INFLUENCE OF CHITIN ON GROWTH AND FATTY ACID COMPOSITION IN GROWING PIGS

By

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THESIS

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DECLARATION

I hereby declare that this thesis entitled **Influence of chitin on growth and fatty acid composition in growing 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, associateship, fellowship or other similar title of any other University or Society.

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Introduction

INTRODUCTION

The present-day pig industry is concerned not only with higher production efficiency, but also has to respond to the growing consumer demand for lean meat, because it is the consumer satisfaction that governs all consideration in production decisions (Rhodes, 1976).

Health concerns have increasingly influenced consumer food choices (NRC, 1988). Consumers have become much more concerned about the health aspect of meat, particularly its fat content. Consumption of saturated fatty acids of meat fat has been considered a factor predisposing to human coronary heart disease (Bender, 1974; Mattson and Grundy, 1985). Hence, reduction of meat consumption has been advised by many nutritionists aiming to reduce the fat content and to increase the ratio of unsaturated to saturated fatty acids in the diet (Rhodes, 1976). However, consumers have been advised to continue to eat meat and to buy lean meat or low-fat meats rather than to exclude meat from the diet (Ambler and Wood, 1990). Leaner meats, besides containing lesser saturated fatty acids than fattier meats, also contain lesser calories, and are considered an asset in diets designed to avoid obesity (Bogart, 1988).

Therefore, pork with less fat containing less saturated fatty acid is the desirable product to satisfy the health conscious consumers' needs of the present day. The meat industry would benefit from the development of products perceived to be more healthful by the consumers.

So far as the farmer is concerned, the benefits of lean animal come not only from the higher price for the carcass but also from more efficient utilisation of feed and faster growth since less feed energy is required for muscle versus fatty tissue accretion (Wood, 1983; Stahly, 1990). Moreover, it has been reported that, in pigs, the lipid present in lean carcasses is relatively more unsaturated (Wood, 1984).

Various growth promoters, in the form of additives, are fed to animals to improve the rate and efficiency of growth leading to a concomitantly higher carcass lean yield. Hundreds of compounds that promote growth have been reported. While, for the most part, these compounds are antimicrobials, other compounds, such as enzymes, hormones and probiotics are also used (O'Connor, 1980). Recently, several synthetic analogues of noradrenaline and adrenaline, called beta-adrenergic agonists, have been identified, which have repartitioning effect on nutrient utilisation in adipose and skeletal tissues. When fed to pigs, these compounds have the

ability to accelerate muscle tissue accretion and reduce fat accretion (Dalrymple et al., 1984; Jones et al., 1985; Cole et al., 1987; Yen et al., 1990).

However, a lower use of chemicals at all stages from birth to slaughter has been envisaged for 'natural' or 'organic' meat production (Ambler and Wood, 1990).

Chitin is a naturally occurring organic compound which has growth promoting, and hypolipidemic and hypocholesterolemic activity when fed to animals.

Chitin is a macromolecular acetylated aminopolysaccharide with a similar structure to vegetable cellulose. It is the major component of exoskeletons of crustaceans, insects, fungi and yeast. Chitin forms about 50 to 80 per cent of organic compounds in crustacean shells, and as such is widely distributed and abdundant in nature (Kobelke, 1990).

The wastes from the shellfish industry in the form of body peelings are the major source of chitin for its current and potential uses in various fields (Muzzarelli, 1986). The body peelings in the crustacean processing plants is a major waste in countries like the USA, Canada, Mexico, Australia, India, China, Japan, Thailand, Malaysia, the Philippines and South Africa where crustacea are abundant (Nair et al., 1987;

Kobelke, 1990). Approximately, 1600 tonnes of chitin is produced globally each year (Kobelke, 1990). An estimated 1.2×10^5 tonnes of annually accessible chitin from seafood processing industry on a world-wide basis is reported (Knorr, 1991).

In India, the most economical source of chitin are the shrimp processing industries which turn out, as industrial waste, enormous quantities of head and shell (Nair et al., 1986). Apart from shrimp, the shell of lobsters and crabs are also excellent sources of chitin. Besides, squilla, a by-catch from shrimp trawlers, is found to contain chitin in its shell (Nair et al., 1986). At present, the total landing of prawns in India is estimated at 186,880 tonnes, which would yield about 3000 tonnes of chitin annually (CIFT, 1992).

Recent research reports stress the nutritional significance of chitin in animals. Chitin and chitosan (deacetylated chitin) are reported to be non-toxic to animals (Arai et al., 1968). A combination of whey and chitin in the diet enabled broiler chicken to utilise whey more efficiently resulting in higher body weight and feed efficiency due to growth of Bifidobacteria in the gut of chicken which was brought about by addition of chitin in the diet (Austin et al., 1981; Zikakis et al., 1982). Addition of chitin to normal commercial diets has been shown to promote growth and

feed efficiency in chicken (Nair et al., 1987; Nair et al., 1993).

Chitin and chitosan have been reported to have hypolipidemic and hypocholesterolemic activity when fed to animals. The hypolipidemic and hypocholesterolemic activity of chitosan has been reported in rats (Sugano et al., 1978; Kobayashi et al., 1979; Vahouny et al., 1983) and in rabbits and chicken (Hirano et al., 1990). Feeding of chitin has been reported to reduce the abdominal fat pad in chicken (Zikakis et al., 1982). Further, Hirano et al. (1990) reported a suppression of cholesterol, triglyceride and free fatty acids in the muscle of hens by feeding of chitosan, indicating a possible production of low-cholesterol meats.

Food applications of chitin and chitosan have been limited, although chitin itself is substantially lower in cost and appears to be amenable to mechanical and chemical modifications (Austin et al., 1981).

Keeping in view the nutritional significance of chitin and its vast resource in India, the present study was undertaken to assess the influence of feeding chitin to pigs on their growth performance, carcass characteristics, serum cholesterol and triglyceride levels, and the fatty acid profile of meat.

REVIEW OF LITERATURE

2.1 Chitin and derivatives

Chitin is a white, hard, inelastic nitrogenous polysaccharide found in the outer skeleton of insects, crab, shrimps and lobsters. This is a polymer of beta-(1-4)-N-acetyl-D-glucosamine. Deacetylation of chitin with strong alkali yields chitosan, polymer of beta-(1-4)-D-glucosamine.

Chemically, chitin and chitosan are polyglucosamines which are differentiated only by the extent of acetylation of amino groups. Although there is no clear distinction between the two, it is generally accepted that chitin is extensively acetylated, while chitosan is virtually deacetylated (Furda, 1983). Chitin has usually 70 to 95 per cent degree of acetylation, while chitosan has 15 to 25 per cent degree of acetylation (Fillar and Wirick, 1978).

2.1.1 Use of chitin in feed

2.1.1.1 Degestion of chitin

Muzzarelli (1977) reported that enzymatic hydrolysis of chitin to acetyl glucosamine could be brought about by two enzymes namely, chitinase and chitobiase. Chitinases were

widely distributed enzymes synthesised by bacteria, fungi and digestive glands of animals whose diet included chitin. Chitinase activity in the entrails of poultry (Muzzarelli, 1977) and in the abomasum of ruminants (Lunblad et al., 1974) were reported to digest chitin. Muzzarelli (1986) stated that mammals in general were able to digest chitin because they possessed chitinase in their gastric mucosa and sometimes in pancreas. Kono et al. (1987a,b) reported chitinase activity in the gastro-intestinal tract of fish.

Patton and Chandler (1975) reported that ruminants by having a large population of microbes in their rumen, were capable of degrading chitin. Patton et al. (1975) observed 66 per cent digestibility of chitin when crab meal was added to the ration of growing calves. White (1981), from his in vivo and in vitro studies, reported 21 per cent digestibility of chitin from crab meal by ruminal micro-organisms. Significant chitin degradation rates were observed in cattle previously adapted to chitinous materials (Patton, 1972; White, 1981; Laflamme, 1988). There appeared to be a shift in ruminal microbial population once chitinous material (crab meal) was added to the diet of cattle (Husby et al., 1981). However, White (1981) reported that the ruminal micro-organisms responsible for chitin degradation had not been identified and the conditions in the rumen ecosystem optimum for rates of

chitin degradation had not been determined. Yokoyama and Husby (1990), from their in vitro study, believed that anaerobic fungi, which were predominant in the rumen, were actively involved in the ruminal degradation of chitin.

Hirano et al. (1990) reported that both chitin and chitosan were digested 35 to 80 per cent by rabbits, and 88 to 95 per cent by hens and broilers.

2.1.1.2 Nutritional aspects

Chitin and chitosan have been found to be non-toxic to animals. When included in the diet of animals, they exihibit growth-promoting as well as strong hypolipidemic and hypocholesterotemic activities, thus showing their nutritional importance.

Arai et al. (1968) reported that chitin and chitosan were of low toxicity, similar to that of salt or sugar. The LD_{50} of chitosan in laboratory mouse was found to be 16 g per kilogram of body weight. Landes and Bough (1976) found chitosan to be safe for rats upto 10 per cent in the diet; at 15 per cent level enlargement of liver and kidneys were observed. Ashford et al. (1977) recommended usage of chitin and chitosan in meat sausage casing as they were edible for human. Blair et al. (1982) observed reduced toxic effects of metals when chitin or chitosan was added to growing cultures

of Chlorella containing various quantities of toxic metals. Hirano et al. (1990) pointed out that chitosan could be useable as an ingredient at an appropriate dosage for domestic animal feeds.

In rats, chitosan had no adverse effect on the nutritional value of protein recovered from food processing wastes (Bough and Landes, 1976). Results on the physiological effects of free chitosan and feed products coagulated with chitosan when feed to young rats showed no adverse effect on growth rate, blood or liver composition at chitosan levels below five per cent of the diet (Bough and Landes, 1978). Green and Krammer (1979) stated that natural coagulating agents such as chitosan were non-toxic to livestock. Knorr (1984) remarked that in addition to the high degree of coagulating efficiency of chitin and chitosan, the application of these substances of natural biological origin could contribute dietary advantages.

Austin et al. (1979), in an eight-week feeding trial, observed that rats, on a diet containing 30 per cent whey and 1.2 per cent Propyl N-acetyl-D-glucosamine (NAG) glycosides, had higher body weights than rats without the propyl NAG glycosides supplement. The later group receiving only whey developed severe diarrhoea and eventually died from dehydration and malnutrition.

Feeding chicks with a feed comprising 78 per cent basal ration, 2 per cent chitin and 20 per cent whey, Austin et al. (1981) observed that chicks receiving both chitin and whey were significantly heavier at 46 days of age. The whey and chitin combination could replace upto 20 per cent of the normal feed.

Zikakis et al. (1982) also reported that a combination of chitinous products in iso-nitrogenous iso-caloric diets enabled broiler chicken to utilize whey more efficiently. Chickens, fed a diet containing 20 per cent dried whey plus 2 per cent chitin for 31 days, were significantly heavier than the control group. In another 6-week broiler experiment, they observed that birds, fed a diet with whey but no chitin, were significantly lighter in weight and had a significantly lower feed efficiency than those fed either the control commercial diet or diets containing both whey and chitin. Moreover, the abdominal fat pads of chickens, fed the chitin - whey diet, weighed significantly less than those of chickens fed the control commercial diet.

The improvement in the utilization of whey, in the presence of chitin, was attributed to the increase in the growth of Bifidobacteria in the gut of chicken by addition of chitin to their diets (Austin et al., 1981; Zikakis et al., 1982). Spreen et al. (1984) also reported that chitinous

materials enhanced the growth and proliferation of Bifidobacteria in the intestine of chicken.

Gordon and Williford (1983) demonstrated that at a 5 per cent level, neither chitin nor chitosan affected growth or food consumption of growing rats over a three-week period, compared to a 5 per cent cellulose control. By increasing chitin to 10 and 20 per cent levels in the diet, iron absorption was depressed, whereas with chitosan, iron absorption was affected only at 20 per cent but not at 10 per cent level. Gordon (1985) reported deaths of rats fed on a diet containing 20 per cent chitosan, the cause of death being the formation of gel in the gut of the animals, thereby inhibiting the availability of nutrients to the animals.

