investigation was designed and conducted to assess the performance of crossbred (Large white Yorkshire x *Desi*) pigs fed three different diets containing maize of different particle sizes.

REVIEW OF LITERATURE

2. REVIEW OF LITERATURE

2.1 NUTRIENT REQUIREMENT OF PIGS

2.1.1 Protein requirements

Cunningham *et al.* (1973) observed that pigs fed the 10 per cent protein diet gained slower and were fatter than pigs fed the 14 per cent protein diet.

Baird *et al.* (1975) observed greater efficiency of protein conversion on low protein diets for Poland China pigs. Growth rate and feed:gain ratio were improved when the protein levels were increased in the diet of pigs from 16 to 20 per cent (Fetuga *et al.*, 1975). Davey (1976) opined that growth rate of Duroc and Yorkshire pigs were decreased when the protein level in their diet was reduced to 11 per cent. Compared to a 12 per cent protein diet, a 16 per cent diet decreased marbling scores and improved feed efficiency (Christian *et al.*, 1980). Indian Council of Agricultural Research (ICAR, 1985) recommended the crude protein levels as 18, 16 and 14 per cent for pigs weighing from 5-10, 10-40 and 40-60 kg, respectively.

National Research Council (NRC, 1998) recommendation of protein for pigs of 3 to 5, 5 to 10, 10 to 20, 20 to 50, 50 to 80 and 80 to 120 kg body weights were 26, 23.7, 20.9, 18, 15.5 and 13.2 per cent,respectively.

2.1.2 Amino acid requirements

As the level of protein increased, the feed intake tended to decrease. The decreased absorption of lysine was the major cause for the increase in lysine requirement with increased dietary protein levels (Klay, 1964).

The study conducted by Meade *et al.* (1966) showed that pigs fed the diet providing the greatest amount of protein demonstrated significantly more rapid gains. Efficiency of feed utilization, carcass length and backfat thickness were unaffected by level of dietary protein (or) supplementation of lysine and methionine. However, Clawson *et al.* (1962) reported that the addition of 0.4 per cent L-lysine to 10 per cent protein diets, significantly increased the loin-eye area.

Baker *et al.* (1969) found that for swine, the first and second limiting amino acids were tryptophan and lysine, respectively in corn protein and isoleucine, threonine or glutamic acid-glycine mixture can be considered as a possible third limiting factor.

The tryptophan requirement of growing pigs for maximal weight gain was specified by Boomgaardt and Baker (1973) as 0.71, 0.67 and 0.66 per cent of the protein, respectively at 10, 14 and 18 per cent dietary protein levels.

An interaction between dietary leucine and isoleucine was demonstrated by Taylor *et al.* (1984). Increasing the dietary leucine concentration to 20.4 g/kg resulted in deficiency of isoleucine in the basal diet. The daily gain, food conversion efficiency and carcass quality were significantly improved by increasing the isoleucine concentration from 3.8 g to 4.5 g/kg diet. Dietary leucine concentration did not influence performance at the higher level of isoleucine supply.

Batterham *et al.* (1985) reported that when Large White Yorkshire pigs were fed `ad libitum', maximum daily gain was obtained by feeding 10 g lysine per kg feed up to 80 kg body weight (8 g/kg thereafter) in males and 9.9 g lysine per kg upto 20 kg body weight (< 5.6 g/kg thereafter) in females. Carcass characteristics were largely unaffected by lysine concentration.

Lewis *et al.* (1981) suggested a tendency for growth rate to decrease when total dietary lysine concentration exceeds 1.25 per cent. Edmonds and Baker (1987) found that twice the recommended level of lysine reduced rate of gain and feed intake but not the feed efficiency. Lysine appeared to reduce growth via amino acid imbalance rather than antagonism.

The nutrient excretion was the lowest in pigs fed low protein (16 per cent protein) diet with 0.2 per cent of synthetic lysine (Han *et al.*, 1995).

Nam *et al.* (1995) suggested that pigs were unable to control their protein and lysine intakes to meet their requirements for growth when given a choice of two isoenergetic diets which differed in protein and lysine contents.

Lenis *et al.* (1996) concluded that for maximum growth performance of growing-finishing pigs, the requirements for apparent ileal digestible methionine + cystine, threonine and tryptophan, relative to apparent ileal digestible lysine, should be 59, 63 and 19 per cent, respectively. With regard to the methionine + cystine requirement, the methionine:cystine ratio should not be below 50 per cent.

Jin *et al.* (1998) quantified the total lysine requirement of 21 days old pigs as 1.45 per cent. They also observed that the lowest digestibility of dry matter and crude fat were in pigs fed 1.15 per cent and highest in 1.65 per cent lysine group. The nitrogen digestibility increased with lysine levels while the digestibilities of gross energy, ash and phosphorus did not differ.

Supplementation of L-lysine at the rate of 0.1 to 0.2 per cent in 16 per cent crude protein diet improved daily weight gain and feed efficiency and were comparable with those of pigs fed 18 per cent crude protein diet and nitrogen excretion was reduced by 19.3 per cent (Han *et al.*, 1995).

Li and Guan (1998) concluded that reducing protein level in swine diets can be reduced by supplementing the amino acids according to the 'ideal protein' pattern. They observed better growth response when aminoacids were added in higher levels.

National Research Council (NRC, 1998) recommendation of lysine for pigs of 3 to 5, 5 to 10, 10 to 20, 20 to 50, 50 to 80 and 80 to 120 kg body weights were 1.5, 1.35, 1.15, 0.95, 0.75 and 0.60 per cent, respectively, while the methionine requirements were 0.40, 0.35, 0.30, 0.25, 0.20 and 0.16 per cent, respectively.

2.1.3 Energy requirements

The study conducted by Ranjhan *et al.* (1972) showed reduction in growth rate and feed efficiency when energy was restricted in the diet of pigs weighing more than 50 kg body weight. Seerley *et al.* (1978) found that the utilization of calories for growth was equal for low and high energy diets during cool season, but high energy diets were more efficient in warm season.

Differences in daily energy intake affected growth rate. Restriction of the daily energy intake by 20 per cent reduced live weight gain (15 per cent), nitrogen retention (12 per cent), protein deposition (8 per cent) and fat deposition (20 per cent) in swine (Metz *et al.*, 1980).

For maintenance, the pigs required 103.4 kcal of metabolizable energy or 76.3 kcal of net energy per kg metabolic body weight (Iliescu *et al.*, 1982).

Campbell *et al.* (1985) showed that the relationship between energy intake and the rate of protein deposition was linear with maximal protein deposition occurring at an intake of about 33 MJ digestible energy per day. They observed a decline in the concentration of dietary protein required to support maximum growth performance when the energy intake of the pigs weighing from 45 to 70 kg was raised from 30 to 39.9 MJ digestible energy per day.

Kyriazakis and Emmans (1992) reported that increased intake of energy increased the live weight, empty body weight and protein and lipid gains of pigs. The energy retention was not affected by stage of growth in pigs (Hata *et al.*, 1993).

Silva *et al.* (1998) and Tavares *et al.* (1999) found that as digestible energy content of the diet was increased, diet and protein intake and serum urea concentration decreased linearly without affecting the average daily gain. Tavares *et al.* (1999) also reported that increasing the dietary digestible energy levels improved feed:gain ratio linearly and increased the fat deposition rate quadratically in gilts without affecting digestible energy intake and protein deposition rate.

Indian Council of Agricultural Research (ICAR, 1985) recommended the digestible energy contents of 3100 and 3000 kcal/kg feed for pigs weighing 5 to 10 and 10 to 60 kg, respectively. Thomas and Singh (1984a) concluded that diets having 90 per cent digestible energy level of National Research Council (NRC) standards promoted economical gains in pigs. The National Research Council (NRC, 1998) recommended 3400 kcal of digestible energy or 3265 kcal of metabolizable energy for pigs of all age groups.

2.1.4 Energy-protein interrelationship

Growth rate during the first 28 days was significantly influenced by energy-protein ratio. The narrow ratio supported the most rapid rate of gain. Added fat resulted in a significant improvement in both rate of gain and in feed per pound of gain (Clawson *et al.*, 1962).

Baird *et al.* (1975) opined that more efficient use of protein is at lower level of intake and that high energy diel has a protein saving effect by improving feed efficiency.

Sivaraman and Mercy (1986) observed no significant difference in the average daily gain and feed efficiency of pigs fed rations containing three levels of protein viz., 14, 17 and 20 per cent and three levels of energy viz., 2900, 3100 and 3300 kcals of digestible energy per kg. However, the cost per kg live weight was the least for the animals maintained on 20 per cent crude protein and 3300 kcals of digestible energy per kg feed.

Kyriazakis and Emmans (1992) showed that efficiency of protein utilization increased with an increase in starch intake.

Lunen *et al.* (1998) reported that pigs given high energy diets (16.40 Mcal/kg) were less sensitive to dietary lysine:digestible energy ratio than those given lower energy diets (14.25 Mcal/kg).

Jung *et al.* (1999) showed that pigs fed high lysine:digestible energy diet showed higher digestibility for most amino acids except glutamine and proline. The optimum lysine:digestible energy ratio appeared to be higher than 3.5 mg/kcal digestible energy.

2.2 FEED CONVERSION EFFICIENCY AND AVERAGE DAILY GAIN

The average daily feed consumption was positively correlated with average daily gain (Magee, 1962). Owen and Ridgeman (1967) observed that the average daily feed intake decreased and gain/feed increased as particle size of corn in the diet of growing pigs was decreased from 1000 to 400 µm. This suggests that fine grinding increased energy value of the corn and the feed intake of growing pigs is influenced by energy concentration of the diet. The decrease in feed intake as particle size was reduced, was greater with pelleted diets.

Reiman *et al.* (1968) also of the view that the gain/feed ratio and average daily gain were higher for finely ground corn than for coarsely ground corn. Similarly, Baird (1973) reported 4.6 per cent faster gain in pigs given pelleted diets.

Lawrence (1973) showed that for maize and barley, the micronization process significantly improved the growth rate and efficiency of conversion of dietary dry matter. Robinson (1976) opined that the decrease in feed efficiency with an increase in body weight was due to increased maintenance costs and not due to increased fat deposition.

Furthermore, fine grinding was reported to improve gain/feed in starter pigs fed sorghum (Ohh *et al.*, 1983) and Barley (Goodband and Hines, 1988). But Thomas and Singh (1984a) did not find significant difference in growth or average daily gain due to variation in particle size. Hedde *et al.* (1985) reported that pigs fed a finely ground diet (<1 mm) grew faster (0.73 vs 0.68 kg/d) and had better feed utilization (3.47 vs 3.75) than those pigs on cracked corn based diet. Hence he concluded that reducing the particle size of the diet, effectively improved growth and feed efficiency of pigs. Since feed intake was not affected by dietary particle size, it appears that the differences in growth and feed efficiency were due to reduced digestibility of the coarse diet. This observation is in concordance with Perry (1986), who found that finely ground corn in swine diets increased feed utilization by 5 to 15 per cent over coarsely ground corn and 1 to 12 per cent over medium ground corn.

Seerley *et al.* (1988) could not find any influence of wheat particle size on feed/gain ratio in piglets. However, feed/gain ratio was improved by smaller particle size in growers and by larger particle size in finishers. Giesemann *et al.* (1990) reported that particle size reduction improved average daily gain and gain/feed ratio in growing-finishing pigs fed corn based diets than for those fed sorghum based diets.