In feeding trials with gerbils, Watkins and Knorr (1983) observed that addition of upto 8.5 per cent chitin in the diet resulted in normal growth rates, organ weights and vigour of the test animals as compared to cellulose-fed controls, indicating that chitin might be an effective dietary fibre.

Kono et al. (1987) studied the effects of dietary chitin, chitosan, and cellulose on the growth of fishes. The growth rates of all fishes (red sea bream, Japanese eel, yellowtail), fed with a 10 per cent chitin-supplemented diet,

recorded the highest values indicating diet superiority. The feed efficiency in red sea bream and Japanese eel which were fed with 10 per cent chitin-supplemented diet, also, recorded the highest values. The level of chitinase activity in the stomach of the three fishes were in proportion to the rate of growth when fed with chitin-supplemented diet.

Nair et al. (1987) observed, over an eight-week period, that chicken, fed on a diet containing 0.5 per cent chitin, showed an increase of 10 per cent weight gain and 5 per cent feed intake over the control birds which were fed on a commercial diet without chitin. The feed efficiency of chitin-fed chicken was 2.38 as compared with 2.50 for the controls. Nair et al. (1993) reported that broiler chicks fed on a diet containing 0.5 per cent chitin showed significant increase in weight gain and decrease in feed consumption as compared to the controls. The chitin-fed group also showed higher feed efficiency and dressing percentage.

Hirano et al. (1990) reported that no abnormal symptom was observed with hens and broilers by feeding <1.4 g chitosan per kg body weight per day for 239 days, and with rabbits by feeding <0.8 g chitosan per kg body weight per day for 239 days. However, hens' appetite and egg-laying rate decreased by feeding an excessive amount of chitosan for a long term

(3.6 - 4.2 g chitosan per kg body weight per day for 185 days). This was because of incomplete digestion of chitosan.

2.1.1.3 Hypolipidemic/hypocholesterolemic effect

Sugano et al. (1978), over a 20-day period trial, compared cellulose, cholestyramine, chitosan, and brown algae at 5 per cent levels in rat diets containing cholesterol. Rat, fed chitosan had the lowest plasma cholesterol, and had greatest excretion of cholesterol in the faeces. The cholestyramine- and chitosan-fed rats showed significantly lower triglyceride levels than cellulose- or algae-fed rats.

Kobayashi et al. (1979) compared the effectiveness of chitosan with konjac flour, and with each of the two hypocholesterolemic drugs, namely, moristerol and benikol. In an one-week trial on rats which were fed diets containing cholesterol, it was observed that chitosan, fed at 4 per cent level, caused the greatest depression in serum cholesterol level. It was found superior to konjac flour fed at the same level, and to moristerol, and benikol fed at 5 and 8 per cent levels respectively. Konjac flour and benikol were found to cause severe diarrhoea in the animals.

Nagyvary et al. (1979) compared the effects of chitosan, cellulose, citrus pectin, and Al salt of pectin at 4 per cent levels in rat diets containing cholesterol. The

serum cholesterol level of chitosan-fed rats was lower by 44 per cent, 22 per cent and 10 per cent than in cellulose-, pectin-, and Al-pectin-fed groups, respectively. The liver cholesterol level of chitosan-fed rats was also significantly lower than those of other groups.

Sugano et al. (1980) reported that addition of 2 to 5 per cent chitosan to a high-cholesterol (0.5 per cent) diet fed to male rats for 20 days resulted in significant reduction (by 25 to 30 per cent) of plasma cholesterol without affecting food intake and growth. The concentrations of liver cholesterol and liver triglyceride also decreased significantly. The plasma cholesterol-lowering effect was comparable with that of cholestyramine. Chitosan at 10 per cent level further reduced plasma cholesterol but depressed growth. It was observed that finer chitosan particles tended to restrain growth even at 2 per cent level. Dietary chitosan increased faeceal excretion of cholesterol, both exogenous and endogenous, whereas faeceal excretion of bile acids remained unchanged. Further, in rats fed a cholesterol-free diet containing 0.5 per cent chitosan, it was observed that more cholesterol existed as high-density lipoproteins and less as very low-density lipoproteins The hypocholesterolemic activity was attributed to the high lipid-binding capacity of chitosan.

Nagyvary et al. (1980) reported that chitosan could

bind as much as 12 mg lipids per mg chitosan. Knorr (1982) reported that the fat uptake of chitin, microcrystalline chitin and chitosan ranged from 170 to 215 per cent with chitosan having the lowest and chitin the highest fat-binding capacity. Nauss et al. (1983) reported that chitosan could bind micellar lipids to the extent of four to six times its own weight. It was suggested that the hypocholesterolemic and hypolipidemic activity of chitosan was by entrapping whole micelles consisting of cholesterol, fatty acids and monoglycerides, which thus escaped absorption in the intestine (Nagyvary et al., 1980; Furda, 1983).

Vahouny et al. (1983) studied the effects of chitosan and cholestyramine on lipid absorption in adult male rats. Rats were given, by gastric intubation, a test emulsion consisting of tritiated cholesterol, oleic acid and sodium taurocholate, to which either 50 mg chitosan or 50 mg cholestyramine was added. The lymph was collected over a 24 hour period by cannulating the thoracic lymphatic channel. In acute conditions, a depression was observed in the absorption of cholesterol and oleic acid by 51 per cent and 41 per cent respectively in the presence of chitosan, and 47 per cent and 32 per cent respectively in the presence of cholestyramine.

In chronic studies, by feeding rats with diets containing chitosan or cholestyramine at 1 per cent level, it

was observed that there was an 18 to 28 per cent reduction in absorption of both the lipids. When either of the test materials were fed at 5 per cent level, absorption of cholesterol was reduced by 63 to 69 per cent, and absorption of oleic acid by 58 to 62 per cent. Furthermore, it was observed that chitosan feeding for 4 weeks did not cause mucosal damage of jejunum or colon unlike as observed with diets containing cholestyramine, pectin, or alfalfa.

Sugano et al. (1988), based on their work on rats, reported that the hypocholesterolemic action of chitosans was independent of their molecular weight and viscosity.

Hirano et al. (1990) reported that an increase in the serum cholesterol and triglyceride values of hens, broilers and rabbits fed cholesterol-additive diets was suppressed by feeding 2 per cent chitosan. High-density lipoprotein cholesterol values in rabbit serum were maintained even as cholesterol values decreased by feeding chitosan. An increase in total cholesterol and triacylglycerol values in the liver of these animals was also suppressed by feeding chitosan. Furthermore, an increase in the values of cholesterol, triacylglycerol and free fatty acid in hen's thigh muscle was also suppressed by feeding of chitosan, indicating a possible production of low-cholesterol meats.

2.2 Patterns of growth in pigs

Growth of meat animals represented by increase in size and weight with age, and development which consists of the changes in body proportion and composition as the animal grows from conception to maturity, are of great economic significance (Pomeroy, 1978). Each animal has an inherent mature body size towards which it grows at a genetically controlled rate (Brody, 1945). Brody (1945) considered growth in terms of size as well as weight, and defined growth as a relative irreversible time change in the measured dimension or function. Growth, form and function of an animal are closely interrelated.

2.2.1 Body weight

2.2.1.1 Live weight at different ages

Brody (1945) recorded the body weight (kg) of female pigs at different ages as follows:

Age in months					
2	4	6	8	10	12
8.0	23.0	55.0	94.0	126.0	152.0

Agarwala (1961) reported that graded Yorkshire pigs averaged 25.20 kg at 3 months and 102.60 kg at 6 months of age.

Batabayal (1969) studied the performance of exotic breeds in India and observed that for males and females respectively, the weaning weight averaged 9.25 ± 1.40 and 8.881 ± 1.61 kg in Australian Large White, and 8.74 ± 0.14 and 8.32 ± 0.17 kg in American Large White pigs.

Bhagwat and Sahastrabuddhe (1971) recorded the body weight (kg) of Yorkshire pigs at different ages as follows:

	Age in months				
	2	3	4	5	6
Male	11.46	15.75	27.50	42.19	62.96
Female	10.75	13.57	23.85	35.64	54.64

Weaning weight at 8 weeks averaged 9.10, 9.0 and 9.20 kg, and final weight at 30 weeks of age 54.51, 55.79 and 61.45 kg, for Yorkshire pigs given dietary energy in the ration at levels of NRC recommendation, 10 per cent less than NRC, and 20 per cent less than NRC, respectively (Rao et al., 1978).

Saseendran (1979) recorded body weight (kg) of Large White Yorkshire pigs at different ages as given below:

	Age in weeks						
	8	12	16	20	24	28	30
Male	15.08	19.42	33.08	47.33	57.25	72.66	83.66
Female	13.58	18.50	32.58	46.74	57.00	70.83	79.66

Gupta (1983) reported that for Large White pigs weaning weight at 8 weeks averaged 9.4 kg (range, 8.4 to 11.1 kg). At 16 weeks body weight averaged 19.1 kg (range, 15.9 to 22.9 kg). At 18 weeks, the body weight averaged 26.0 and 26.5 kg for males and females, respectively. The ranking of pigs on body weight at 8 and 18 weeks was not the same.

Matousek et al. (1990) reported that terminal hybrids (Synthetic line 98 x Landrace x Czech Improved White) those were finished to 6, 7, 8 or 9 months of age respectively, slaughter weight averaged 104.4, 124.6, 145.9 and 171.3 kg, daily gain 566, 579, 609 and 618 g from birth to slaughter, and 811, 810, 810 and 795 g from 30 days to slaughter.

Sharma et al. (1990) reported that for Landrace, large White, desi, Landrace x desi and Large White x desi respectively, weight at 8 weeks of age averaged 9.63, 9.79,

5.30, 6.68 and 7.62 kg, and at 30 weeks 41.8, 33.7, 19.9, 25.9 and 30.3 kg.

For Large White pigs, weight at birth, 8 weeks and 16 weeks of age averaged 1.30, 7.77 and 12.07 kg respectively versus 0.52, 3.50 and 5.22 kg for desi pigs, and 0.91, 7.23 and 11.52 kg for Large White x desi cross breds. Post-weaning daily gain for the three groups averaged 65.6, 28.8 and 69.1 g, and food conversion ratio 4.45, 4.95 and 4.62 (Singh et al., 1990).

2.2.1.2 Growth curve

Growth curves of swine have been described by several authors. The data of Bywaters and Willham (1935) and Ittner and Hughes (1938) suggested a smooth curve with a linear growth between about 70 and 168 days with a diminishing increment after 168 days. Post-weaning body weight curves between 134 and 174 days of age (Taylor and Hazel, 1955) and between 53 and 346 days (Abarca and Tapia, 1963) were found to be linear. The data of Donald (1940), and Lush and Kincaid (1943), on the other hand, showed that a quadratic equation best fit the data. Similarly, the data of Quijandria and Robison (1971) covering the ages 119 to 154 days with a final weight of approximately 82 kg, and the data of Standal (1973) covering an age range of 135 to 225 days with a final weight

upto 130 kg, suggested a quadratic growth model; however, the percentage of the variation accounted for was only slightly larger than for the linear model (less than 1 per cent). Also, the data of Doornenbal (1971) with an age range of 78 to 210 days and a final weight of 130 kg though suggested a significant quadratic regression, the quadratic term accounted for only one per cent of the variance. It appeared that in swine the quadratic function was significant statistically but of little biological (practical) importance for post-weaning gains to about 130 kg (Robison, 1976).

While Joubert (1963) linked the point of inflection which separates the rising and declining segments of growth curves with the concept of puberty, Robison (1976) observed that such a concept could not be clearly established. However, Matousek et al. (1989) observed that the point of inflection of the growth curve occured at 169.5 days of age and 90.7 kg body weight with the decrease in growth rate being highest at 251.9 days in commercial hybrid pigs born to Landrace x Czech Improved White and sired by Duroc x Belgian Landrace boars.