Fine grinding could be of particular benefit to newly weaned pigs, with their immature digestive tracts. Healy *et al.* (1994) observed linear increases in average daily gain and gain/feed ratio as particle size of maize was reduced from 900 to 300 μm in the diet of nursery pigs. They also concluded that gain/feed was greatest at 500 μm for all grain types. Particle size of the grain sources did not affect average daily gain significantly, but gain/feed increased quadratically with the greatest gain/feed at 500 μm for all grain sources.

Wondra *et al.* (1995a) stated that average daily feed intake was increased by 6 per cent (from 4.19 to 4.43 kg/day) as corn particle size was decreased from 1200 to 400 μm in the diet of sows. But in finishing pigs, feed intake decreased with reduced particle size. They also reported that litter body weight gain, intakes of drymatter and digestible energy were increased by 11, 6 and 14 per cent, respectively as corn particle size was reduced from 1200 to 400 μm. In another experiment Wondra *et al.* (1995b) found that feed intake and milk production were increased in sows fed diets with finely ground corn (444 μm).

Luce *et al.* (1996) showed that the pigs fed corn diets gain faster, consume more feed and gain less efficiently than pigs fed wheat diets. Pigs fed dry rolled diet were more efficient than those fed ground wheat diet. Zanotto *et al.* (1996) was of the view that feed intake and feed to gain ratio increase linearly with increasing particle size. Best results were obtained with particle sizes from 509 to 645 μm.

Fantuz *et al.* (1997) concluded that average daily gain was negatively correlated with mean particle size while mill type (hammer mill vs roller mill) and screen size (1.25 vs 2.00 mm) did not affect average daily gain feed conversion efficiency, dressing percentage or backfat thickness. Only mill type had an effect on mean particle size of diets, screen size did not influence the physical features of diets.

2.3 GRINDING AND MEASUREMENT OF PARTICLE SIZE

Grinding is that process by which a feedstuff is reduced in particle size by impact, shearing or attrition. It may change the digestibility of cellulose and protein (Ensminger *et al.*, 1990).

Factors influencing the nature of ground feed are screen size, hammer mill size, power and speed, type of grain and moisture content of grain. The methods used for the measurement of particle size of ground feed are sieving, microscopic measurements and sedimentation method. The particle size of a ground feed is commonly expressed as the number or size of the pores and sieve through which all particles pass. Usually 250 or 100 g sample is used for sieving. In a seven sieves system the sieves of 0.375, 4, 8, 14, 28, 48 and 100 mesh size are used in descending order. The particles remaining on screens 0.375, 4 and 8 are termed as “coarse” particles, that on number 14 and 28, as “medium” particles and remaining as “fine particles”. This is determined by separation of particles after five minutes shaking in a standard sieve shaker. The method of expressing the fineness of a ground feed is called “modulus of uniformity and fineness”. This is expressed on a ten point scale (Pathak, 1998).

2.4 APPARENT DIGESTIBILITY OF NUTRIENTS

2.4.1 Influence of processing methods

Lawrence (1970) reported that the diet with the particle size of 1.56 mm was retained in the gut significantly longer and gave the highest coefficient of apparent digestibility for both the ether extract and crude fibre fractions in the diet of growing pigs than those diets with the particle size of 4.68 mm or 9.36 mm. Similarly, the micronization process increased dry matter, nitrogen and gross energy digestibility (Lawrence, 1973).

Noland *et al.* (1976) observed a significant improvement in the digestibility of energy and nitrogen was obtained in the diets containing extruded sorghum grain in contrast to the ground form. Maximum energy and nitrogen digestibilities were observed with the diet containing soybean flakes cooked for 12 minutes.

Owsley *et al.* (1981) opined that reduction in particle size of sorghum from 1262 to 802 and 471 µm improved the apparent digestibilities of dry matter, starch, nitrogen and gross energy measured at the terminal ileum and for the total digestive tract of growing pigs.

The study conducted to determine the ileal digestibilities of amino acids in corn, rice, barley, naked barley and wheat for growing pigs by Furuya and Kaji (1987) revealed that the increasing fineness of the rice grind, improved the ileal crude protein and energy digestibilities by 10 and 7 digestibility units, respectively. They further reported that the digestibilities of dry matter, crude protein and energy were higher for pelleted diets than for the meal diets. But crude protein digestibility of the meal diets was higher when the maize was ground through a 4 mm screen.

Giesemann *et al.* (1990) observed improvements in digestibilities of dry matter, nitrogen and gross energy of corn based diets fed to growing pigs, as particle size was reduced from 1506 µm to 641 µm.

Increased energy digestibility in nursery pigs and broiler chicks was reported by Healy *et al.* (1994) as the particle size of corn and sorghum grain was decreased from 900 to 300 µm.

Wondra *et al.* (1995a) reported increased digestibility of dry matter, nitrogen and gross energy with increased particle uniformity. They also suggested that increased nutrient digestibility with reduced particle size may result both from increased surface area and increased uniformity of particle size. They observed the digestible energy value of the diet with 400 μm corn as 7 per cent greater than the digestible energy of the diet with 1200 μm corn. Sows fed the 400 μm diet also digested 14 per cent more nitrogen and 11 per cent more dry matter than sows fed the 1200 μm diet. Hence 21 per cent and 31 per cent reductions in fecal excretions of dry matter and nitrogen were noticed. In another experiment, Wondra *et al.* (1995b) observed that the metabolizable energy and apparent nitrogen retention value of the diet were maximised with the 400 μm and 600 μm diets respectively.

An interaction between pelleting and particle size reduction, for gross energy digestibility was stated by Wondra *et al.* (1995c). In the pelleted diets gross energy digestibility increased as particle size of corn was reduced from 1000 to 400 μm but in meal diets, gross energy digestibility was not increased by the reduction from 1000 to 800 μm and was increased by reduction from 800 to 400 μm.

Chae *et al.* (1997) reported that pigs fed finely ground and pelleted diets improved average daily gain and feed/gain ratio (13.4 and 9.8 per cent) compared to those fed mash diets. Pelleting also improved the digestibility of crude protein and fat.

2.4.2 Influence of genotype

Yen *et al.* (1983) stated that contemporary, lean and obese genotype in pigs had little or no effect on coefficients of digestibility of nitrogen and energy.

2.4.3 Influence of body weight

Saitoh and Takahashi (1985) noticed that the digestibilities of dry matter, gross energy, crude protein and crude fibre were decreased with increased feed intake while nutrient digestibilities increased with increasing body weight. However, the variations in nutrient digestibilities were least in pigs weighing from 30 to 70 kg and when fed at 3 to 4 per cent of body weight.

2.4.4 Influence of age

Comparative digestibility experiments conducted by Fernandez *et al.* (1986) showed that the sows had superior digestibility of nutrients than growing pigs. On an average, the sows digested 150 g more crude protein, 100 g more crude fat, 300 g more crude fibre per kg diet and proportionately 9 per cent more gross energy than the young animals.

2.4.5 Influence of crude fibre levels

A significant reduction in apparent digestibility of dry matter, nitrogen free extract and crude protein was reported when fibre was added to the low protein ration (Pond *et al.*, 1962).

Eggum *et al.* (1982) found that growth rate and digestibility of dry matter, organic matter, nitrogen, crude fat, crude fibre, nitrogen free extract, gross energy and metabolizable energy:gross energy ratio were decreased when high fibre diet was fed to pigs.

The apparent digestibilities of nitrogen, dry matter, energy, neutral detergent fibre and acid detergent fibre decreased with increased level of crude fibre (Stanogias and Pearce, 1985). They further reported that the average daily feed intake increased linearly, but average daily digestible energy intake decreased with increased fibre level.

2.4.6 Influence of protein levels in the diet

Sikka *et al.* (1987) conducted metabolism trials to see the effect of protein level on nitrogen digestibility and found that in summer, the apparent nitrogen digestibilities at 14 and 16 per cent protein diets were lower (71.20 and 72.00) than those of 20 and 22 per cent protein diets (76.8 and 77.8). In winter, the digestibility of nitrogen of the 14 per cent protein diet was lower than that of 20 and 22 per cent (71.3 against 76.8 and 77.8).

2.5 ESTIMATION OF DIGESTIBILITY BY INDICATOR METHOD

Olsen *et al.* (1975) conducted an experiment to assess the effect of roasting and particle size on the digestibility of soybeans by pigs and rats. The diets were given to appetite and contained chromic oxide. Intake of feed was recorded and samples of faeces were collected during the second week of each period. They concluded that different grinding treatments had no influence on digestibility.

Yen *et al.* (1983) suggested that 4N HCl insoluble ash may be used as a natural indicator for estimating apparent nutrient digestibility in pigs, especially at younger ages.

Kohler *et al.* (1990) used chromic oxide and titanium oxide as solid phase markers and Co-EDTA as liquid phase marker in pigs. The pectin-rich and fibre-rich diets lowered the recovery of markers.

Moughan *et al.* (1991) added chromic oxide and acid insoluble ash as faecal markers in young growing pigs. They found that total faecal collection gave higher apparent digestibility coefficients than those calculated by reference to chromic oxide for dry matter, organic matter and gross energy.

Jagger *et al.* (1992) concluded that the most appropriate inert marker for the determination of ileal and faecal apparent digestibility in pigs, was titanium oxide added at the level of 1 g/kg feed.

The indicator most commonly added to feed to determine the digestibility coeficients of nutrients was chromium in the form of chromic oxide (McDonald *et al.*, 1995).

Kemme *et al.* (1996) calculated apparent total tract digestibility of calcium and phosphorus by using chromic oxide as the marker.

Schiavon *et al.* (1996) compared total collection and chromic oxide techniques for the evaluation of apparent digestibility in pigs fed different diets and with different adaptation and collection periods. They suggested that seven days adaptation and four days collection were sufficient to obtain constant digestibility coefficients for organic nutrients.

Garcia *et al.* (1999) used microwave digestion and atomic absorption spectrophotometry to determine chromic oxide as a digestibility marker in feed, faeces and ileal contents.

2.6 BODY WEIGHT AND BODY MEASUREMENTS

Berge (1951) reported that live weight, body length, shoulder height, heart and abdominal girth were highly correlated and an increase in any of the traits was accompanied by a similar increase in others. But body length was unreliable, while the chest measurement increased with increase in live weight.

The regression of gain on age and on heart girth was investigated by Berge and Indrebo (1959) in Norwegian Landrace pigs from birth to 250 kg body weight. The increases were not uniform throughout the period as at times, body length increased to a greater extent than did heart girth. However, Gruev and Machev (1970) was of the view that the six month body weight of both male and female pigs were correlated with body length, height at withers and heart girth. According to Mickwitz and Bobeth (1972) the body measurement most highly correlated with live weight was chest circumference in pigs.

However, Deo and Raina (1983) stated that although the genetic correlation of body length with height at withers and barrel and chest girths were positive, it was non-significant at all ages. In Large White Yorkshire pigs, the contribution of length, height, heart and abdominal girths towards the live weight were 3.11, 27.02, 23.08 and 36.80 per cent, respectively. The above values for crossbred piglets were 1.95, 25.76, 53.06 and 17.07 per cent, respectively.

Sahaayaruban *et al.* (1984) also established the highly positive correlations between body weight, body length, chest girth, shoulder height and hip width.

Dash and Mishra (1986) reported that the body length, height, heart girth and abdominal girth of Large White Yorkshire and crossbreds at the slaughter age of 24 weeks were 96.54 and 94.23 cm, 54.27 and 52.61 cm, 71.27 and 68.23 cm 66.18 and 63.23 cm, respectively. They also concluded that the heart girth in cross breds and abdominal girth in Large White Yorkshire were the important body measurements contributing towards increase in the body weight.

Ensminger *et al.* (1990) suggested the following relationship: Heart girth x heart girth x length ÷ 400 = weight in pounds. They also suggested that for hogs weighing less than 150 lb, 7 lb has to be added to the weight figure obtained from formula.

2.7 CARCASS QUALITY

The nutritional factors concerned with the carcass quality are of prime importance when compared to other factors such as breed and sex (Sharda and Vidyasagar, 1986).

2.7.1 Influence of energy levels

Various methods are practised by restricting the energy intake at the finishing time in order to have leaner carcasses. Robinson (1976) reported that with an increase in the dietary level of energy, there is a faster growth rate and lower lean content. Significant difference was observed in some loin fat measurement and fat overlying the eye muscle on the lower levels of feed intake. The dressing percentage was significantly higher in the case of animals on low plane of nutrition than those on high plane.

Higher energy level increased carcass back fat thickness while lower energy level decreased back fat thickness and dressing percentage (Baird *et al.*, 1970; Talley *et al.*, 1976).

Russo (1973) reported that in Large White Yorkshire pigs from 40 to 90 kg, weight gains, conversion of feed, cost of production and profit were most favourable with the high energy feed (supplying from 7989 to 9872 kcal digestible energy daily, from 3.0 to 4.2 times the maintenance requirement and with a ratio of daily intakes of kcal digestible energy to g crude protein from 22.7 to 23.6). The percentage of lean and fat cuts in carcass were not affected by the intake of energy.

Ramachandran (1977) reported that variation in dietary energy and protein levels in the rations of pigs did not have any effect on carcass traits. However, Metz *et al.* (1980) observed that restriction of the daily energy intake by 20 per cent caused a 8 per cent lower carcass muscle growth and a 28 per cent lower fatty tissue growth.

Huegtan and Stumpf (1996) reported that a metabolizable energy level of 3275 kcal/kg gain was sufficient to maximise average daily gain and a further increase in the level of energy resulted in increased backfat thickness in finishing pigs. Similarly, Kyriazakis and Emmans (1992) indicated that an increase in the intake of energy significantly increased the body weight, protein and lipid gains of pigs slaughtered.

2.7.2 Influence of dietary protein levels

Aunan *et al.* (1961) reported that dietary protein levels of 14, 16 or 18 per cent did not have a significant effect on daily gains and carcass measurements in pigs. This report is in concordance with that obtained by Clawson *et al.* (1962). But several researchers reported improvements in carcass desirability with increasing levels of dietary protein (Cunningham *et al.*, 1973; Baird *et al.*, 1975 and Davey, 1976).

Pigs fed high protein diet showed higher feed efficiency, better average daily gain, yielded carcass containing a higher percentage of lean cut, less back fat and more loin eye area than pigs fed low protein diet (Cromwell *et al.*, 1978).

Shields and Mahan (1980) opined that moderate temporary protein restrictions can be made on pig diets without adversely affecting overall gains or carcass quality.

For pigs given diets deficient in crude protein, rate of protein deposition was linearly related to protein intake but independent of energy intake, where as for pigs given a diet adequate in crude protein, rate of protein deposition was related to energy intake and independent of protein intake (Campbell *et al.*, 1984).

Latimier and Dourmad (1993) studied the effect of three protein feeding strategies for grower and finisher pigs and found that growth rate and feed conversion efficiency were similar in all groups, while the dressing percentage decreased with increased dietary protein.

Castell *et al.* (1994) reported that an increase in lysine:energy ratio led to a significant improvement in lean content. When low protein diets were supplemented with lysine for heavy finishers, there was no significant difference in carcass yield and quality (Kuhn and Burgstaller, 1995).

Xie *et al.* (1995) reported that the back fat thickness was affected by energy level and the lean percentage by crude protein level.

2.7.3 Influence of season

Baird *et al.* (1970) found that winter-fed pigs gained more slowly, had a higher dressing per cent, yielded more lean and primal cuts with larger longissimus dorsi areas than the summer-fed pigs.

In contrast, Baird (1973) reported that summer fed pigs were significantly leaner than the winter-fed pigs and the winter-fed pigs required more feed per unit of gain.

In summer, when pig diets were supplemented with 9 per cent fat, the carcasses yielded had higher dressing percentage, more back fat and lesser loin eye area.

2.7.4 Influence of calorie:protein ratio

Sharda and Vidyasagar (1986) reported that pigs fed diets containing 16.2, 14.4, 12.6 and 11.7 per cent CP and 3500, 3300, 3300 and 3300 kcal digestible energy per kg diet during 10-20, 20-35, 35-60 and 60-75 kg body weight periods, respectively, produced leanest carcasses. The dressing per cent and carcass length were not influenced to a great extent by altering the calorie:protein ratio in the diet.

2.7.5 Influence of the levels of crude fibre in the diet

The yields of lean cuts and primal cuts decreased with high fibre level (Baird *et al.*, 1970). There was a significant reduction in back fat thickness when the fibre level was increased and energy level was decreased in diet of pigs after they reached 50 kg body weight (Ranjhan *et al.*, 1972).

Baird *et al.* (1975) showed that feeding a diet which had 4 per cent crude fibre, resulted in lower dressing percent and back fat thickness, but higher percentages of ham and loin and significantly more lean cuts than did a diet, which had 8 per cent crude fibre. Varel *et al.* (1984) concluded that pigs fed the high fibre diet which contained 35 per cent alfalfa meal, gained 17.3 per cent less, had increased feed to gain ratio, less carcass weight, 35-42 per cent less back fat and 1.8 per cent less loin eye area than those fed the low fibre diet without alfalfa meal.

2.7.6 Influence of processing methods

Meade *et al.* (1966) concluded that the carcass traits were not affected greatly by pelleting or particle size of the diet. Similarly, the study conducted by Baird (1973) and Chae *et al.* (1997) showed that pelleting swine diets had no effect on the growth and carcass characteristics. However, Lawrence (1973) observed that pigs fed the diets based on the cereals in micronized form had significantly higher killing out percentage and more carcass length than did those which were offered their diets in ground form.

Thomas and Singh (1984b) also could not find significant changes in the carcass traits when the particle size of the grower cum finisher diet was changed from 2-3 mm to less than 1 mm. Reducing the particle size did not affect the average daily gain, feed intake, feed conversion efficiency and carcass composition of crossbred pigs (Wu and Cheng, 1988).

Wondra *et al.* (1995c) reported that last rib back fat thickness and dressing percentage were not affected by pelleting or reducing particle size of corn from 1000 to 400 μm. They also opined that the increase in dressing percentage with smaller particle sizes might have resulted from reduced feed intake and thus reduced weight of intestines.

Mill type (hammer mill vs roller mill) and screen size (1.25 vs 2.00 mm) did not affect feed conversion efficiency, dressing percentage or back fat thickness (Fantuz *et al.*, 1997).

2.6.7 Effect of sex

Many researchers opined that gilts yielded better carcasses with lesser back fat (Christian *et al.*, 1980 and Shields and Mahan, 1980).

Meade *et al.* (1966) showed that gilts had significantly larger cross-sectional area of the longissimus dorsi muscle and greater yields of trimmed ham and loin when maintained on oats based pelleted diet.

Baird (1973) reported that when fed a pelleted diet, barrows gained significantly faster than gilts. Russo (1973) reported that male pigs grew faster and used feed more efficiently than the female from 90 kg onwards. The female pigs had a higher dressing percentage and a greater proportion of fat cuts and a smaller proportion of lean cuts than male pigs. For male pigs, the cost of production was lower and the profit per kg live weight, was higher when sold on the basis of carcass quality.

Shields and Mahan (1980) found that barrows gained faster than gilts but gilts had leaner carcasses, as indicated by lean cut percentage, back fat thickness and longissimuss muscle area.

Arora *et al.* (1994) found that males had higher loin eye area, head weight and shoulder percentage than females, while females had significantly longer carcass length.

Sex and its interaction with genetic group had non significant effect on slaughter weight, back fat thickness, carcass weight and loin eye area (Singh *et al.*, 1997) but significant effect on post weaning body weight (Singh *et al.*, 1998b), carcass length (Arora *et al.*, 1994) and on dressing percentage (Kumar and Barsaul, 1987).

2.6.8 Effect of breed

Aunan *et al.* (1961) indicated that there was a highly significant effect of breed on all measures of carcass leanness in pigs. Duroc pigs gained weight faster and more efficiently than Hampshire. Hampshire pigs produced longer carcass with less fat, larger loin area and higher yield of lean cut.

The genetic group had highly significant effect on weight at slaughter, carcass length, carcass weight, dressing percentage and loin eye area (Deo *et al.*, 1992). But Arora *et al.* (1994) reported nonsignificant effect of genetic group on carcass traits except the loin eye area.

Singh *et al.* (1997) reported that crossbred pigs had more dressing percentage compared to pure breeds including exotic and *Desi* pigs. He has also reported that among pure breeds Hampshire pigs had significantly higher (30.43 cm^2) loin eye area than Large White Yorkshire crosses (23.66 cm^2).

The study conducted by Singh *et al.* (1998a) to assess the influence of age on carcass traits showed that, the optimum slaughter age for Landrace and Large White Yorkshire pigs was 131 to 190 days and 371 to 430 days, respectively.

2.6.9 Influence of age at slaughter

Deo *et al.* (1980) did not observe significant influence of age at slaughter on dressing percentage and loin eye area. Kumar and Barsaul (1987) concluded that the slaughter of pigs at 70 kg body weight would be better and more economical than at higher weights.

Singh *et al.* (1997) observed progressive increase in carcass length, carcass weight and back fat thickness, with the advancement of age. He also suggested that the amount of fat in the early age is comparatively lesser.

2.6.10 Influence of live weight

Kumar *et al.* (1974) concluded that slaughter of pigs at 70 kg would be more economical than slaughtering at 50 or 90 kg weights. The yield of head, hot and chilled carcass, dressing percent, back fat thickness and loin eye area were significantly more in higher age groups while percent ham and lean cut of carcass were significantly higher in young animals (Anjaneyulu *et al.*, 1984).

Mishra and Sharma (1991) observed an increasing trend in the dressing percentage, carcass length and back fat thickness with increase in carcass weight. Cisneros *et al.* (1996) was also of the view that as the slaughter weight increased, feed intake, back fat thickness and loin eye area increased and growth rate was not influenced by the slaughter weight. Pigs with lesser weight are more desirable for lean cuts as with advancing age and live weight above 70 kg the proportion of ham was reduced and that of bacon was increased (Singh *et al.*, 1998a).

However, dressing percentage in different sexes of Large White Yorkshire pigs at different live weights (50 kg, 70 kg and 90 kg) did not differ significantly (Kumar and Barsaul, 1987).

2.7 Economics of gain

Healy *et al.* (1994) studied the effect of particle size of corn on the growth performance of nursery pigs. They reported cost of gain per kg as Rs.15.78, 15.52 and 13.42 for diets having maize with the particle size of 900, 700 and 300 μm, respectively.

MATERIALS AND METHODS

3. MATERIALS AND METHODS

3.1 Animals

Twenty four female, weaned, crossbred piglings with an average body weight of 14.5 kg belonging to the Center for Pig Production and Research, Mannuthy were used as the experimental animals.

The piglings were divided into three groups of eight piglings each, as uniformly as possible with regard to age and body weight. Eight piglings in each treatment were randomly distributed into four replicates of two piglings each. The three groups of piglets were randomly allotted to three dietary treatments (T_1, T_2 and T_3). Each replicate was housed in different pens. All the animals were dewormed before the commencement of the experiment and maintained under identical managemental conditions during the experimental period of 153 days.