According to Jung et al. (1989), growth curves indicated that daily gain in Large whites was the highest at 130 and 123.9 days of age for males and females respectively (1.029 and 0.824 kg), and the corresponding figures for

Landraces were 132.7 and 112.9 days (1.013 and 0.780 kg). Pavlik and Pulkrabek (1989), on analysis of growth curve traits, observed that the age at highest average daily gain averaged 122.5 to 169.6 days for Prestice and 116.7 to 167.1 days for Large white pigs. Kanis and Koops (1990) reported that the maximum daily gain was, on an average at live weight of 64 kg for barrows and 77 kg for gilts.

2.2.1.3 Rate of growth

According to Pomeroy (1955), the rate at which an animal grows is of greater importance for the livestock owner than its mature weight as only a few animals live long enough to reach the mature weight. There is close correlation between rapid growth and good life-time performance.

Mugge (1961), from his experiment on German Landrace pigs, observed that from 50 kg each gain of 10 kg took about 14 days. Daily gain from 40 to 110 kg was 704 to 723 g, while from 30 to 100 kg daily gain was 669 to 701 g. Brooks et al. (1964) observed that in the successive periods from birth to 50, 50 to 100, 100 to 150 and 150 to 200 lb, average daily live weight gains were 0.70, 1.52, 1.76 and 1.96 lb, respectively.

Daily weighing of spotted Belorussian pigs from birth

to 10 months of age revealed that there was a rhythm of growth rate with peaks at intervals of 12 days, not being significantly affected by sex or season of birth (Thompson, 1965).

Walstra (1980) observed that animals grew well upto 36 weeks of age (125-165 kg live weight) with maximum growth cbetween 13 to 24 weeks of age for boars and gilts, and between birth to 18 weeks for barrows.

Morrison (1984) reported that growth rate in pigs increased gradually until the pig reached a weight of about 102 kg and then decreased slightly. When carried to higher weight than 136 kg the rate of gain was considerably less.

Gu et al. (1991), working on barrows of various crosses involving Hampshire, Yorkshire, Landrace and Duroc breeds, observed that among the three growth periods (59 to 100 kg, 73 to 114 kg, 86 to 127 kg body weight) daily gain was the highest in the second period (73 to 114 kg).

Schmitten et al. (1986) reported average daily gains of 753, 758 and 712 g for Pietrain x German Landrace pigs finished to 80, 100 and 120 kg respectively.

Pavlik et al. (1988) observed in Czechoslovakian Large White pigs that body weight ranged from 23.4 kg at 80 days to

101.1 kg at 180 days. Daily gain averaged from 667 g at 81 to 90 days to 817 g at 121 to 130 days. From 30 to 100 kg daily gain averaged 773 g, and feed efficiency 2.06 kg.

2.2.1.4 Feed consumption, feed efficiency and weight gain

Magee (1962) reported a linear relation between daily gain and daily feed consumption; however, there was a negative correlation between daily feed consumption and feed efficiency. Biswas et al. (1966) also reported that daily gain was positively correlated with daily intake of feed and efficiency of feed conversion, and intake was negatively correlated with efficiency. Various workers have reported that feed efficiency decreased with increasing weight (Wallace et al., 1959; Mugge, 1961; Buck, 1963; Gu et al., 1991). It was pointed out that the decrease in feed efficiency with increasing weight was primarily due to increased maintenance costs, and not to increased fat deposition (Robison, 1976). Robison (1976) reported that rate of growth was highly correlated with feed efficiency.

For Yorkshire graded pigs from three to six months of age, average daily gain was found to be 0.92 lb, feed efficiency 3.61, and average daily feed intake 3.33 lb (Agarwala, 1961). For Yorkshire pigs given dietary energy at levels of NRC recommendation, 10 per cent less than NRC, and

20 per cent less than NRC respectively, average daily gain from weaning (8 weeks) to 210 days averaged 294.9, 303.8, 339.8 g; average daily feed consumption 1.425, 1.565 and 2.092 kg; and feed efficiency 5.279, 5.246, and 6.978 (Rao et al., 1978).

Jarkova (1962) reported an intake of 226 feed units upto 4 months of age in Large White pigs. From 4 months to slaughter at 176, 206 and 241 days of age, feed intakes were 157.2, 254.9 and 372.0 feed units respectively. Cost for unit live weight gain increased with live weight, but per unit total live weight or dressed carcass cost was less in the heavier pigs. It was recommended that pigs be slaughtered for bacon at 95 to 100 kg, or otherwise at 110 to 120 kg live weight. Gregor et al. (1986) suggested that pigs should not be fattened beyond a weight of 105 to 110 kg.

Holme (1963) reported a decrease in rate of gain and feed efficiency with increasing slaughter weight from 170 to 290 lb. Absolute amount of lean increased by 8 to 10 lb for each 30 lb increase in slaughter weight. Mugge (1963), by comparing the growth performance over the period from 20 to 90, 30 to 100 and 40 to 110 kg live weight, found that the period 30 to 100 kg had several advantages including lower feed consumption for the same gain.

Nowicki et al. (1963) reported that the daily gains to respective live weights of 100, 115 or 130 kg were, for Large Whites 650, 678 and 641 g, and for Swedish Landrace 628, 625 and 690 g. Intakes per kilogram gain, in that order, were 4.35, 4.52, 4.86, 4.50, 4.76 and 5.14 feed units.

For male and female Duroc pigs, daily gain averaged 246 and 246 g of respectively, from birth to 20 kg body weight, 294 and 306 g from 60 to 80 kg, 420 and 406 g from 80 to 90 kg, 432 and 420 g from 90 to 100 kg, 446 and 442 g from 100 to 110 kg, 469 and 446 g from 110 to 120 kg, and 484 and 485 g from 120 to 130 kg. The consumption of feed units per kilogram gain to 40, 60, 80, 90, 100, 110, 120 and 130 kg averaged 3.5, 3.4, 3.7, 3.7, 3.8, 3.8, 3.9 and 4.0, respectively. The correlation of daily gain with body weight and age were highly significant (Koinarski, 1983).

For barrows and gilts kept to 220 days, daily gain averaged 626 and 549 g, and feed efficiency 2.30 and 2.02 kg respectively. At 240 days, daily gain averaged 624 and 536 g, and feed efficiency 2.38 and 2.08 kg, while at 260 days, daily gain averaged 573 and 552 g, and feed efficiency 2.29 and 2.09 kg, respectively (Otto et al., 1983).

For Yorkshire, Landrace and Duroc boars respectively, age at 90 kg averaged 167, 174 and 172 days; daily gain 784,

727 and 763 g; daily feed intake 1.87, 1.79 and 1.88 kg; feed conversioin ratio 2.41, 2.48 and 2.49 (Arganoza et al., 1986).

For Yorkshire boars, barrows and gilts respectively, weight gain averaged 46, 45.5 and 49.0 kg, daily gain 365, 361 and 388 g; feed consumption per day 1.76, 1.78 and 1.86 kg, and feed conversion ratio 4.83, 4.95 and 4.81, between day 1 (15 kg body weight) and 126. Between days 126 and 159, weight gain averaged 11.5, 11.0 and 8.3 kg; daily gain 360, 360 and 280 g; feed consumption per day 1.80, 2.66 and 2.07 kg; and feed conversion ratio 5.0, 7.40 and 7.40 (Kumar and Barsaul, 1987).

By inseminating gilts and sows of Large White breed with semen of Large White, Belgian Landrace, Duroc and Spotted boars, Bittante et al. (1989a) observed that for the four groups of progeny, in that order, body weight averaged 110.3, 111.2, 113.7 and 108.9 kg at 34 weeks, and 143.2, 148.2, 145.2 and 145.6 kg at 42 weeks. Feed conversion ratio was 2.20, 2.58, 2.58, 2.68 and 2.86 from 10 to 22 weeks of age, 3.48, 3.56, 3.15 and 3.74 from 22 to 24 weeks of age, and 5.15, 4.75, 4.79 and 4.96 from 34 to 42 weeks of age. In a similar study (Bittante et al., 1989b), daily gain from birth to 8 months of age averaged 459, 563, 473 and 450 g for the four groups of progeny, respectively, and that from birth to 10 months 478, 496, 515 and 486 g. The corresponding figures for

feed conversion ratio were 2.93, 3.16, 2.96 and 3.36, and 3.46, 3.49, 3.38 and 3.70.

Albar et al. (1990) reported that increase of slaughter weight by 10 kg from 105 to 125 kg resulted in increased food consumption by 0.10 to 0.15 kg feed per kilogram of gain.

2.2.2 Body form

During the process of growth animals not only increase in size but also undergo changes in form due to differential growth rates of their constituent parts (Brody, 1945). While weight growth prior to puberty tends to occur in a geometric progression, linear growth tends to occur in an arithmatic progression. Following poberty, both weight and linear growth decline exponentially. The inflection in linear growth occurs at different ages for different linear dimensions (Brody, 1945). Palsson (1955) reported that during post-natal stage of growth measurements of the height at withers increased at a much slower rate than the measurements of circumference and width of the heart girth. In post-natal life, the body increases in length, depth and width in that order, due to the heterogonic growth of its constituent tissues and parts.

Comstock and Winters (1944) reported that, in pigs

from 8 weeks of age until 180 days, the depth of body increased the most followed by width of loin, body length and width behind the shoulders. Meeker (1973) stated that body measurements increased linearly from 230 to 290 lb of body weight.

Cuthbertson and Pomeroy (1962) observed in Large White pigs that of the major anatomical regions of the skeleton, sacrum grew fastest between 50 and 68 kg, and the cervical vertibrae between 68 and 92 kg of live weight. The limb bones grew in length in the early period and in thickness in the later. Kresan and Studena (1988) reported that bone growth was most intensive from birth to 60 days. Body weight increased 81.6-fold from birth to slaughter at 240 days (108.3 kg) while skeleton weight increased 36.5 fold. The greatest growth intensity was obtained for the bones of the trunk (50.7-fold), and the smallest for the skull (25-fold).

Bowland et al. (1965) observed higher rates of carcass weight gain to be associated with longer carcasses.

Dubreuil et al. (1989) found significant correlations with daily gain for height at withers and chest measurements in Czech Improved White gilts. In prestice gilts all body measurements were highly significantly correlated with daily

gain. Also, for boars of Landrace, most body measurements were significantly correlated with daily gain.

Hladky and Fl'ak (1989) reported a correlation of $\geq$0.96 between allometric growth of body measurements and live weight. Further, body length, withers height and chest depth showed positive allometric growth in Large Whites, while in Landraces and their back crosses growth in body measurements showed negative allometry.

The studies of Delate and Basu (1990) revealed that except for females of less than 45 kg body weight, chest circumference alone accounted for 79 to 96.5 per cent and chest circumference plus body length for 87.5 to 98.5 per cent variation in body weight.

2.3 Carcass characteristics

According to the Pig Industry Development Authority, (1962), increased lean in the carcass was found to be associated with thinner backfat, larger eye-muscle area and more bone. Increased length was associated with better carcass conformation, thinner backfat and more bone. It was futher observed that for Large White Pigs slaughtered at 150, 200 and 260 lb live weight respectively, dressing percentage averaged 70.1, 72.4 and 75.2. Jarkova (1962) observed in Large White pigs that from 4 months to slaughter at 176, 206

and 241 days, dressing percentage averaged 71.2, 73.4 and 77.1 respectively.

Varney et al. (1962), by slaughtering male Hampshire pigs at 159 or 215 lb live weight, found that heavier pigs had higher carcass yield mainly because of more fat. Lighter pigs had thinner backfat and larger eye-muscle area. Also, lean cuts and primal cuts were significantly more in lighter pigs than in heavier pigs, as percentage of both live weight and carcass weight. Similarly, Holme (1963) also reported increasing killing-out percentage and percentage of fat in the carcass, and decreasing percentage of lean as slaughter weight increased from 170 to 290 lb. Absolute amount of lean increased by 8 to 10 lb for each 30 lb increase in slaughter weight.

Babatunde et al. (1966) observed in Yorkshire pigs that as slaughter weight increased from 79 to 102 kg, the per cent of all lean cuts decreased, while that of fat cuts and backfat thickness increased significantly. Absolute amounts of both fat and lean cuts increased with slaughter weight. For slaughter weight groups of 79, 90 and 102 kg respectively, warm dressing percentage averaged 75.1, 75.3 and 75.6; backfat thickness 3.3, 3.8 and 4.0 cm; loin-eye area 27.5, 28.0 and 29.6 cm^2; ham weight 18.1, 17.6 and 17.6 kg; ham percentage of

chilled carcass 22.2, 20.8 and 20.8; weight of leaf fat 0.9, 1.3 and 1.7 kg, and leaf fat as percentage of empty body weight 1.3, 1.6 and 1.8.

For Large White Yorkshire female pigs slaughtered at 7 months of age (74-78 kg live weight), dressing percentage with head averaged 78.32, dressing percentage without head 68.57, loin-eye area 27.0 cm^2, weight of ham 16.77 kg, ham percentage 31.63, and backfat thickness 2.06 cm (Saseendran, 1979).

Anjaneyulu et al.(1982) observed that for carcasses weighing 65 to 74, 75 to 84 and 85 to 94 kg, dressing percentage averaged 68.24, 68.54 and 69.86, respectively; trimmed ham weight 10.35, 11.09 and 12.47 kg; ham percentage 21.49, 20.59 and 20.18; backfat thickness 2.46, 2.83 and 3.37 cm^2; and loin-eye area 20.00, 20.50 and 22.52 cm^2 in Middle White Yorkshire barrows.

For Yorkshire boars and barrows slaughtered at 95 kg live weight, dressing percentage averaged 81.89 and 83.0 respectively, percentage of leaf fat in the left side 1.62 and 2.08, and percentage of trimmed boneless ham 14.8 and 13.9 (Fontin et al., 1983). From a similar study, Matenko (1983) reported that for boars and barrows fattened to 6 months old or to 96 kg live weight, backfat thickness averaged 2.9 and 3.4 mm respectively, loin-eye area 36.82 and 32.69 cm^2, weight

of leaf fat 0.73 and 0.96 kg, and percentage of lean in ham 67.7 and 64.1.

Otto et al. (1983) reported that for gilts slaughtered at 220, 240 and 260 days, hot carcass weight averaged 76.8, 94.1 and 102.0 kg, respectively; backfat thickness 2.4, 3.3 and 3.0 cm; and eye-muscle area 41.1, 39.8 and 43.0 cm^2.

For cross-bred pigs of meat/lard type Russian Large Whites, lean type Estonian Whites, meat/lard type Russian Large White x lean type Estonian White, and lean type Estonian White x meat and lard type Russian Large White pigs, dressing percentage averaged 77.0, 76.6, 77.1 and 77.4, respectively at 100 kg slaughter weight, and 78.9, 78.3, 79.1 and 79.5 at 120 kg; eye-muscle area 26.7, 31.0, 29.4 and 30.2 cm^2 at 100 kg, and 28.5, 34.0, 32.2 and 33.3 cm^2 at 120 kg; and backfat thickness at 7th rib 34, 29, 31 and 30 mm at 100 kg, and 41, 34, 36 and 35 mm at 120 kg (Orlov and Pogodaev, 1983).

Shields et al. (1983), by slaughtering cross-bred pigs at 18 kg intervals from 1.5 to 145 body weight, observed that backfat thickness, eye-muscle area and body length increased as weight of pigs increased.

Prabhakar (1984) reported that for Large White and local pigs respectively, body weight before slaughter averaged

78.42 ± 7.07 and 77.86 ± 10.46 kg, carcass weight 57.57 ± 5.89 and 54.63 ± 7.46, dressing percentage 73.54 ± 1.40 and 70.39 ± 1.15, loin-eye area 29.47 ± 5.29 and 16.56 ± 4.89 cm^2, and backfat thickness 2.96 ± 0.29 and 3.10 ± 0.63 cm.

For Large White x Large White, White-Russian meat type x (Large Black x Large White), Duroc x (Large Black x Large White), Duroc x (Landrace x Large White), White-Russian meat type x (Duroc x Large White), Landrace x (Duroc x Large White), and Duroc x (White- Russian meat type x Large White) pigs, slaughtered at 100 kg body weight, backfat thickness at 6th/7th thoracic vertibrae averaged 38, 34, 35, 33,31, 33 and 32 mm; eye-muscle area 28.4, 31.7, 29.2, 34.1, 35.3, 34.0, 32.0 and 35.0 cm^2 respectively. For pigs alaughtered at 120 kg live weight backfat thickness averaged, in that order, 41, 37, 38, 34, 36, 35, 34 and 36 mm; and eye-muscle area 31.2, 31.4, 32.5, 35.8, 36.7, 35.1, 33.1 and 36.7 cm^2 (Kavanov and Koshel, 1985).

For Pietrain x German Landrace pigs finished to 80, 100 and 120 kg respectively, dressing percentage averaged 76.8, 79.4 and 80.5; backfat thickness 1.9, 2.2 and 2.4 cm; and lean fat ratio 1:0.33, 1:0.36 and 1:0.40 (Schmitten et al., 1986).

For Yorkshire x (Landrace x Duroc) barrows and gilts,

slaughtered at 60, 70, 80, 90, 100 or 110 kg body weight respectively, dressing percentage averaged 66.9, 70.1, 70.4, 70.0, 69.7 and 69.5; and backfat thickness 24.7, 26.3, 29.3, 32.0, 34.2 and 36.7 mm (Cruz Bustillo et al., 1987).

Pulkrabek et al. (1987) working on Czechoslovakian Improved White, Landrace and Prestice pigs, observed that for the three breeds in that order, carcass length averaged 79.48, 81.55 and 78.56 cm; backfat thickness 25.4, 24.4 and 27.7 mm; eye-muscle area 3803, 3967 and 3600 mm^2; and ham weight as percentage of carcass weight 19.33, 19.48 and 18.03.

Kolesen and Kurilo (1988) from their work involving Russian Large White and Byelorussian Large White x Byelorussian Black Pied x Estonian White pigs, observed that for the pigs slaughtered at 100, 130, 140 or 150 kg body weight respectively, mid-back backfat thickness averaged 31.3, 36.7, 36.2 and 34.6 mm; carcass length 94.3, 102.7, 103.7 and 107.5 cm; and percentage of sub-cutaneous fat 28.3, 29.7, 29.1 and 27.1.

Matousek et al. (1988) working on pure-bred terminal hybrid pigs (Czech Improved White x Landrace x synthetic line 98) found that, for pigs finished to 180, 210, 240 or 270 days of age respectively, dressing percentage from 30 kg to slaughter averaged 80.4, 81.1, 82.7 and 84.1, carcass length

793, 820, 868, 898 cm; eye-muscle area 3752, 4356, 4841 and 4890 mm^2; backfat thickness 30.0, 33.8, 38.4 and 44.1 mm; ham percentage 17.8, 18.4, 17.0 and 15.9; and slaughter weight 104.4, 124.6, 146.0 and 171.3 kg. Vaclavovsky et al. (1988), from a similar experiment using the same terminal hybrids, reported that, for pigs slaughtered at 180, 210, 240, 270 or 300 days, slaughter weight averaged 104.4, 124.6, 146.0, 171.3 and 182.0 kg at the five ages respectively, the effect of slaughter weight on backfat thickness (30.0, 33.8, 38.4, 44.1 and 42.0 mm), ham weight (7.3, 9.1, 10.0, 11.2 and 12.6 kg), eye-muscle area (3751, 4355, 4840, 4890 and 5323 mm^2), and weight of primal cuts (18.9, 22.9, 29.2 and 32.6 kg) being significant. Matousek et al. (1990) found that, for terminal hybrid pigs that were finished to 6, 7, 8 or 9 months of age, slaughter weight averaged 104.4, 124.6, 145.9 and 171.3 kg, respectively; dressing percentage 80.4, 81.1, 82.7 and 84.1; eye-muscle area 3752, 4356, 4841 and 4890 mm^2; percentage of ham 17.8, 18.4, 17.0 and 15.9; and backfat thickness 31.7, 35.9, 41.8 and 47.4 mm.

Pavlik et al. (1988) reported that for Czechoslovakian Large White pigs that were slaughtered at 100 kg, backfat thickness averaged 25.4 mm, eye-muscle area 37.50 mm^2, percentage of ham in the carcass 19.2 and percentage of primal cuts in the carcass 48.5.

Lefaucheur et al. (1989) observed that, at slaughter weight of 90 kg of Large White barrows, pigs raised at 12°C were shorter and more compact and had lower dressing percentage than those kept at 28°C. Body composition was similar in the two groups in spite of a difference in the composition of ham and higher weight of leaf fat in pigs kept at 28°C. At 12°C, percentage of unsaturated fatty acids in the backfat increased.

For Large White Yorkshire pigs slaughtered at five weight ranges of 51-60 kg, 61-70 kg, 71-80 kg, 81-90 kg and above 90 kg respectively, carcass weight averaged 36.33 ± 0.32, 47.87 ± 0.79, 54.41 ± 0.96, 63.05 ± 0.93 and 67.69 ± 1.54 kg; dressing percentage 64.00 ± 1.09, 69.24 ± 0.70, 71.22 ± 1.10, 73.21 ± 0.84 and 69.30 ± 1.29; ham weight 8.88 ± 0.28, 10.83 ± 0.20, 10.42 ± 3.12, 11.89 ± 3.81 and 14.23 ± 0.60 kg; ham percentage 25.30 ± 0.62, 23.18 ± 0.50, 10.90 ± 0.85, 18.73 ± 0.88 and 21.46 ± 1.09, and backfat thickness 1.70 ± 0.08, 2.28 ± 0.06, 2.46 ± 0.08, 2.75 ± 0.08 and 2.33 ± 0.11 cm (Mishra et al., 1989).

Albar et al. (1990) reported that increasing slaughter weight by 10 kg from 105 to 125 kg increased dressing percentage by 0.5 per cent units, percentage of lean in the carcass by 1.0 per cent unit, and significantly increased backfat thickness. However, slaughter weight had no

significant effect on the percentage of ham plus loin, eye-muscle are and fatty acid composition of backfat.

For Large White Yorkshire female pis slaughtered at 7 months of age, which were provided floor space area of 1 m^2, 0.75 m^2 and 0.5 m^2 per pig respectively, the dressing percentage with head averaged 75.81, 68.06, 74.18; dressing percentage without head 67.82, 59.73, 66.37; weight of ham 5.58, 3.57 and 5.40 kg; carcass length 71.33, 64.66 and 71.33 cm; eye-muscle area 31.62, 24.21 and 27.42 cm^2, and backfat thickness 2.41, 1.50 and 2.39 cm (Leena, 1992).

Sebastian (1992) studied the effect of season of birth on carcass characteristics of Large White Yorkshire female pigs. The pigs born in rainy season attained a slaughter weight of 91 kg at 11 months of age and those born in dry season 92 kg at 8 months of age. For the pigs born in rainy and dry season respectively, carcass length averaged 78.8 and 80.0 cm, backfat thickness 3.0 and 3.8 cm, eye-muscle area 40.5 and 41.2 cm^2, weight of ham 7.35 and 7.89 kg, dressing percentage with head 77.0 and 81.3, and dressing percentage without head 71.3 and 74.4.

2.4 Weight of internal organs

The metabolic processes of the body are dependent on,

or activated by, the visceral organs (Brody, 1945). The internal organs increase in weight with increse in live weight, suggesting that these organs increase to accommodate the increased requirements of larger body size and mass; however, the internal organs grow relatively slower than the increase in live weight (McKay et al., 1984).

On a weight basis, visceral organs may contribute more to heat loss than skeletal tissues, and hence differences in relative organ weights may be a source of variation in heat loss among pigs of similar fat-free mass, suggesting that increased organ size relative to body weight may result in higher maintenance requirements (Tess et al., 1986). Heavier organ weights would also contribute to the lower dressing percentage of animals (Sather et al., 1991).