3.2 Experimental diets

The piglings were fed rations formulated to contain 18 per cent and 14 per cent crude protein, during the grower and finisher phase, respectively. They were fed the grower ration until they attained an average body weight of 50 kg and thereafter changed to the finisher ration until the animals were slaughtered.

The rations were given twice a day. The piglets of the three groups were fed the same diet containing maize ground to three different particle sizes. They were randomly allotted to the following dietary treatments.

T_1 - Diet containing maize of particle size 3 mm (coarse)

T_2 - Diet containing maize of particle size 1 mm (medium)

T_3 - Diet containing maize of particle size < 0.1 mm (fine)

The method described in Association of Official Analytical Chemists (AOAC, 1990) was followed to estimate the chemical composition of the diets.

The ingredient composition and the chemical composition of the experimental diets are given in Table 1 and 2, respectively.

The maize for the coarse form (used in T_1 diet) was ground in a hammer mill (M/S Azras poultry equipments, Miller Tank Bunk Road, Bangalore) using 3 mm mesh, while the medium and fine types used in T_2 and T_3 diets were ground in a pulveriser (Johnson Engineering Works, Kuttanallur, Thrissur, Kerala). The ground nut cake and unsalted dried fish used in all the three diets were ground in the hammer mill using 3 mm mesh.

3.3 Feeding trial

The piglets of each pen were group fed. Restricted feeding was followed throughout the experimental period. They were fed in the morning (7.00 AM) and evening (16.30 PM) and were allowed to consume as much feed as they could, within a period of one hour. Clean drinking water was provided in all the pens throughout the experimental period.

Body weight and body measurements were recorded monthly. The quantity fed was increased according to their requirement. Body measurements such as length, girth and height were recorded as described below.

3.4 Body length

An imaginary line was projected from the anterior border of the shoulder joint of one side to the same border of the other side and the point of bisection of this line in the mid dorsal line was taken as the anterior land mark. Similarly, an imaginary line was projected from the mid point of the external aspect of the hock joint of one side to the same point of the other side and the point of bisection of this line in the mid dorsal line was taken as the posterior land mark. The distance in centimetres between these two land marks was taken as the body length.

Table 1

Ingredient composition of experimental diets.

Ingredients	Grower diet (%)	Finisher diet (%)
Yellow maize	40.0	60.5
Groundnut cake (expellar)	11.0	5.0
Rice polish	15.0	19.0
Wheat bran	20.5	6.0
Unsalted dried fish	12.0	8.0
Mineral mixture*	1.0	1.0
Salt	0.5	0.5

* Keyes mineral mixture without salt (KSE Ltd., Irinjalakuda)
Ingredients : Calcium - 24.0%, Phosphorus - 12.0%, Magnesium - 6.5%, Sulphur - 0.5%, Iron - 0.5%, Zinc - 0.38%, Manganese - 0.15%, Copper - 0.5%, Iodine - 0.03%, Cobalt - 0.02%, Fluorine (max) - 0.04%, Acid insoluble ash (max) - 2% and Moisture - 4%

Vitamin supplement (INDOMIX ®) added @ 10 g per 100 kg feed mixed. (Nicholas Piramal India. Ltd., Mumbai). Composition per gram: Vitamin A - 40,000 IU, Vitamin D_3 - 5,000 IU and Vitamin B_2 - 20 mg.

DL - Methionine added @ 30 g per 100 kg feed mixed (Degussa Antwerpen NV., Belgium).

Table 2

Chemical composition of experimental diets[a].

Item	Grower diet (%)	Finisher diet (%)
Dry matter	90.86	90.37
Crude protein (N x 6.25)	18.25	14.11
Ether extract	4.90	5.91
Crude fibre	6.13	5.79
Nitrogen free extract	61.49	65.09
Total ash	9.23	9.10
Acid insoluble ash	5.01	5.26
Calcium	1.20	1.41
Phosphorus	0.72	0.70

a - on dry matter basis

3.5 Body girth

The circumference of the body barrel just behind the forelimb was taken in centimetres as the body girth.

3.6 Body height

Height of the animal was measured in centimetres at the dorsal border of the scapula.

3.7 Digestibility trial

Digestibility trial was conducted at the end of the experiment to determine the digestibility coefficients of nutrients of the experimental diets. Chromic oxide was added@ 0.05 per cent to each experimental diet as an external indicator for measuring the digestibility coefficients of nutrients. Chromic oxide was mixed first with small quantity of feed and then with the already mixed feed in a vertical feed mixer for 10 minutes to ensure proper mixing.

The animals were fed chromic oxide mixed rations for a period of four days. Faeces was collected for three days from the second day onwards.

Faecal grab samples, uncontaminated with urine, were collected from different places of each pen at 07.00, 13.00 and 16.30 hrs, during the collection period of three days. The samples of faeces from each pen taken each day were pooled accordingly and were placed in double lined polythene bags, labelled and kept in the deep freezer for analysis. From the pooled feed and fecal samples, subsamples were taken and analysed for proximate composition as per standard methods (AOAC, 1990).

The chromium content was determined using Atomic Absorption S pectrophotometer. The digestibility coefficients were calculated using appropriate formulae (Maynard *et al.*, 1979).

3.8 Slaughter studies

Four animals from each treatment were selected randomly and slaughtered at the end of the experiment for evaluation of their carcass traits.

The head was removed at the atlanto-occipital joint and the dressed weight of the carcass without head was recorded to determine the dressing percentage of hot carcass. Weight of head was also recorded.

The length of the carcass was measured from the anterior edge of the aitch bone (Os-sacrum) to the anterior aspect of the first rib. The back fat thickness was estimated as an average of the measurements taken opposite to the first rib, the last rib and the last lumbar vertebra. The loin eye area or the area of the *Longissimus dorsi* muscle between 10^{th} and 11^{th} rib was cut and traced on a transparent paper and the area was calculated by plotting the trace surface on graph paper. The dressing percentage (carcass weight divided by live body weight x 100) was calculated after removing the head, feet and kidney from the carcass.

3.9 Statistical analysis

The data obtained were analysed by the Completely Randomized Design (CRD) method as described by Snedecor and Cochran (1981). The means were compared using least significant difference test.

RESULTS

4. RESULTS

4.1 Average daily gain and Feed conversion efficiency

The results on the average daily gain and average feed conversion efficiency of pigs under the three dietary treatments T_1, T_2 and T_3 are set out in the Table 7, Fig.1 and 3. The animals fed with diet containing finely ground (< 0.1 mm) maize recorded higher ($P < 0.01$) average daily gain and feed conversion efficiency than those fed diet having medium ground (1 mm) or coarsely ground (3 mm) maize. The values were 317 g and 5.38, 335 g and 5.08 and 373 g and 4.57 respectively for the groups T_1, T_2 and T_3. There was no difference ($P > 0.05$) between the groups T_1 and T_2 for average daily gain and feed conversion efficiency.

4.2 Body weight and body measurements

Data on body weight gain and body measurements of pigs in the three treatment groups T_1, T_2 and T_3 recorded at monthly intervals are presented in Tables 3 to 6. Table 7 contains the consolidated data on gain in body measurements and body weight. The monthly body weight of experimental animals is presented in Fig. 2. The average values for gain in body weight of animals belonging to the groups T_1, T_2 and T_3 were 48.4, 51.3 and 57.3 kg, respectively. The values for body length of animals were 80.4, 84.9 and 86.0 cm, respectively. The chest girths were 86.6, 90.1 and 94.6 cm and the shoulder heights were 55.4, 56.3 and 62.4 cm, respectively.

The body weight gain and body measurements were higher ($P < 0.01$) for pigs fed finely ground maize (<0.1 mm) than for those fed medium ground (1 mm) maize or coarsely ground maize (3 mm).

Table 3

Body length (cm) of pigs maintained on different dietary treatments at monthly intervals[1]

Treatments	Months					
	0	1	2	3	4	5
T_1	56.0 ± 1.45	60.3 ± 1.50[a]	65.1 ± 1.33[a]	70.3 ± 1.41[a]	75.4 ± 1.20[a]	80.4 ± 1.10[a]
T_2	58.6 ± 0.68	66.8 ± 0.77[b]	72.1 ± 0.83[b]	76.0 ± 0.87[b]	80.4 ± 0.94[b]	84.9 ± 0.93[b]
T_3	57.1 ± 1.46	64.6 ± 1.25[b]	70.4 ± 0.85[b]	76.0 ± 0.60[b]	80.5 ± 0.50[b]	86.0 ± 0.68[b]

1 - Mean of eight values with SE
a, b, c - Means with different superscripts within the same column differ (P<0.01)

Table 4

Chest girth (cm) of pigs maintained on different dietary treatments at monthly intervals[1]

Treatments	Months					
	0	1	2	3	4	5
T_1	63.8 ± 1.34	67.4 ± 1.57	71.8 ± 1.46	76.8 ± 0.84[a]	81.8 ± 0.89[a]	86.6 ± 0.82[a]
T_2	65.2 ± 0.95	70.0 ± 0.29	75.6 ± 1.15	80.9 ± 1.12[b]	85.5 ± 1.07[b]	90.1 ± 0.97[b]
T_3	63.4 ± 1.33	67.8 ± 0.98	74.9 ± 1.14	82.6 ± 0.93[c]	88.3 ± 0.82[c]	94.6 ± 0.65[c]

1 - Mean of eight values with SE
a, b, c - Means with different superscripts within the same column differ (P<0.01)

Table 5

Shoulder height (cm) of pigs maintained on different dietary treatments at monthly intervals[1]

Treatments	Months					
	0	1	2	3	4	5
T_1	41.6 ± 1.55	45.5 ± 1.53	48.9 ± 1.27	51.0 ± 1.24[a]	53.1 ± 1.22[a]	55.4 ± 1.21[a]
T_2	42.4 ± 0.85	45.8 ± 0.80	48.3 ± 0.75	51.0 ± 0.86[a]	53.6 ± 1.07[a]	56.3 ± 1.23[a]
T_3	40.9 ± 1.34	45.9 ± 1.45	50.5 ± 1.15	55.3 ± 0.62[b]	59.1 ± 0.44[b]	62.4 ± 0.50[b]

1 - Mean of eight values with SE
a, b, c - Means with different superscripts within the same column differ ($P<0.01$)

Table 6

Body weight (kg) of pigs maintained on different dietary treatments at monthly intervals[1]

Treatments	Months					
	0	1	2	3	4	5
T_1	14.5 ± 1.00	25.8 ± 1.57	35.3 ± 1.18	45.3 ± 1.12[a]	54.7 ± 1.16[a]	62.9 ± 0.85[a]
T_2	14.5 ± 1.25	26.5 ± 1.04	36.5 ± 0.92	47.6 ± 1.05[a]	55.9 ± 1.07[a]	65.8 ± 1.40[a]
T_3	14.6 ± 1.10	26.2 ± 1.08	37.4 ± 1.09	49.7 ± 0.95[b]	59.9 ± 1.44[b]	71.6 ± 1.68[b]

1 - Mean of eight values with SE
a, b, c - Means with different superscripts within the same column differ ($P<0.05$)

Table 7

Consolidated data on average gain in body measurements (cm), body weight (kg) and feed conversion efficiency of the pigs maintained on different experimental diets[1].