Various factors influence the weights of the internal organs.

2.4.1 Genotype

Davey and Bereskin (1978) reported that at 100 kg live weight the high-fat pigs had higher organ weights than low-fat pigs as given below.

Breed-line	Organ weight (kg)		
	Liver	Heart	Kidney
Duroc high-fat	1.33	0.19	0.28
Duroc low-fat	1.43	0.28	0.29
Yorkshire high-fat	1.22	0.22	0.26
Yorkshire low-fat	1.25	0.26	0.33

The livers of Duroc low-fat pigs were significantly heavier than those of pigs from the other breed-lines. The kidneys of Yorkshire low-fat pigs were significantly heavier than those from the two Duroc lines.

Prabhakar (1984) recorded the organ weights as percentage of live weight for Large White Yorkshire (78.43 ± 7.08 kg) and indigenous (77.86 ± 10.46 kg) pigs and observed non-significant differences.

Organ	Percentage of live weight	
	Indigenous	Large White Yorkshire
Liver	1.67 ± 0.15	1.17 ± 0.37
Lungs	1.09 ± 0.12	1.08 ± 0.25
Heart	0.23 ± 0.03	0.26 ± 0.06
Spleen	0.18 ± 0.05	0.16 ± 0.04

Tess et al. (1986) studied the visceral organ development in three genetic stocks: Beltsville High-fat (HF), Duroc-Yokshire Low-fat (LF) and a Hampshire x Large White cross (CX); and found significant differences in organ weights among the stocks.

Age in weeks	Genetic stock	Empty body weight (kg)	Mean weights (g) of internal organs				
			Heart	Lung	Spleen	Kidney	Liver
10	HF	13.65	71	161	29	82	409
	LF	14.91	84	196	36	96	507
	CX	17.59	98	267	41	88	549
17	HF	40.05	138	303	51	160	816
	LF	42.55	199	421	73	179	962
	CX	56.10	252	470	95	193	114
24	HF	71.28	178	318	70	215	1015
	LF	81.79	290	533	126	248	1070
	CX	100.59	350	554	151	253	1393

Jones et al. (1988) reported that the organs were a higher proportion of live weight (95 kg) in halothane-negative line (genotype NN) as compared to halothane-positive line

(genotype nn), while their crosses (genotype Nn) had intermediate values. The barrows had higher proportions of body organs than gilts for halothane-negative line only. It was observed that the genotype x gender interactions were significant for the proportion of kidneys and livers.

	Genotype					
	nn		NN		Nn	
	Gilts	Barrows	Gilts	Barrows	Gilts	Barrows
Body organs (g/kg)						
Kidneys	2.9 ± 0.08	2.7 ± 0.08	3.4 ± 0.07	3.6 ± 0.08	3.3 ± 0.07	3.2 ± 0.07
Heart	2.8 ± 0.07	2.7 ± 0.08	3.1 ± 0.07	3.0 ± 0.08	2.8 ± 0.07	2.7 ± 0.07
Liver	14.9 ± 0.31	13.4 ± 0.31	17.5 ± 0.29	17.9 ± 0.31	16.4 ± 0.28	16.2 ± 0.27
Spleen	1.2 ± 0.07	1.2 ± 0.07	1.6 ± 0.07	1.4 ± 0.07	1.4 ± 0.06	1.3 ± 0.06

Pond et al. (1988) observed that at 6 months of age the relative weights (percentage of live body weight) of liver and heart were significantly greater in genetically lean and contemporary than in obese pigs, and significantly greater in pigs fed high- than in pigs fed low-fibre diet.

	Obese		Lean		Contemporary	
	High	Low	High	Low	High	low
Organs, % of body weight						
Liver	0.866	0.809	0.908	0.896	1.010	0.917
Heart	0.243	0.216	0.330	0.316	0.286	0.273
Kidney	0.222	0.204	0.243	0.212	0.226	0.190

Sather et al (1991) reported that Landrace pigs as compared to Large White pigs, at 93 kg body weight, had heavier kidneys (0.35 vs. 0.31 kg), livers (1.67 vs. 1.61 kg) and full gut (5.99 vs. 5.41 kg), which contributed to their lower carcass dressing percentage.

2.4.2 Age and body weight

Brody (1945) reported that the visceral organ weights in mature animals of different species increased with a fractional power of body weight, that is, the weights of visceral organs did not increase as rapidly as the body weight as a whole. The ratio of visceral organ weight to body weight declined with increasing body weight.

Palsson (1955) stated that the different organs and organ groups exhibited marked heterogononic growth. The

thoracic organs as a whole were earlier maturing than the digestive tract. Moughan et al. (1990) observed that the kidneys, liver, heart and small intestine were early developing organs.

Doornenbal and Tong (1981) reported growth coefficients of 0.75, 0.80, 0.74, 0.69 and 0.66 respectively for heart, lungs, spleen, kidneys and liver relative to body weight.

McKay et al. (1984) observed that the internal organs grew relatively slower than live weight increased, and the majority of leaf fat deposition occurred as the animals approached 90 kg live weight.

They recorded the organ weights in Yorkshire pigs slaughtered over five developmental stages: 35 days of age (Stage 1), 22.5 kg (Stage 2), 45.0 kg (Stage 3), 67.5 kg (Stage 4), and 90.0 kg (Stage 5) live weight as follows:

Organ	Weight (g)				
	Stage 1	Stage 2	Stage 3	Stage 4	Stage 5
Liver	148.60± 7.03	555.08± 18.75	941.67± 31.05	1210.90± 41.86	1418.19± 63.07
Kidney	36.87± 1.81	108.03± 4.98	166.35± 5.59	201.00± 8.28	265.48± 10.85

Heart	33.56± 1.97	113.59± 8.26	168.42± 6.82	214.08± 6.62	276.00± 9.71
Spleen	13.04± 1.12	36.71± 2.90	74.55± 4.21	104.94± 5.94	145.89± 7.50
Leaf fat	16.89± 2.41	82.29± 11.00	265.68± 27.90	556.34± 64.19	1051.16± 136.51

2.4.3 Sex

Davey and Bereskin (1978) recorded the sex differences in organ weights of pigs of different breed-lines at 100 kg live weight as follows:

Breed-line sex	Organ weight (g)		
	Liver	Heart	Kidney
Duroc high-fat barrow	1.293	200	277
Duroc high-fat female	1.379	194	297
Duroc low-fat barrow	1.449	285	292
Duroc low-fat female	1.427	283	300
Yorkshire high-fat barrow	1.271	214	275
Yorkshire high-fat female	1.179	232	261
Yorkshire low-fat barrow	1.246	265	332
Yorkshire high-fat female	1.264	271	334

There were few sex differences within breed lines with the exception of heart weights for Yorkshire high-fat pigs.

Saseendran (1979) recorded the weights of internal organs for male and female Large White Yorkshire pigs at 7 months of age.

Organ	Sex	Weight (kg)	Percentage of live weight
Liver	Male	1.13	1.65 (1.20-1.89)
	Female	1.30	1.71 (1.69-1.72)
Heart	Male	0.26	0.38 (0.35-0.42)
	Female	0.23	0.30 (0.27-0.35)
Lungs	Male	1.15	1.73 (1.54-2.09)
	Female	1.04	1.37 (1.22-1.46)
Kidney	Male	0.24	0.33 (0.28-0.38)
	Female	0.23	0.30 (0.28-0.33)

Sather et al. (1991) reported that at 93 kg slaughter weight boars, as compared to gilts, had heavier kidneys (0.34 vs. 0.32 kg) and livers (1.67 vs. 1.62 kg), and lighter spleens (0.16 vs. 0.18 kg.)

2.4.4 Nutrition

Babatunde et al. (1966) found that pigs on restricted feed intake had lower proportions of gut, respiratory tract and internal organs than the pigs fed ad-libitum. Christon (1988), on the other hand, did not observe any difference in organ weights as percentage of empty body weight between restricted and ad-libitum-fed pigs slaughtered at 79 kg live weight.

Davey and Bereskin (1978) observed in pigs, slaughtered at 100 kg live weight, that as compared to the group fed a 14 per cent protein diet the group fed a 20 per cent diet had heavier livers (1271 vs. 1355 g) and kidneys (276 vs. 316 g). Dietary energy level (3.6 or 3.2 Kcal per g of diet) had no effect on the weight of organs.

From 30 to 100 kg live weight, four groups of Large White pigs were given the recommended amount of protein or 24 per cent less, in part or completely as plant protein. Weights of liver in pigs given animal and plant protein were 1.77 and 1.64 kg, and in those given plant protein alone 1.66 and 1.57 kg, at 100 and 76 per cent of recommended intakes respectively. The weights of heart were 334, 319, 312 and 289 g for the same groups in that order (Widenski and Wojcik, 1984).

Jones et al. (1985) studied the effect of cimaterol fed at four levels (0, 0.25, 0.5 and 1.0 ppm) to pigs from 64.5 to 103.7 kg live weight. Heart weights decreased with increased cimaterol levels. The leaf fat weights also decreased with increasing levels of cimaterol in the diet. Moser et al. (1986) reported that addition of cimaterol in the diet resulted in a linear decrease in liver weight and kidney weight, but had no effect on leaf fat.

Jones et al. (1988) studied the effect of fasting period prior to slaughter on the weights of internal organs. Liver weight was reduced by 2.9 g per kg over 24 hours and by 3.6 g per kg over 48 hours of fasting.

Batterham et al. (1991) reported that pigs given linseed meal had lighter kidenys, pancreas and spleen than those given soyabean meal. Corino et al. (1991) observed higher liver weights in pigs given larger amounts of rapessed meal, while Petersen and Sether (1979) did not find any significant influence of rapeseed oil on the weights of kidneys, heart, liver and spleen in growing pigs.

2.4.5 Management and environment

Gadzier (1962) observed that pigs given exercise had higher weights of heart, lungs and digestive tract than those kept indoors in pens.

Fuller (1965) observed that with increase in the environmental temperature from 10°C to 30°C, the weights of peritoneal fatty tissue, heart, spleen and kidneys increased. However, it was suggested that most of the differences in mean weights of major organs were related to differences in body weights at different temperatures.

Alaku et al. (1984) reported that pigs reared in tropical regions had higher heart weights relative to body weights than those reared in temperate regions, which indicated physiological adaptation to increased work load on the heart under tropical conditions.

Christon (1988) observed no difference in organ weights as percentage of empty body weight for pigs reared in temperate and tropical climates, slaughtered at 50 or 79 kg live weight.

2.5 Haematological studies

Both the cells of the blood and it's fluid components carry out vital physiological functions in the animal's bodily system. The leukocytes defend the body against microorganisms, and the erythrocytes contain haemoglobin which transports oxygen and carbon dioxide. In swine, in the young particularly, anaemia has been a serious problem, a condition in which there is a reduction in the number of circulating

erythrocytes or in the concentration of haemoglobin in the peripheral blood, causing a decrease in the oxygen carrying capacity of the blood. According to Doornebal and Martin (1965) blood volume and total red cell mass can be of importance in predicting body composition of pigs of market weight.

Giltner (1907) recorded the haematological values of swine of 2.5 to 6 months of age as under:

RBC (10^6/cumm)	WBC (10^3/cumm)	Lympho-cyte (%)	Mono-cyte (%)	Neutro-phil (%)	Eosino-phil (%)
6.8-8.8	9.5-25.0	30.0-79.8	0.8-10.0	13.0-60.0	1.2-11.0

According to Swenson (1982), the erythrocyte count of pigs is 6-8 million per cumm, and there are 400 erythrocytes to one leuckocyte. As a rule, in most mammals, normal blood haemoglobin values are between 13 and 15 g per 100 ml.

The total leukocyte count and differential leukocyte count for pigs of 6 weeks and older age were reported by Swenson (1982) as follows:

Total leukocyte count (10^6/cumm)	Neutrophil (%)	Lymphocyte (%)	Monocyte (%)	Eosinophil (%)	Basophil (%)
15-22	30-35	55-60	5-6	2-5	<1

According to him, the factors which affect the cellular constituents of blood included age, sex, exercise, nutritional status, lactation, pregnancy, excitement, blood volume (hemodilution or hemoconcentration), stage of oestrus cycle, breed, time of the day, environmental temperatures, altitude and other climatic factors.

The blood picture and haemoglobin concentration of pigs are influenced by various factors.

2.5.1 Genotype

Large White Poltava cross-bred pigs, as compared to their purebred counterparts, had 3.4 to 5.1 per cent more erythrocytes and 4.0 to 7.8 per cent more haemoglobin in peripheral blood (Rybalko and Saglo, 1983).

2.5.2 Age

The normal haemoglobin level for new-born pigs was 11

to 12 g per 100 ml. During the first ten days of life the haemoglobin level decreased to about 8 g per 100 ml, increasing thereafter gradually until 11 g per 100 ml at 6 months of age (Coffin, 1953).

Weide and Twiehaus (1959) recorded a gradual rise of erythrocyte count in pigs from 4.7×10^6 per cumm at ten days to 6.32×10^6 per cumm at 50 days old after which fluctuations occurred with slight elevation in total numbers which was 7.63×10^6 per cumm at 94 days old. Total leukocyte count also rose from 7.53×10^3 per cumm at ten days to 15.30×10^3 per cumm at 50 days old, after which a fluctuating level was attained. Differential counts revealed an increase in neutrophils at the expense of lympocytes, while monocytes and eosinophils remained fairly constant, and basophils were few.

Miller et al. (1961) observed that changes in values of blood haemoglobin, hematocrit and erythrocyte population, which occured throughout the life of swine, were relatively parallel. Values for new-born pigs were similar to those found in adult swine. By 3 days of age, a 25 per cent reduction in haemoglobin, hematocrit and red blood cells had occured. After weaning, the haemoglobin, hematocrit and red blood cell values increased to essentially adult values at 5 months of age. Reticulocyte numbers in the pig at birth were less than one per cent of total erythrocytes. By 3 days of

age there was a definite increase followed by another marked increase after weaning and was sustained for a period of 2 weeks. Reticulocyte numbers were generally less than 1 per cent of the total erythrocytes in older animals with the exception of females in the middle or late gestation.

2.5.3 Sex

There were no sex differences in differential or erythrocyte counts but the leukocytes tended to be higher in male animals (Palmer, 1917).

Miller et al. (1961) reported that castrated male pigs tended to have slightly higher red blood cell values than females but haemoglobin and hematocrit values did not appear to be influenced by sex. There was a reduction of haemoglobin, hematocrit and red blood cell values of sows in late pregnancy. There appeared to be no sex influence on reticulocyte numbers in swine. Also, sex was not found to influence on mean corpuscular haemoglobin concentration.

2.5.4 Nutrition

Bunch (1963) reported that added iron in the diet increased haemoglobin values while copper decreased it if iron was not given also. Poznanski (1964) reported that supplement of minerals like iron, copper, magnanese, magnesium and cobalt

significantly increased haemoglobin, red cell count and gain in piglets. BiaLkowshi (1983) observed a 10 per cent decrease of haemoglobin, hematocrit and red cell count in piglets given no iron with high mortality (13.7 per cent). By supplement of ferrous sulphate or ferrous lactate in the diet of piglets weaned at 26 days of age, and in another experiment by ferrous sulphate, ferrous lactate or ferrous methionate in the diet of early-weaned piglets, the concentration of haemoglobin was 11.5, 13.0, 11.9, 13.1 and 13.6 g per 100 ml; and erythrocyte count was 5.2, 6.0, 6.08, 7.04 and 7.20 x 10^6 per cumm, respectively (Pavlov, 1983).

Brooks et al. (1964) reported that lysine supplement in the diet of growing swine resulted in decreased white cell count, and increased hematocrit value, red cell count and haemoglobin concentration.

Growing pigs given cassava peel at 40 per cent level in the diet had an increased lympocyte count, and decreased neutrophil and total white cell count because of interaction of cassava peel and protein deficiency (Tewe, 1984).

Honeyfield and Barke (1985) studied the performance as well as physiological and metabolic consequences of three dietary levels of sodium (0.03, 0.09 and 0.1 g per cent) and of chloride (0.08, 0.17 and 0.12 per cent) in growing-

finishing pigs (36 to 89 kg). Haemoglobin increased linearly as dietary sodium increased (15.9, 12.8 and 12.4 g per 100 ml). With the three levels of dietary chloride, in that order, the values were 14.4, 13.1 and 13.5 g per 100 ml, which were not significantly different.

Chichlowska et al. (1986) reported that for pigs fattened from 30 to 115 kg body weight on barley or maize silage, alone or mixed with 1:1, or on barley with 25 or 50 per cent ammoniated maize grain, haemoglobin increased significantly after 6 weeks from 6.9 on barley to 7.6 m mol per liter on 50 or 100 per cent maize silage and to 7.5 and 7.7 m mol per litre on 25 or 50 per cent ammoniated maize. After 12 weeks the differences were not significant. Red cell count was similar with all diets.

2.5.5 Environment and Management

Mandel et al. (1962) observed in piglets, suckled to 56 days or weaned at 10 days, that the values for red cell count, haemoglobin and hematocrit at 28 days were significantly higher in the early weaned pigs, and for the first two indices remained so to 56 days. At that time the values for haemoglobin and red cells were significantly higher in the early-weaned. White cell counts, basophils and young forms of neutrophils were higher in the early-weaned pigs.

French and Bussell (1963) reported that pigs with more than 5 g haemoglobin per 100 ml grew normally and that supplement of iron in creep feed was adequate for normal growth. It was observed that for piglets not given injection of iron in the first week had lower haemoglobin in the first 3 weeks and that overall value upto 63 to 70 days of age was only 7.6 g per 100 ml compared with 9.6 g for the group given iron-dextrin and 10.4 g for that given iron-dextran.

Kolacz et al. (1983) reared for 52 days weaned piglets, about 4 to 5 weeks old, in three-storey batteries stocked at 10 piglets per cage, equivant to 0.2 m^2 per piglet. Temperature in the bottom storey was from 2 to 5.6°C less than on the top storey, and relative humidity and cooling power were more. For piglets in the bottom, middle and top storey respectively, red cell counts were 7.1, 8.2 and 8.6 x 10^6 per cumm; haemoglobin concentrations were 8.7, 9.8 and 10.1 g per 100 ml.

Ruda and Majewski (1985) studied the effect of floor type and supplement of vitamin A and D_3 on growth and development of piglets. Piglets were kept from birth to weaning (42 days old) on concrete floors with straw bedding or on wooden planks and straw bedding; some of them were given injections of vitamin A and cholecalciferol twice at 3 and 10 days of age. For the two types of floors respectively, and

with or without vitamin injection, in that order, red cell count at 42 days was 3.2, 3.6, 2.5 and 2.1 x 10^6 per cumm; haemoglobin was 5.3, 5.0, 3.7 and 3.9 m mol per litre and hematocrit 0.28, 0.32, 0.25 and 0.26.

Shurson et al. (1990) reported that haemoglobin and hematocrit were higher in germ-free pigs than in conventionally reared pigs. Germ-free pigs had lower leukocyte count, and the relative percentages of differentiated leukocytes were altered compared with the conventionally-reared pigs. In both groups, the hematocrit and erythrocyte count were reduced by feeding a high-copper (283 ppm) diet. It was further found that high-copper diet increased the percentages of band neutrophils and monocytes in germ-free pigs but reduced the percentage of these cells in conventionally-reared pigs.

2.6 Cholesterol and Triglyceride levels in blood

The blood lipid levels vary among species, among individuals, and at various times. Factors which influence these lipid levels include quantity and type of lipid in the diet, time after consumption of food, health and age of the subject, and energy needs. While there is a constancy in the cholesterol-cholesterol ester, and cholesterol-phospholipid ratios within a given species, the levels of triglycerides,

however, vary greatly depending on dietary intake, storage in or mobilisation from, adipose tissues, and on synthesis by the liver (Scott Allen, 1982). According to Martincic et al. (1984) the serum lipid values vary with age, diet and body weight; the major influence on lipid values being a carbohydrate-rich diet. The total lipid values are correlated with cholesterol values.

Various factors are found to influence the cholesterol and triglyceride concentrations in blood.

2.6.1 Heredity

Higher concentrations of cholesterol and low-density lipoproteins (LDL) were found in genetically fat than in lean pigs (Lewis and Page, 1956). However, genetically lean pigs showed a greater rise than obese pigs in plasma cholesterol when fed on a low-protein diet (Pond et al., 1986).

Anderson and Fausch (1964) reported great variations in serum lipid levels between breeds. As compared to Minnesota #1 breed the Minnesota #3 breed had markedly lower cholesterol (103.6 vs. 87.0 mg per 100 ml) but slightly higher serum triglyceride levels (34.6 vs. 38.4 mg per 100 ml). The breed influence of Landrace lowered while that of the Hampshire raised the cholesterol (84.3 vs. 111.4 mg per 100 ml) and triglyceride (33.3 vs. 47.8 mg per 100 ml) levels in

the cross-bred pigs compared to the pure bred Minnesota #1. It was believed that the differences in serum lipid levels observed was of a true genetic nature.

Bakke (1975) reported that sows and young pigs, selected for low thickness of backfat and higher weight gain, had a higher level of serum cholesterol than those selected for high thickness of backfat and low weight gain. A negative correlation was found between serum cholesterol and amount of depot fat. Serum triglyceride levels in the two groups showed the opposite effect although the differences were not significant.

2.6.2 Age and body weight

Heidenreich et al. (1964) stated that the total serum cholesterol varied significantly with age and body weight. It was believed that the serum cholesterol at 125 days and daily live weight gain were related. Serum cholesterol at slaughter (200 lb liveweight) was positively correlated with thickness of backfat.

Agarwal and Arora (1973) reported that pigs in three groups of ages 1 to 24, 24 to 48, and over 48 months respectively, had total cholesterol 135, 175 and 249 mg per 100 ml, triglycerides 32, 47 and 65 mg per 100 ml phospholipids 118, 149 and 187 mg per 100 ml, and lipids 229,

367 and 465 mg per 100 ml serum. The differences between groups were significant except those of cholesterol. Beta-lipoprotein as percentage of lipoproteins rose significantly with age.

Bakke (1975) observed that sows (400 to 900 days old) had lower serum cholesterol than young pigs (86 to 140 days old). No effect of age on serum cholesterol in the sows was found.

The serum cholesterol levels decreased from one to two months of age, and also linearly from five to thirty-six months of age in both gilts and boars (Tumbleson et al., 1976).

Mersman and MacNeil (1985) observed that for obese and lean pigs respectively, fed and libitum, the levels of triglyceride were 69 and 80 mg per dl at 2 months, 46 and 50 mg per dl at 4 months, and 62 and 59 mg per dl at 6 months of age. For the obese and lean pigs respectively, fasted for 30 hours, the levels of triglyceride were 206 and 137 mg per dl at 2 months, 72 and 76 mg per dl at 4 months, and 63 and 53 mg per dl at 6 months of age. In the case of contemporary pigs, fed ad-libitum, the triglyceride levels were 156 mg per dl at 2 months, 59 mg per dl at 5.2 months, and 40 mg per dl at 10 months of age. When the pigs were fasted for 18 to 25 hours,

the triglyceride levels were 104 mg per dl at 2 months, 63 mg per dl at 5.2 months, and 44 mg per dl at 10 months of age.

For young growing (8 to 25 kg), growing (29 to 50 kg) and finishing (59 to 79 kg) pigs respectively, reared under tropical environmental temperature, the blood cholesterol levels were 118.9, 98.5 and 113.0 mg per dl, and the blood triglyceride levels 93.6, 53.7 and 63.0 mg per dl (Christon, 1988).