Parameter	T_1	T_2	T_3
Body length gain (cm)	24.4 ± 0.75^{a}	26.3 ± 0.77^{ab}	28.9 ± 1.29^{b}
Chest girth gain (cm)	24.4 ± 1.29^{a}	26.6 ± 0.96^{a}	33.9 ± 0.92^{b}
Shoulder height gain (cm)	13.8 ± 0.84^{a}	13.9 ± 1.06^{a}	22.9 ± 2.03^{b}
Body weight gain (kg)	48.4 ± 1.24^{a}	51.3 ± 1.15^{a}	57.3 ± 1.19^{b}
Total feed intake (kg)	259.5 ± 0.00	259.5 ± 0.00	259.5 ± 0.00
Average daily gain (g)	317.0 ± 8.13^{a}	335.0 ± 7.49^{a}	373.0 ± 7.51^{b}
Average feed conversion efficiency	5.38 ± 0.13^{a}	5.08 ± 0.11^{a}	4.57 ± 0.09^{b}

1 - Mean of eight values with SE

a, b, c - Means with different superscripts within the same row differ (P<0.01)

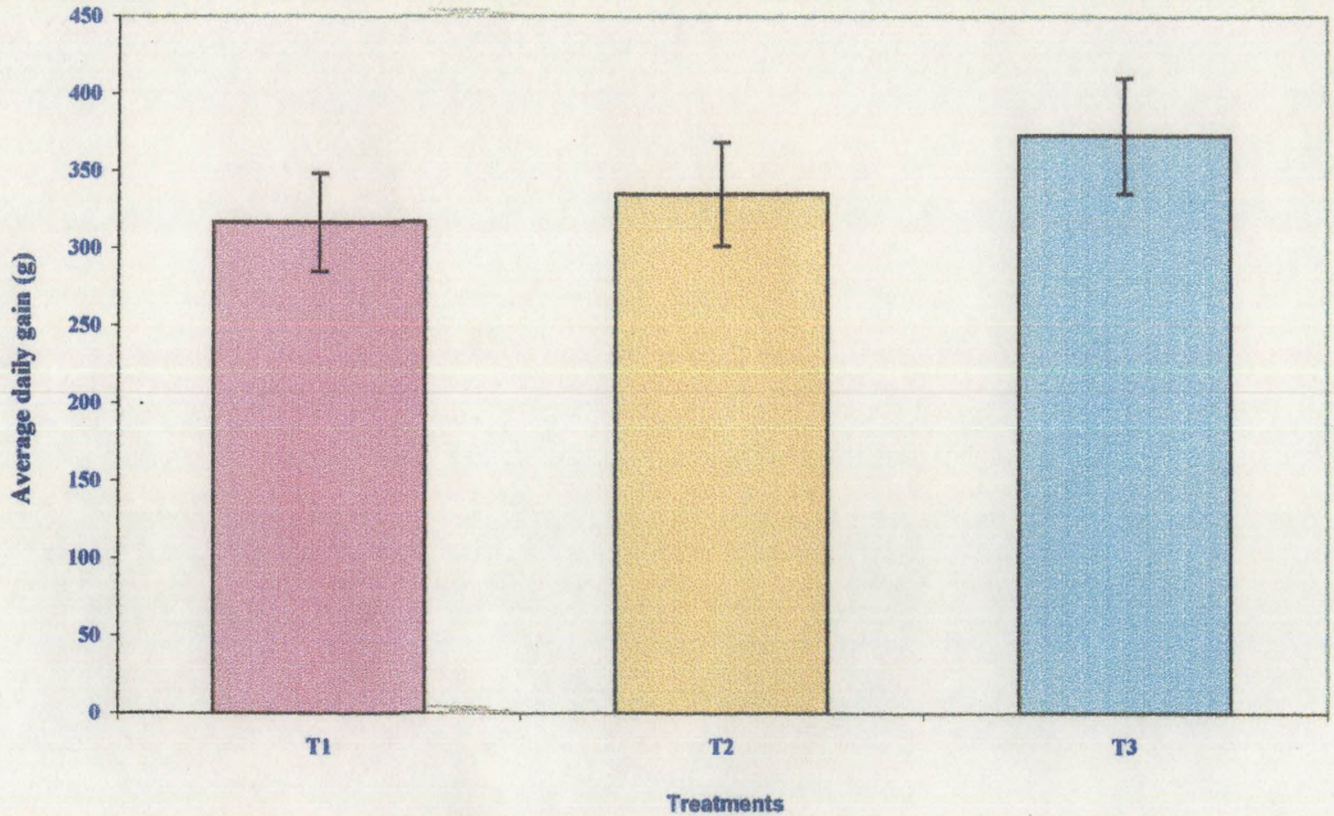

Fig. 1 Average daily gain (g) of pigs fed different experimental diets. T1 - Diet containing maize of particle size 3 mm (coarse), T2 - Diet containing maize of particle size 1 mm (medium) and T3 - Diet containing maize of particle size < 0.1 mm (fine)

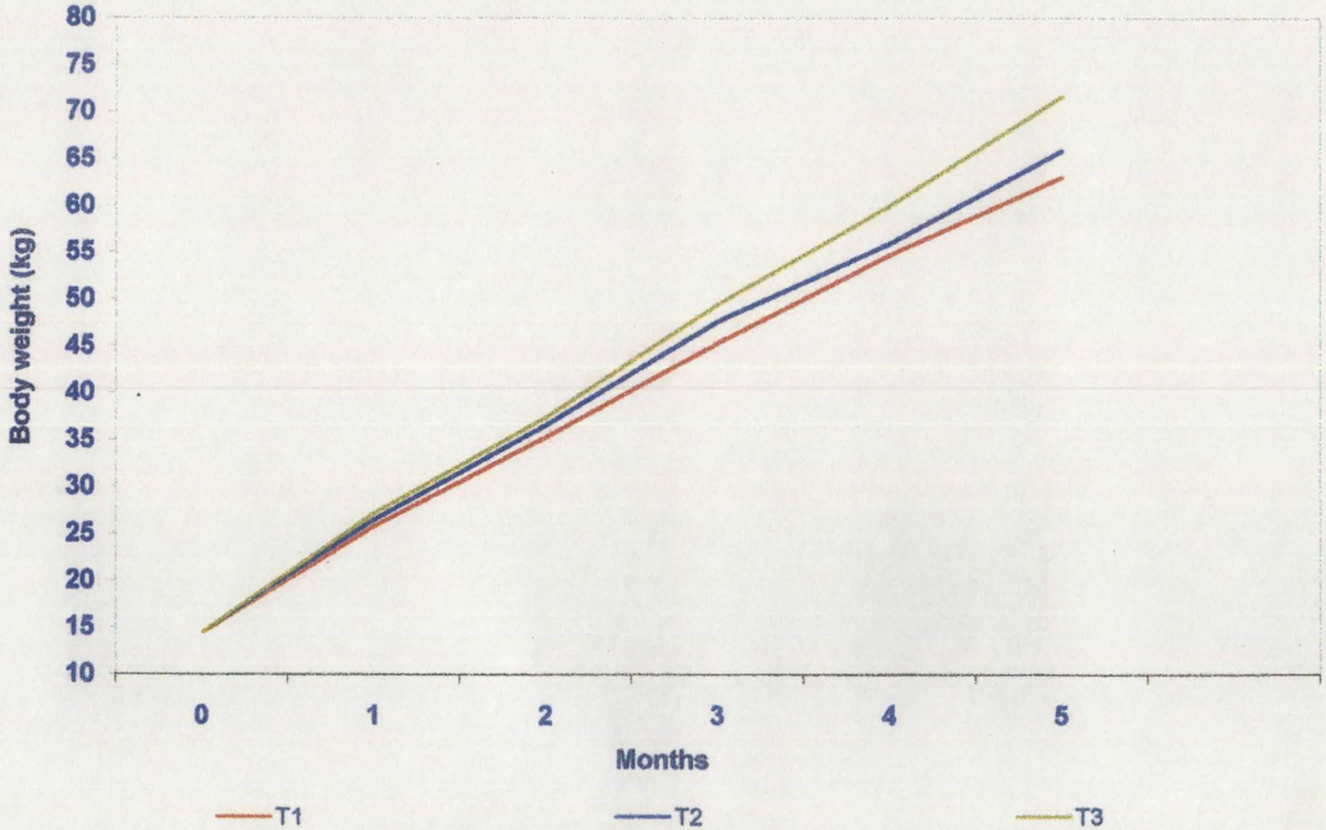

Fig. 2 Average monthly body weight (kg) of pigs fed different experimental diets. T1 - Diet containing maize of particle size 3 mm (coarse) T2 - Diet containing maize of particle size 1 mm (medium) and T3 - Diet containing maize of particle size < 0.1 mm (fine)

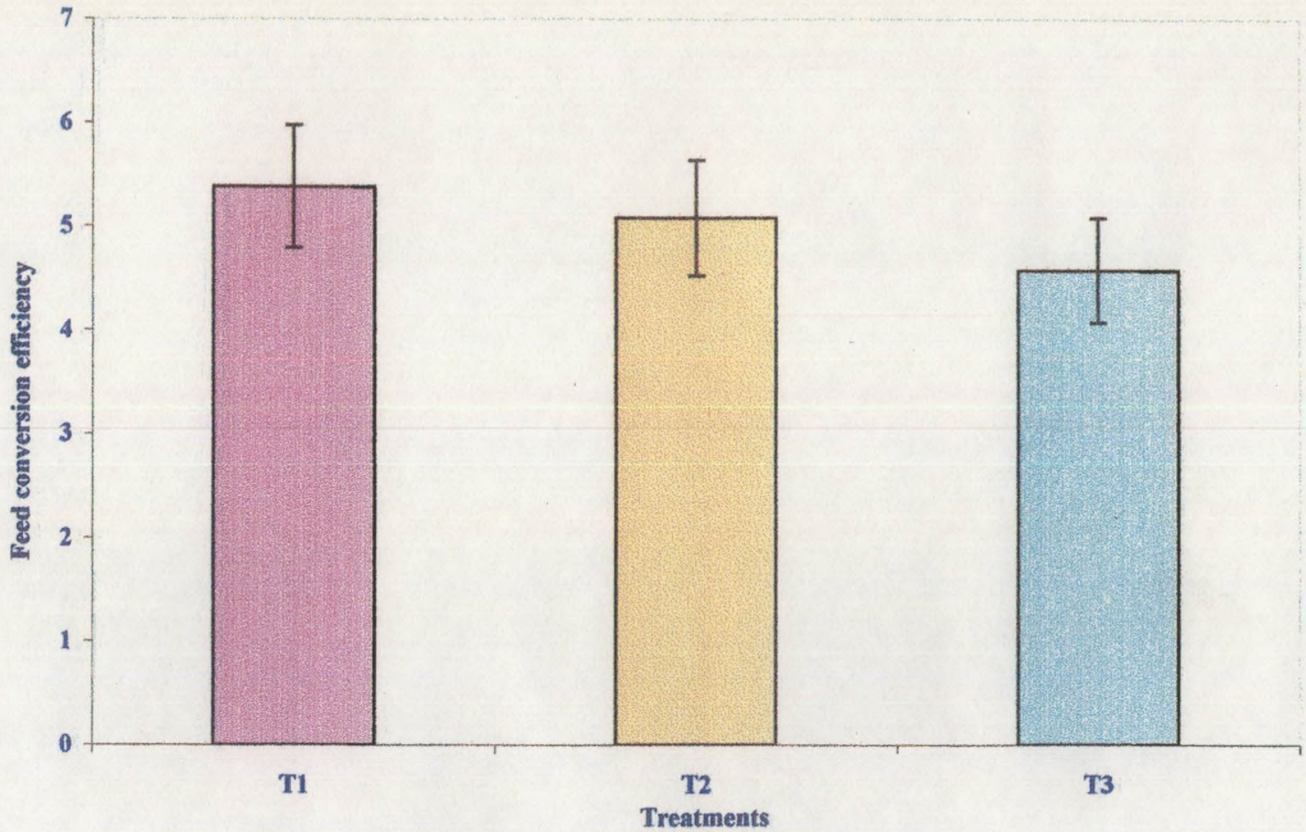

Fig. 3 Average feed conversion efficiency of pigs fed different experimental diets. T1 - Diet containing maize of particle size 3 mm (coarse) T2 - Diet containing maize of particle size 1 mm (medium) and T3 - Diet containing maize of particle size < 0.1 mm (fine)