2.6.3 Sex

Anderson and Fausch (1964) observed that intact males, as compared to gilts and barrows, had lower serum cholesterol (83.8 vs. 94.7 and 96.0 mg per 100 ml) and triglyceride (28.6 vs. 38.7 and 37.8 mg per 100 ml) levels.

Tumbleson et al. (1976) also reported that the serum cholesterol levels from 5 to 36 months age, and serum triglyceride level from 3 to 36 months age were greater for females than for males.

Odink et al. (1990) recorded the mean serum cholesterol values for gilts, boars and barrows, all 6 months old and weighing approximately 110 kg, as 2.23, 2.28 and 2.36 mM, respectively, with an average value of 2.29 mM.

2.6.4 Nutrition

2.6.4.1 Effect of fasting period

Morrow et al. (1963) observed that pigs fasted upto 48 hours did not have any significant difference in values for lipids as compared to those fed constantly, however, lipid values were higher for the pigs fasted for 56 hours. It was further observed that, after 8 hours of refeeding after 48 hours of fasting, the lipid values were lower than those for the groups fed constantly.

Anderson and Fausch (1964) observed, in pigs fed for 84 days after weaning that the serum cholesterol level was significantly higher for ad-libitum-fed pigs (97.0 $\pm$ 1.92 mg per 100 ml) as compared with either of the groups receiving two 1-hour feeding (90.0 $\pm$ 1.95 mg per 100 ml) or one 2-hour feeding (91.2 $\pm$ 1.95 mg per 100 ml). Serum triglyceride levels were unaltered by the method of feeding (37.0 $\pm$ 1.96, 36.4 $\pm$ 1.99 and 35.2 $\pm$ 1.99 mg per 100 ml for the three groups in that order). In the case of the pigs fed for 173 days after weaning, the values for serum cholesterol and triglyceride levels respectively, for the three groups of pigs in that order, were 104.5 $\pm$ 2.3 and 30.5 $\pm$ 4.1, 102.2 $\pm$ 2.3 and 41.8 $\pm$ 4.1 mg per 100 ml, and 100.6 $\pm$ 2.3 and 48.2 $\pm$ 4.1 mg per 100 ml. No statistically significant differences were

noted between groups in any of the serum lipids except in triglyceride which was found to be significantly lower in ad-libitum-fed pigs compared with pigs receiving one 2-hour feeding.

Mersmann and MacNeil (1985) observed that the plasma triglyceride concentration tended to increase with time of fasting from 2 hours to 72 hours in large pigs (87.9 ± 3.3 kg), whereas in small pigs (24.2 ± 1.7 kg) a plateau was reached at 30 hours of fasting.

2.6.4.2 Effect of dietary fat level

Howard et al. (1965) did not observe any difference in the serum cholesterol or triglyceride contents of pigs receiving diets containing no fat, beef tallow or maize oil, or a normal commercial diet.

Berschauer et al. (1983a) found that in pigs from 3 to 30 kg body weight, increasing dietary fat level from 5 to 35 per cent increased blood values for free fatty acids by 33, neutral lipids by 48 and cholesterol by 20 per cent. However, the concentration of these lipids did not clearly differ among groups during the subsequent fattening period of 30 to 100 kg body weight (Berschauer et al., 1983b).

Siebert et al. (1987) observed that when the diets

were isoenergetic, the plama total and high-density lipoprotein concentrations did not differ in pigs fed the cereal diet or the low fat meat diet, but were significantly higher in pigs fed on the high-fat meat diet. Plasma low-density and very-low-density lipoprotein cholesterol concentrations were also raised with increased consumption of saturated fat. The plasma cholesterol concentrations were higher with a diet consisting almost entirely of cereal grains than with a diet containing lean meat and plant products. It was further observed that the source of dietary protein had little influence on plasma lipids at low amounts of fat intake and the main factor affecting plasma cholesterol concentration during meat consumption was dietary fat both in absolute terms and polyunsaturated to saturated fat ratio.

2.6.4.3 Effect of dietary fatty acid

Leat (1963) reported that by increasing linoleic acid in the diet (0.07 to 3.67 per cent of energy value as linoleic acid in the diet), the cholesterol concentration of serum increased from 101 to 125 mg per 100 ml, while other lipids were unaffected.

Walsh et al. (1983) found no significant difference in total plasma cholesterol or liver cholesterol in pigs fed diets containing soyabean oil, soyabean protein isolate or

beef. Diersen-Schade et al. (1985), on the otherhand, reported that the plasma cholesterol and triglyceride levels were greater in soy-fed (96 and 106 mg per dl) and beef-fed (122 and 109 mg per dl) than in conventionally-fed (75 and 69 mg per dl) pigs.

For pigs fed a ration containing 12 per cent sunflower oil or coconut fat, or a control ration, the blood cholesterol 4 hours after feeding reached 72.1 mg per 100 ml in the controls and about 22 per cent more in others. The triglyceride values of the groups were 57.8, 83.1 and 24.9 mg per 100 ml respectively (Berschauer et al., 1984).

2.6.4.4 Effect of dietary cholesterol level

Calvert and Scott (1974) reported higher serum cholesterol and low-density lipoprotein concentrations in pigs given high-cholesterol diets. The high-cholesterol diet had no consistent influence on serum triglyceride concentration.

Pond and Mersmann (1991) reported that dietary cholesterol deprivation of pigs during the first 4 weeks of post-natal life reduced serum cholesterol response to a high-cholesterol diet fed from 4 weeks to 20 weeks of age, but had no effect after 20 weeks of age.

2.6.4.5 Effect of dietary protein and energy levels

Pond et al. (1986) reported that the plasma cholesterol concentration was increased by low-protein, high-fat, or high-cholesterol diet, and that lean pigs showed greater rise than obese pigs in plasma cholesterol when fed on a low-protein diet.

Hale et al. (1986) reported that, as compared to the pigs fed a high-energy diet, the pigs fed a low-energy diet had lower serum cholesterol (100.1 vs. 85.9 mg per dl) and triglyceride (72.2 vs. 58.4 mg per dl) concentrations.

Mersmann et al. (1987) reported that the plasma cholesterol, triglyceride and fatty acid concentrations were higher for pigs given high-protein (18 per cent) as compared to those given low-protein (14 per cent) diets. Dimov and Banskalieva (1990), on the otherhand, found no change in plasma triglyceride values due to change in dietary protein or energy levels.

Stoll et al. (1991) reported that variations in the amino acid composition of the diets within a physiological range had no effect on the concentrations of plasma cholesterol and triglyceride levels. However, it was observed cthat plasma lipid values were significantly lower when pigs received diets containing milk instead of the diet without

milk. The levels of cholesterol, triglyceride and low-density-lipoprotein-cholesterol were reduced by 5.6, 5.8 and 10 per cent respectively, while high-density-lipoprotein-cholesterol was unaffected when milk was incorporated into the diet. Beynen et al. (1991), on the otherhand, reported that cholesterol absorption in the intestine was stimulated by dietary casein.

2.6.5 Season/environment

Heidenreich et al. (1962) studied the seasonal influence on serum cholesterol levels in swine. Total cholesterol in serum was about 152 and 150 mg per 100 ml at 123 and 172 days of age in January and March, that is, in winter; about 118, 105 and 112 mg per 100 ml at 92, 126 and 182 days in July, August and October. The seasonal differences between pigs of similar age were highly significant.

Morrow et al. (1963) observed a diurnal variation in the values of plasma lipids, which fell from 181 mg per 100 ml at 4.00 a.m. to 142 mg at 4.00 p.m. This was subsequently explained to be due to temperature; lower temperatures (31 to 40°F) resulting in elevated lipid levels (261 $\pm$ 40 mg per 100 ml) and higher temperatures (57° to 80°F) in lower plasma lipid levels (182 $\pm$ 33 mg per 100 ml).

Christon (1988) observed that tropical environment (21.9 to 28.8°C) as compared to a control environment (19.5 to 20.8°C) brought about a rise in plasma total cholesterol concentrations (98.5 mg vs. 81.8 mg per 100 ml). In another experiment, it was observed that tropical environment (22.8 to 29.2°C) as compared to a control environment (16.7 to 17.7°C) caused an elevation of plasma levels of triglycerides (63.0 vs. 41.6 mg per 100 ml) and total cholesterol (113.0 vs. 106 mg per 100 ml) in ad-libitum-fed pigs. Environmental temperature also affected the blood lipid levels of restricted-fed pigs in the similar way.

2.7 Fatty acid composition of pig meat

The fat quality of pig meat is largely dependent on the fatty acid composition, which is influenced by various factors such as breed, sex, age, stage of growth, anatomical location, nutrition and environment. In general, a large part of the variation in fat quality is caused by the variation in the amount of fat tissue (Babatunde et al., 1966; Wood, 1984) and the gross composition of fat tissue and it's fatty acid composition (Wood, 1984). In pigs, the lipids present in lean carcasses are relatively unsaturated, and fat quality differences between breeds and sexes are also largely caused by the differences in the amount of fat tissue (Wood, 1984). Differences in fat characteristics between breeds are largely

attributable to diffence in fatness rather than inherent breed factors, because within a breed, the heritabilities of the chemical fat content of the muscle and the total amount of carcass fat are high but genetic correlation between these two characteristics are very low (Warriss et al., 1990). However, two factors that influence the chemical composition of fat tissues independently of carcass fatness are castration in male pigs and the dietary concentration of unsaturated fatty acids, particularly linoleic acid (Wood et al., 1985).

The fatty acid composition of adipose tissue lipids and muscle lipids are influenced by various factors.

2.7.1 Breed

Garcia et al. (1986) reported a generally higher concentration of linoleic acid in the intramuscular fat of Hampshire pigs than that of Duroc Jersey pigs.

The iodine value and percentage of unsaturated fatty acids were lowest for Large White x (Large White x Landrace), highest for Hampshire x (Landrace x Large White), and intermediate for Duroc x (Large White x Landrace) (Barton-Gade, 1987). These differences could be partly explained by the breed combinations' different backfat thickness. A thinner backfat layer corresponded to a higher iodine value and more unsaturated fatty acids (Barton-Gade, 1984).

Large White breed, as compared to Dutch Landrace x Large White crosses, contained a higher percentage of unsaturated fatty acids in the subcutaneous adipose tissue (Fiego, 1988).

Honkavaara (1989) reported that the percentage of linoleic acid, linolenic acid, arachidonic acid and total polyunsaturated fatty acid in the backfat were higher in Finish Landrace x Finish Yorkshire pigs than in Duroc x (Finish Landrace x Finish Yorkshire) pigs. It was also reported that the halothane-positive stress-susceptible pigs had a higher percentage of linoleic, linolenic and total polyunsaturated fatty acids in the backfat than in stress-resistant pigs. It was, however, concluded that breed type had a greater effect than stress susceptibility on fatty acid composition of subcutaneous and intramuscular fat.

Bout et al. (1990) found that the intramuscular lipids contained more monounsaturated fatty acids and less polyunsaturated fatty acids in Duroc than in Large White.

The subcutaneous backfat of Duroc pigs had higher concentrations of myristic and linoleic fatty acids and lower concentrations of oleic acid than Landrace pigs (Cameron, 1990).

Gandemer et al. (1990) observed that the muscle lipids from pigs with 0 or 25 per cent Meishan inheritance contained a higher proportion of polyunsaturated acids than those from pigs with 50 per cent Meishan inheritance.

Maitre and Kerist (1990) reported that double-muscled breeds had increased percentage of unsaturated fatty acids in the backfat. This resulted in softfat.