4.3 Apparent digestibility coefficients of nutrients

The chemical composition of faeces of pigs fed different experimental diets are set out in Table 8. The apparent digestibility coefficients of nutrients in the three experimental diets T_1, T_2 and T_3 are presented in Table 9 and represented in Fig.4. The digestibility coefficients of drymatter for T_1, T_2 and T_3 were respectively, 55.5, 57.2 and 60.4; 63.9, 70.1 and 74.4 for crude protein; 54.1, 57.2 and 62.5 for ether extract; 21.7, 25.9 and 26.9 for crude fibre and 57.8, 58.6 and 62.2 for nitrogen free extract. The apparent digestibilities of dry matter, crude protein and ether extract were higher ($P < 0.01$) for pigs fed diets containing finely ground (< 0.1 mm) maize, than for those fed diets containing medium ground (1 mm) maize, which were higher ($P < 0.01$) than for those fed diets containing coarsely ground maize (3 mm). Pigs fed diets T_2 and T_3 recorded higher ($P<0.01$) crude fibre digestibility than those fed diet T_1 and there was no difference ($P>0.05$) between the groups T_2 and T_3. The apparent digestibility of nitrogen free extract was higher ($P<0.01$) for the treatment group T_3 while it was similar for T_1 and T_2.

4.4 Carcass characteristics

Data on the carcass characteristics of pigs maintained on three experimental diets T_1, T_2 and T_3 are set out in Table 10. Pigs fed diet containing finely ground (<0.1 mm) maize (T_3) recorded higher ($P<0.01$) body weight at slaughter, dressed weight with head and dressed weight without head than those fed diet containing medium ground (1 mm) maize (T_2) which were higher ($P<0.01$) than those pigs fed diets containing coarsely ground (3 mm) maize (T_1). There was no difference ($P>0.05$) among treatments for dressing percentage, carcass length, backfat thickness and loin eye area.

The body weights at slaughter were 64.3, 68.8 and 75.0 kg, respectively for T_1, T_2 and T_3; 51.1, 54.1 and 59.7 kg for dressed weight with head; 46.1, 49.1 and 54.4 for dressed weight without head; 71.3, 71.5 and 72.5 for dressing

Table 8

Chemical composition of faeces of pigs fed different experimental diets[a]

Item	Treatments		
	T_1 (%)	T_2 (%)	T_3 (%)
MOISTURE	55.84	57.50	60.47
Crude protein (N x 6.25)	11.63	9.88	9.25
Ether extract	6.16	5.98	5.60
Crude fibre	10.26	10.08	10.70
Nitrogen free extract	62.20	63.43	68.58
Total ash	10.52	10.45	10.27
Acid insoluble ash	6.64	6.72	6.83
Percentage of chromium[b]			
- in feed	0.034	0.034	0.034
- in faeces	0.077	0.080	0.086

a - Average of twelve values
- On dry matter basis

b - Chromic oxide (Cr_2O_3) was used as an external indicator and added to the feed @ 0.05 per cent.

Table 9

Apparent digestibility by pigs fed different experimental diets[1].

Nutrients	Treatments		
	T_1	T_2	T_3
Dry matter	55.5 ± 0.50^a	57.2 ± 0.38^b	60.4 ± 0.31^c
Crude protein	63.9 ± 0.93^a	70.1 ± 0.42^b	74.4 ± 0.33^c
Ether extract	54.1 ± 0.85^a	57.2 ± 1.01^b	62.5 ± 1.28^c
Crude fibre	21.7 ± 1.26^a	25.9 ± 0.98^b	26.9 ± 1.18^b
Nitrogen free extract	57.8 ± 0.59^a	58.6 ± 0.40^a	62.2 ± 0.51^b

1 - Mean of twelve values with SE

a, b, c - Means with different superscripts within the same row differ ($P<0.01$)

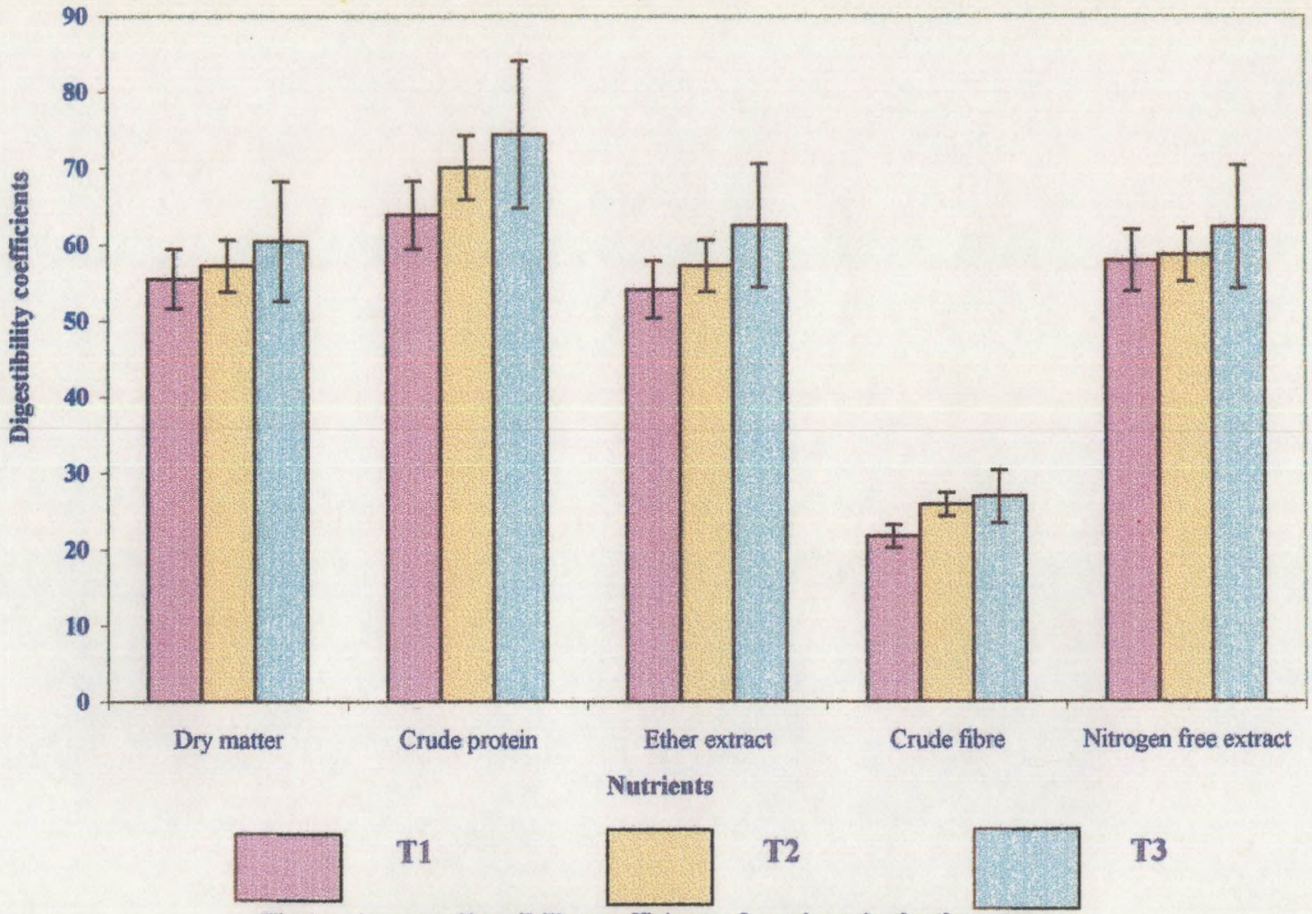

Fig.4 Average digestibility coefficients of nutrients in the three experimental diets. T1- Diet containing maize of particle size 3 mm (coarse) T2 - Diet containing maize of particle size 1 mm (medium) and T3 - Diet containing maize of particle size < 0.1 mm (fine)

Table 10

Carcass characteristics of pigs fed experimental diets[1]

Treatment	Live body weight (kg)	Dressed weight		Dressing percentage	Carcass length (cm)	Back fat thickness (cm)	Loin eye area (cm^2)
		With head (kg)	Without head (kg)				
T_1	64.3 ± 1.03^{a}	51.1 ± 0.62^{a}	46.1 ± 0.64^{a}	71.3 ± 0.93	66.2 ± 0.71	2.8 ± 0.23	26.3 ± 1.77
T_2	68.8 ± 0.83^{b}	54.1 ± 0.65^{b}	49.1 ± 0.65^{b}	71.5 ± 0.85	66.6 ± 0.48	2.7 ± 0.16	26.5 ± 1.90
T_3	75.0 ± 0.71^{c}	59.7 ± 0.91^{c}	54.4 ± 0.82^{c}	72.5 ± 0.76	67.2 ± 0.38	2.5 ± 0.17	27.5 ± 1.41

1 - Mean of four values with SE

a, b, c - Means with different superscripts within the same column differ ($P<0.01$)

percentage; 66.2, 66.6 and 67.2 for carcass length, 2.8, 2.7 and 2.5 for backfat thickness and 26.3, 26.5 and 27.5 for loin eye area.

4.5 Economics of gain

Data on cost of feed per kg body weight gain of pigs maintained on the three dietary treatments are presented in Table 11 and Fig.5. The values were Rs.42.34, 40.49 and 37.11 for T_1, T_2 and T_3, respectively.

Table 11

Cost of feed (Rs.) per kg body weight gain of pigs maintained on different dietary treatments

Item	T_1	T_2	T_3
Cost/kg of grower ration[ab]	8.07	8.17	8.32
Cost/kg of finisher ration[ab]	7.67	7.77	7.92
Cost of feed per kg body weight gain (Rs.)	42.34	40.49	37.11

a - Cost of feed ingredients is based on the rate contract fixed for the supply of various feed ingredients to the farm for the year 1999-2000

b - Approximate cost of grinding per kg is Rs. 1.00, 1.10 and 1.25 for coarse, medium and fine grinding, respectively.

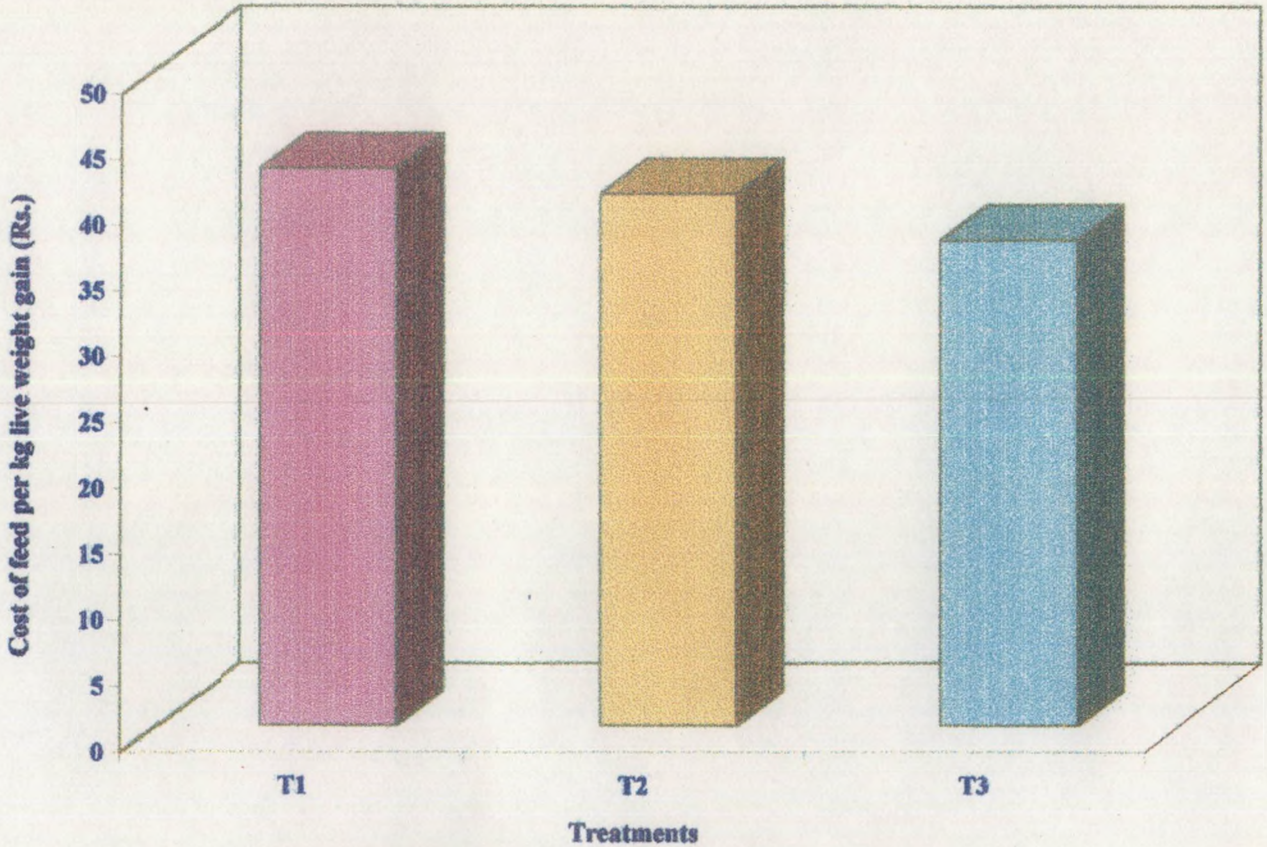

Fig. 5 Cost of feed per kg weight gain of pigs fed different experimental diets. T1 - Diet containing maize of particle size 3 mm (coarse) T2 - Diet containing maize of particle size 1 mm (medium) and T3 - Diet containing maize of particle size < 0.1 mm (fine)

DISCUSSION

5.DISCUSSION

5.1 Average daily gain

A perusal of the data presented in the Table 7 and Fig.1 reveals that highest weight gain was recorded for pigs fed diet having finely ground (< 0.1 mm) maize (T_3) which was higher ($P < 0.01$) than that of those fed diet having medium ground (1 mm) maize (T_2) and coarsely ground (3 mm) maize (T_1). The values were 317, 335 and 373g for the groups T_1, T_2 and T_3, respectively. Finely ground maize in the diet of growing - finishing pigs improved the average daily gain by 6 per cent over medium ground maize and 18 per cent over coarsely ground maize.

Baird (1973) and Wondra *et al.* (1995c) reported that fine grinding and pelleting of corn-soybean meal based diet improved average daily gain of growing pigs by 5 per cent. Hedde *et al.* (1985) found that pigs fed a finely ground diet (< 0.1 mm) gained higher (730 g/day vs 680 g/day) than those pigs received a cracked corn-based diet. Klisurov (1988) and Giesemann *et al.* (1990) reported that particle size reduction improved average daily gain and feed conversion efficiency more for growing pigs fed corn based diets than for those fed sorghum based diets. Healy *et al.* (1994) found that when the particle size of maize in the diet of nursery pigs was reduced from 900 to 500 µm, the average daily gain improved from 276 to 332 g. Finely ground maize in the diet of growing finishing pigs improved average daily gain by 6 per cent over medium ground maize and 18 per cent over coarsely ground maize.

These results are in agreement with those obtained in the present investigation. But Yang *et al.* (1988) and Wondra *et al.* (1992c) reported that the average daily gain was not affected by particle size reduction.

5.2 Feed conversion efficiency

Pigs fed finely ground (<0.1 mm) maize (T_3) recorded higher ($P<0.01$) feed conversion efficiency than those fed diets containing medium ground (1 mm) maize (T_2) and coarsely ground (3 mm) maize (T_1). The values were 5.38, 5.08 and 4.57 for T_1, T_2 and T_3, respectively (Table 7 and Fig.3). Finely ground maize in the diet of growing - finishing pigs improved the feed conversion efficiency by 6 per cent over medium ground maize and 15 per cent over coarsely ground maize.

Baird (1973) and Wondra *et al.* (1995c) observed that fine grinding improved feed conversion efficiency by 8 per cent in pigs. Finely ground corn in swine diets increased feed utilization by 5 to 15 per cent over coarsely ground corn and 1 to 12 per cent over medium ground corn (Perry, 1986). Similar results were reported for sorghum (Ohh *et al.*, 1983), barley (Goodband and Hines, 1988) and wheat (Seerley *et al.*, 1988) based diets. Healy *et al.* (1994) observed that gain/feed increased from 798 to 938 g/kg when the corn particle size was reduced from 900 to 500 μm in the diet of nursery pigs. Zanotto *et al.* (1996) noticed that feed to gain ratio increased linearly with increasing particle size. He obtained best results with particle sizes 509 to 645 μm. These results are consistent with those obtained in the present study.

5.3 Body weight

Pigs fed finely ground (<0.1 mm) maize (T3) recorded higher ($P<0.01$) body weights than those pigs fed medium ground (1 mm) maize (T2) and coarsely ground (3 mm) maize (T1) from the third month onwards. No difference ($P>0.05$) could be observed in the body weight of experimental animals upto the third month. The body weights 62.9, 65.8 and 71.6 kg were recorded for groups T_1, T_2 and T_3, respectively at the fifth month (Table 6 and Fig.2).

Baird (1973) reported 99.6 and 98.8 kg body weights for Yorkshire pigs fed on meal and pelleted diets, respectively at marketing age. Thomas and Singh

(1984a) reported final weight of 85.7 and 86.2 kg for Large White Yorkshire pigs at 8 months of age fed on diets having particles size 2-3 mm and 1 mm, respectively.

5.4 Body measurements

The body length of pigs fed diets T_2 and T_3 was higher (P<0.01) than those pigs fed diet T_1. Pigs fed finely ground (<0.01 mm) maize (T_3) recorded higher (P<0.01) chest girth and shoulder height than the other two groups from the third month onwards (Tables 3 to 5). The gain in body measurements takes place parallel to gain in body weight. The body weight and body measurements are correlated with each other as reported by Berge and Indrebo (1959). The linear relationship between live weight gain and body measurement was also recorded by several other workers (Deo and Raina, 1983; Sahaayaruban *et al.*, 1984, Sinthiya, 1998 and Ramamoorthi, 1999).

5.5 Digestibility coefficient of nutrients

5.5.1 Dry matter

The digestibility coefficient of dry matter of the three experimental diets T_1, T_2 and T_3 were 55.49, 57.24 and 60.40, respectively (Table 9 and Fig.4). Pigs fed finely ground (< 0.1 mm) maize had higher (P < 0.01) dry matter digestibility than those fed medium (1 mm) ground maize which had higher (P < 0.01) dry matter digestibility than those fed coarsely ground (3 mm) maize.

Researchers generally agree that nutrient digestibility increases as mean particle size diameter is reduced (Owsley *et al.*, 1981 and Giesemann *et al.*, 1990). Wondra *et al.* (1993) reported that when the particle size of maize was reduced from 800 to 400 μm, the apparent digestibility of dry matter increased from 82.5 to 86 per cent.

Healy *et al.* (1994) found that apparent digestibility of nitrogen, dry matter and gross energy were improved from 85.1 to 87.6, 89.4 to 90.8 and 89.2 to 91.1 as the particle size of maize in the diet of nursery pigs reduced from 900 to 300 µm. Similar increase in the dry matter digestibility from 84.2 to 88.3 per cent as the particle size of maize in the diet of lactating sows decreased from 1200 to 400 µm was reported by Wondra *et al.* (1995a). They attributed this increase in dry matter digestibility to increased surface area and uniformity of particle size. Wondra *et al.* (1995d) observed that pigs fed on roller-milled maize had higher nutrient digestibilities than those fed on hammer-milled maize.

On the contrary, the study conducted by Lawrence (1973) and Garcia and Torres (1993) showed that particle size of maize had no effect on the digestibility of dry matter in pigs.

5.5.2 Crude protein

The data on digestibility coefficients of crude protein presented in Table 9 and Fig.4 show a higher ($P < 0.01$) digestibility in pigs fed finely ground (<.1 mm) maize as compared to those fed on coarsely (3 mm) and medium (1 mm) ground maize. The values being 63.9, 70.1 and 74.4 for the groups T_1, T_3 and T_3, respectively. These results are in agreement with that of Lawrence (1973) who reported increased nitrogen digestibility with finely ground, pelleted oat based diets. Yang *et al.* (1988) reported that the nitrogen digestibility of the meal diets was significantly higher than that of pelleted diets when the maize was ground through a 4 mm screen. Wondra *et al.* (1995b) reported that reducing the particle size of corn from 1200 to 400 µm increased apparent digestibilities of dry matter and nitrogen by 7 and 10 per cent, respectively.

On the contrary, Furuya and Kaji (1987) and Garcia and Torres (1993) reported that maize particle size in the diet of growing pigs had no influence on nitrogen digestibility.

5.5.3 Ether extract

The digestibility coefficients of ether extract presented in Table 9 and Fig.4 show a higher ($P < 0.01$) value for diet containing finely ground (< 0.1 mm) T_3 maize, than those obtained for diets T_1 and T_2, containing coarsely ground (3 mm) and medium ground (1 mm) maize. The values being 54.1, 57.2 and 62.5 for the diets T_1, T_2 and T_3, respectively.

These results are in agreement with those obtained by Lawrence (1970). He reported the ether extract digestibility coefficient values as 67.3, 32.4 and 35.9 for swine diets with particle size of 1.56 mm, 4.68 mm and 9.36 mm, respectively. Lawrence (1973) also reported that apparent digestibility of the ether extractable fraction was significantly poorer in the diets based on coarsely ground oats, with the mean particle size of 4.68 mm compared with those based on finely ground oats with the mean particle size of 1.56 mm. Chae *et al.* (1997) observed a significantly higher ether extract digestibility coefficient in pigs fed pelleted diets than those fed on mash diets (72.09 vs 56.83).

The study conducted by Thomas and Singh (1984a) showed that particle size of diet had no influence on the ether extract digestibility in pigs.

5.5.4 Crude fibre

The apparent crude fibre digestibility coefficients for the three dietary treatments T_1, T_2 and T_3 are 21.7, 25.9 and 26.9 respectively (Table 9 and Fig.4). Pigs fed medium ground (1 mm) maize and finely ground maize (<0.1 mm) did not differ ($P>0.05$) in crude fibre digestibility. Pigs fed coarsely ground (3 mm) maize (T_1) recorded lower ($P<0.01$) crude fibre digestibility than the other two groups.

Lawrence (1970) reported that the apparent digestibility coefficients of crude fibre were 31.4, 25.3 and 22.1 for swine diets with the mean particle size of 1.56 mm, 4.68 mm and 9.36 mm respectively.

However, Lawrence (1973) and Thomas and Singh (1984a) did not observe significant influence of diet particle size on crude fibre digestibility.

5.5.5 Nitrogen free extract

Pigs fed finely ground (<0.1 mm) maize (T_3) had higher ($P<0.01$) apparent nitrogen free extract digestibility than those fed other two diets while there was no difference ($P>0.05$) between those pigs fed medium ground (1 mm) maize (T_2) and coarsely ground (3 mm) maize (T_1). The values were 57.8, 58.6 and 62.2 for T_1, T_2 and T_3, respectively (Table 9 and Fig.4).

Lawrence (1970) reported higher values viz., 85.1, 84.8 and 82.9 for diets with particle size of 1.56 mm, 4.68 mm and 9.36 mm respectively. Baird (1973) opined that physical form of the diet had no significant effect on the digestibility of nutrients in swine. Similar results were obtained by Thomas and Singh (1984a).

5.6 Carcass characteristics

5.6.1 Live weight at slaughter

The live weight at slaughter for the pigs fed different experimental diets T_1, T_2 and T_3 were 64.3, 68,8 and 75.0, respectively (Table 10). Pigs fed finely ground (<0.1 mm) maize (T_3) had higher ($P<0.01$) live weight at slaughter than those fed diets having medium ground (1 mm) maize (T_2) which showed higher (<0.01) live weight at slaughter than those fed coarsely ground (3 mm) maize (T_1).

Baird (1973) could not observe significant difference in carcass traits of pigs fed meal and pelleted diets when slaughtered at 99.6 and 98.8 kg, respectively. Lawrence (1973) reported that the carcass characteristics of pigs fed ground maize were superior ($P<0.05$) than that of those pigs fed ground wheat or barley diets when slaughtered at 90 kg live weight.

Thomas and Singh (1984b) reported average slaughter weight of 99.2 and 97.0 kg at the age of 240 days for Large White barrows fed on diets with particle size of 2-3 mm and 1 mm respectively, and these values did not differ ($P>0.05$).

5.6.2 Dressing percentage

The dressing percentage for the pigs in the three dietary treatments T_1, T_2 and T_3 presented in Table 16 were 71.32, 71.45 and 72.45 per cent respectively and they did not differ ($P> 0.05$).

Similar values viz., 70.8 and 74.7 were obtained by Meade *et al.* (1966) and Baird (1973) respectively for pigs maintained on corn-soybean based diet fed as meal. They also reported that there was no significant carcass differences due to form of diet. Thomas and Singh (1984b) also noticed that dressing percentage was not affected by reducing the particle size of the grower diets from 2-3 mm to less than 1 mm. Their observation is in agreement with those obtained in the present study. Wondra *et al.* (1992c) reported dressing percentage values of 73.4 and 74.0 for pigs fed diets which has particle size of maize 1000 µm and 400 µm respectively. Lawrence (1973) observed that diets based on the micronized maize gave higher ($P < 0.5$) dressing percentage (79.2) compared with those obtained from the diets based on the ground maize (78.5).

5.6.3 Carcass length

Data on the carcass length of pigs in the three dietary treatments T_1, T_2 and T_3 presented in Table 10 showed average carcass length of 66.23, 66.55 and 67.20 cm, respectively and they did not differ significantly.

Higher values viz. 75.2 cm and 78.7 cm were reported by Meade *et al.* (1966) and Baird (1973) respectively for pigs maintained on meal diets. Lawrence (1973) found that carcass length was greater ($P<0.05$) in pigs given the micronized maize diet (800 mm) compared with those given the ground maize diet (780 mm).

The results of the present study are in concordance with the findings of Thomas and Singh (1984b) and Wondra *et al.* (1992c) who reported that the particle size of swine diets had no significant effect on the carcass length.

5.6.4 Back fat thickness

The back fat thickness of pigs maintained on the three dietary treatments T_1, T_2 and T_3 were 2.8 cm, 2.7 cm and 2.5 cm respectively (Table 10) and they did not differ (P> 0.05). There is a trend for a decrease in the back fat thickness with reduction in the particle size of maize.

Higher values viz, 3.89 and 3.71 were reported by Meade *et al.* (1966) and Baird (1973) for pigs maintained on meal diets. These values were not affected by pelleting. Lawrence (1973) observed that the back fat thickness at shoulder position was greater (P<0.05) for the ground maize diet (50.2 mm) compared with the micronized maize diet (48.5 mm). Thomas and Singh (1984b) suggested that an average back fat thickness of 44.6 mm may be considered within acceptable limits in India, a value not affected by reducing the particle size of pig diets. Similar results were reported by Wondra *et al.* (1992c) and Wondra *et al.* (1995c). Luce *et al.* (1996) reported that the average back fat thickness of pigs fed diets with the particle size of 1000, 800, 600 and 400 µm were 2.92, 3.1, 3.19 and 2.94 cm, respectively, the values comparable to those obtained in the present investigation.

5.6.5 Eye muscle area

It is an indirect measurement for assessing total lean meat. The average values for eye muscle area of pigs on three dietary treatments T_1, T_2 and T_3 were 26.3, 26.45 and 27 cm^2, respectively which did not differ (P> 0.05) (Table 10). Similar value of 29.7 cm^2 was reported by Baird (1973) for pigs maintained on corn-soybean meal based, methionine supplemented diet fed as meal. Thomas and Singh (1984b) reported that the eye muscle area of pigs fed diets with the particle size of 2-3 mm and less than 1 mm were 30.9 and 29.6 cm^2 respectively. Wu and

Cheng (1988) could not observe significant difference in carcass traits of crossbred pigs fed diets which contained maize ground in a roller mill with bottom roll spacings of 0.254, 0.762 or 1.524 mm.

5.7 Economics of gain

The cost of feed per kg body weight gain of pigs maintained on the three dietary treatment groups T_1, T_2 and T_3 were Rs.42.34, 40.49 and 37.11, respectively (Table 11). The approximate cost of grinding per kg is Rs.1.00, 1.10 and 1.25, respectively for coarse, medium and fine grinding. The increased cost of milling was justified by improved growth performance of animals fed diets containing medium and finely ground maize.

An overall critical evaluation of the results obtained in the present study indicates that fine grinding of maize improves growth rate and feed conversion efficiency as a result of better nutrient digestibility in crossbred pigs.

SUMMARY

6. SUMMARY

A study was undertaken to assess the effect of particle size of maize on the growth performance, digestibility of nutrients and carcass characteristics in crossbred (Large White Yorkshire x *Desi*) pigs. Twenty four weaned crossbred female piglings with an average body weight of 14.5 kg were selected from the Centre for Pig Production and Research, Mannuthy and divided into three groups viz., T_1, T_2 and T_3 of eight piglings each, as uniformly as possible with regard to age and body weight. Eight piglings in each treatment group were randomly distributed into four replicates of two piglings each. They were subjected to three dietary treatments viz., T_1 - diet containing maize of particle size 3 mm (coarse), T_2 - diet containing maize of particle size 1 mm (medium) and T_3 - diet containing maize of particle size <0.1 mm (fine).

The experiment was conducted for five months. The piglings were fed twice daily. The piglings were fed with grower ration having 18 per cent protein until they reached an average body weight of 50 kg and then with finisher ration having 14 per cent protein, till slaughter. Each replicate was housed in separate pens and maintained under identical managemental conditions. Records of monthly body weight and body measurements were maintained throughout the experimental period. A digestibility trial using chromic oxide as external indicator was carried out to determine the digestibility coefficients of nutrients in the three experimental diets when the pigs attained seven months of age. Four animals from each treatment group were randomly selected and slaughtered at the end of the experiment to obtain the data on carcass characteristics.

The animals fed with finely ground maize with particle size <0.1 mm had a higher ($P<0.01$) weight gain and showed better ($P<0.01$) feed conversion efficiency than those fed diets containing medium and coarsely ground maize. The average daily gains were 317, 335 and 373 g and the cumulative feed conversion efficiencies were 5.38, 5.08 and 4.57 for the three groups T_1, T_2 and T_3,

respectively. Finely ground maize in the diet of growing-finishing pigs improved average daily gain and feed conversion efficiency by 6 per cent each over medium ground maize and by 18 and 15 per cent over coarsely ground maize, respectively.

The gain in body measurements were higher ($P<0.01$) in pigs in the group T_3 when compared to those for pigs in the other two groups.

An improvement in the digestibility of nutrients was observed with reduction in the particle size of maize. It was higher ($P<0.01$) for those pigs fed with diets containing finely ground maize.

Carcass characteristics like dressing percentage, carcass length, back fat thickness and loin eye area were not significantly influenced by the particle size of maize.

From an overall assessment of the results obtained in the present investigation, it is reasonably concluded that fine grinding of maize can be of particular benefit to weaned, crossbred piglets in terms of better growth rate, feed conversion efficiency and nutrient digestibility. The cost of feed per kg weight gain of animals in dietary treatment group T_1, T_2 and T_3 were found to be Rs. 42.34, 40.49 and 37.11, respectively. This decrease in the cost of feed per kg gain of animals with reduction in particle size of maize is due to better feed conversion efficiency as a result of increased digestibility of nutrients. The increased cost of milling was justified by improved growth performance of animals. Thus reducing the particle size of maize will make swine husbandry more eco-friendly by decreasing the amount of nutrients excreted leading to less environmental pollution.

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EFFECT OF PARTICLE SIZE OF MAIZE ON THE GROWTH PERFORMANCE AND DIGESTIBILITY OF NUTRIENTS IN CROSSBRED (LARGE WHITE YORKSHIRE x DESI) PIGS

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ABSTRACT OF A THESIS

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ABSTRACT

An investigation was carried out to assess the influence of particle size of maize on the growth performance, digestibility of nutrients and carcass quality in crossbred pigs.

Twenty four female weaned crossbred (Large White Yorkshire x *Desi*) piglings with an average live weight of 14.5 kg were divided into three groups (T_1, T_2 and T_3) of eight animals as uniformly as possible. They were maintained on the same diet containing maize with the particle size of 3 mm, 1 mm and <0.1 mm, respectively for a period of five months. The average daily gains of 317, 335 and 373 g were recorded for the groups T_1, T_2 and T_3, respectively. The cumulative feed conversion ratios were 5.38, 5.08 and 4.57 for the groups T_1, T_2 and T_3, respectively. Finely ground maize in the diet of growing-finishing pigs improved average daily gain and feed conversion efficiency by 6 per cent each over medium ground maize and by 18 per cent and 15 per cent over coarsely ground maize, respectively.

As the particle size of maize reduced an overall improvement in the digestibility of nutrients was observed. The pigs fed diet containing finely ground maize showed better nutrient digestibility than those fed with coarse or medium ground maize.

Results of the studies on carcass traits revealed that there was no significant difference in the dressing percentage, carcass length, back fat thickness and loin eye area due to variation in the particle size of maize.

Cost of feed per kg live weight of animals in the three groups T_1, T_2 and T_3 were Rs. 42.34, 40.49 and 37.11, respectively.

This decrease in cost of feed per kg weight gain of pigs with reduction in the particle size of maize is due to better feed conversion efficiently as a result of increased nutrient digestibility.

The above results confirm the positive influence of fine grinding of maize on the growth performance, feed conversion efficiency and nutrient digestibility in cross bred pigs. The additional benefit of reduced nutrient excretion due to increased digestibility will make swine husbandry more eco-friendly.