2.7.2 Sex

Malmfors et al. (1978) reported that the intramuscular fat from boars contained a greater proportion of polyunsaturated fatty acids than did fat from castrates, and that preferential deposition of linoleic acid seemed to some extent compensated by decreased deposition of oleic acid, thereby maintaining a fairly constant degree of unsaturation. A significantly higher proportion of total unsaturated fatty acids (61.6 per cent) in the backfat of boars as compared to that of barrows was also reported by Smithard et al. (1980) who stated that the sex difference was due to lower palmitic acid content and higher linoleic and linolenic fatty acid levels in the backfat of boars. Gilts were intermediate to boars and barrows in the degree of unsaturation of backfat. Similar findings were also made by Barton-Gade (1987). The higher percentage of unsaturated fatty acids in the backfat of

boars was due to a higher linoleic acid content, and the higher percentage of saturated fatty acids in the backfat of castrates was due to a higher palmitic acid content. These differences were, to a high degree, a reflection of the sexes' different backfat thickness. A thinner backfat layer corresponded to a higher iodine value and more unsaturated fatty acids. But Fiego (1988) reported a higher percentage of unsaturated fatty acids in the backfat of barrows than that of gilts.

Nurnberg and Ender (1990) reported higher contents of meat linoleic acid for boars as compared to gilts or barrows. It was further observed that the content of linoleic acid in the carcass increased with an increasing percentage of lean in the carcass. Similar findings by Cameron (1990) further revealed that boars had lower concentrations of oleic, stearic and monoene to saturated ratio and higher concentrations of linoleic and linolenic than gilts.

Sather et al. (1991) stated that males castrated prior to 16 weeks of age had iodine values less than those of gilts, while those castrated between 16 and 20 weeks had values similar to those of gilts. Entire males had iodine values greater than gilts.

2.7.3 Age and body weight

The findings of Babatunde et al. (1966) revealed that the saturated fatty acids of the backfat were positively correlated to all fat measures and gross energy of the body and negatively correlated to all lean measures and with protein and water, and the reverse was true for unsaturated fatty acids. Linoleic acid was more highly correlated, positively or negatively, to most of the physical and chemical measurements than were the saturated fatty acids.

Ohtake et al. (1975) reported that intramuscular fat from pigs at weight 90 kg had more palmitic, stearic and total saturated fatty acids than pigs at weight 60 or 120 kg. The linoleic acid content decreased with increasing weight. It was further observed that from 60 to 90 kg, myristic, palmitic, stearic and total saturated fatty acids in triglycerides increased and oleic, linoleic and unsaturated fatty acids decreased; from 90 to 120 kg, myristic, palmitic and total saturated fatty acids decreased and oleic acid increased. Depot fats had varying fatty acid composition but changes associated with growth were similar in same depot sites.

Malmfors et al. (1978) reported that the total relative content of polyunsaturated fatty acids in Swedish

Landrace pigs decreased with increasing weight from 70 kg upto about 110 kg and thereafter showed a parallel increase upto 130 kg, whereas in Swedish Large white breed, the fatty acid composition was only slightly influenced by body weight.

With increasing slaughter weight from 30 to 80 kg, concentrations of oleic acid increased while concentrations of palmitoleic, linoleic, linolenic acids decreased; resulting in subcutaneous fat becoming more saturated and harder (Cameron, 1990).

Nurnberg and Wegner (1991) observed that the percentage of polyunsaturated fatty acids was approximately 10 up to 100 days of age, decreased to approximately 8.5 at 180 days, then increased to approximately 9.0 at 220 days. The percentage of saturated fatty acids increased from 37.5 at 70 days to 42.0 at 180 days, and then decreased to 40.0 at 220 days.

2.7.4 Anatomical location

The distribution of palmitic, stearic, oleic and linoleic acids differed according to the site of depot fat and was little affected by diet containing lard or no lard (Flanzy et al., 1965).

Ohtake et al. (1975) observed only small differences

in fatty acid composition among supraspinum, longissimus dorsi and biceps femoris muscles.

Malmfors et al. (1978) on the other hand reported highly significant differences in fatty acid composition between different muscles and between backfat layers within the same animal.

Marchello et al. (1983) studied the differences in fatty acid composition among five locations (leaf fat, flank fat, inner backfat, outer backfat, intramuscular fat) in the carcass. Intramuscular fat had a substantially different profile than the other locations. It was significantly lower in linoleic acid, and higher in oleic and palmitoleic acids. It had a significantly lower percentage of stearic acid, except for outer backfat. Saturated fatty acids were preferentially deposited in leaf fat rather than subcutaneous fat and within inside subcutaneous fat rather than outer layer. An opposite pattern was observed with the saturated acids. Maitre and Kerist (1990) also reported that internal fat was richer in lipids and saturated fatty acids than subcutaneous fat.

Garcia et al. (1986) reported that the difference in concentration of linoleic acid in many muscles were highly significant in both Duroc and Hampshire pigs. The most

striking difference was in the concentration of linolic acid which ranged from 3.2 per cent in longissimus to 8.5 per cent in adductor muscle in Duroc Jersey pigs. The concentration of linoleic acid in the triglyceride fraction was higher in the different depot fats than in the intramuscular fats.

Wood et al. (1986) reported that the fatty acid composition differences between sites within subcutaneous fat and between subcutaneous and intermuscular fat were less marked than those between perirenal and the rest. Perirenal depot had the highest concentrations of saturated fatty acids, and a high concentration of linoleic acid and low concentration of oleic acid.

Fiego (1988) stated that the percentage of unsaturated fatty acids were 65.39 and 61.12 in the outer and inner layers of backfat, respectively. Anatomical location affected the content of several fatty acids, but not the percentage of unsaturated fatty acids.

Honkavaara (1989) observed that the fatty acid composition of intramuscular fat varied greatly between muscles in stress-susceptible pigs but not in stress-resistant pigs.

Miller et al. (1990) reported that the perirenal fat had the highest amount of saturated fatty acids and a lowest

level of oleic acid than did fat from subcutaneous or intermuscular adipose tissues, or longissimus muscle. Busboom et al. (1991) also reported similar observations.

Casa et al. (1991) reported that linoleic acid values were lower in internal than in external layers of backfat, while oleic acid was more in the internal layer.

Leseigneur-Meynier and Gandemer (1991) reported that the triglycerides of intramuscular fat contained 34-43 per cent saturated, 50-57 per cent monounsaturated and 7-15 per cent polyunsaturated fatty acids, many varying from muscle to muscle. The longissimus dorsi contained less linoleic acid than other muscles (Trapezius, Psoas major, Biceps femoris, Masseter). The Biceps femoris contained a higher amount of polyunsaturated fatty acids and a lower amount of saturated fatty acids as compared to other muscles. The five muscles were similar in the saturated fatty acid proportions, but varied in the relative proportions of monounsaturated and polyunsaturated fatty acids. The Longissimus dorsi contained less polyunsaturated and more monounsatured fatty acids than other.

2.7.5 Nutrition

Wood (1984) stated that diet had a more marked effect on fat quality than breed or sex, especially in pigs.

2.7.5.1 Effect of feed restriction

Cortamira and Garcia (1984) observed that when pigs were fed on seven or six days weekly from 23.5 to 95 kg body weight, or restricted to six or five non-consecutive days weekly from 60 to 95 kg, feed restriction, especially in the later group, caused a significant lowering of linoleic acid in the backfat. Restriction did not affect fatty acid composition of muscle lipids.

Grela (1983) observed that protein and energy content of feed did not affect the fatty acid composition of backfat and lard so much as that of depot fat. It was also found that the fatty acids in the liver, backfat and lard were not directly related to their values in feed. Garcia et al. (1984b) reported that protein intake did not affect the composition of lipids in the Semitendinosus or Biceps brachis muscles or in subcutaneous fat. Yatsenko (1986) stated that the iodine value numbers of fat was lower in pigs given reduced protein in their diet. Doberschutz et al. (1990) observed that by differing energy concentration in the diet the concentrations of oleic, linoleic and linolenic acid in the backfat were influenced. Compared with medium dietary energy, high or low-dietary energy influenced palmitic and stearic acid contents, while myristic acid was not affected. When equal proportions of heptadecenoic and heptadecanoic

acids were added to the diet, the low-energy diets increased C_{17} content of backfat.

2.7.5.2 Effect of dietary fatty acid

Leat (1962) reported that by supplying linoleic acid in the diet, 95 per cent of the fatty acids of depot fat contained 16 or 18 C atoms, and less than two per cent had more than 18 C. Seher et al. (1984) observed that dietary fat, containing high amount of linoleic and linolenic acid, inhibited the metabolic conversion of linoleic acid into arachidonic acid by linolenic acid, and to a lesser extent by oleic acid. Osterballe et al. (1990) observed that with increasing the levels of linoneic and linolenic acid in the diet, the concentration of polyunsaturated fatty acid in muscle and backfat increased.

Luck et al. (1964) reported that coconut oil in the diet reduced the iodine value and increased the saponification value of the omental fat because of accumulation of higher content of lauric and myristic acids. Wood oil in the diet increased proportions of oleic acid and of tri-unsaturated C_{18} acids, chiefly elaeostearic acid.

Flanzy et al. (1965) observed that when lard was incorporated at 13 per cent level in the diet, the depot fats had higher iodine numbers, while the distribution of palmitic,

stearic, oleic and linoleic acids differed according to the site of depot fat and were less affected by diet. Berschauer and Ehrensvard (1984) observed that on transfer to control feed at 60 kg until 100 kg body weight, the linoleic acid content of backfat in barrows previously (20 kg to 60 kg body weight) given lard decreased from 15.7 to 11.2 per cent, compared with 7.3 per cent for groups receiving the control diet throughout. With vegetable fat, backfat contained more linoleic and linolenic and less palmitic, stearic and oleic acid (Oslage et al., 1984).

Skelly et al. (1975) reported that incorporation of roasted soyabean in the diet of pigs resulted in a directly proportionate increase in the linoleic acid content of meat and backfat. Supplementation of soyabean oil meal during the finishing period caused on increase in palmitic, oleic and linoleic acid in belly fat, while backfat and neckfat showed a decrease in palmitic and oleic acid content (Osorio Bueno et al., 1983). Inclusion of whole soyabeans in diet significantly increased linoleic acid in backfat and decreased fatty acids usually present in large amounts, such as palmitic, stearic and oleic (Casa et al., 1991). Irie (1988) also reported that soyabean oil affected fat at each fat deposit site. Saturated fatty acids (Palmitic and stearic)

decreased, while linoleic acid increased with increasing soyabean oil in the diet.

Inoue et al. (1980) reported a significant increase in the melting point of all fat depots with increasing dietary oil level. The oleic acid content of inner backfat decreased significantly. With increasing dietary kapok oil concentrations, the stearic acid and total saturated acid content, saturated/unsaturated acid ratio and stearic/oleic acid ratio of abdominal fat increased and its oleic acid content decreased significantly. Similar results were reported by Irie (1988) who stated that supplementary meal (containing cyclopropenoic fatty acids) significantly increased melting point of depot fat without affecting the iodine number and retractive index.

KreLowska-Kulass et al. (1982) reported that by feeding pigs on a feed mixture containing yeast the percentage of unsaturated fatty acids in the backfat increased.

Marchello et al. (1983) and Hartman et al. (1985) reported that incorporation of sunflower seed in the diet of pigs resulted in decreases in myristic, palmitic, stearic, palmitoleic and oleic acids, and increase in linoleic acid of carcass fat. Wahlstrom (1984) also observed a progressively

less saturation of carcass fat with increasing sunflower seed in the diet.

Berschauer et al. (1983c) observed higher linoleic, and lower lauric and myristic acid in the backfat of pigs receiving rations containing sunflower seed as compared to those receiving coconut fat. Similar findings have also been reported by Berschauer et al. (1984).

The linoleic acid in muscle decreased with the type of dietary cereal in order, maize, low-tannin sorghum, high-tannin sorghum (Garcia et al., 1984a). When given a mixed diet with 20 per cent cereal and 5.8 per cent crude fat or a cereal based diet with 3.1 per cent crude fat, the backfat of pigs (35 kg body weight) given the low-cereal diet had increased proportions of oleic, linoleic and linolenic acid, while palmitic and stearic acids decreased (Brenner and Tholking, 1991).

Feeding of peanut (West and Mayer, 1987) and rapeseed (Hoppenbrock, 1985) have been reported to increase the proportion of unsaturated to saturated fatty acid in the backfat of pigs.

By replacing 50 or 100 per cent maize (in a maize and soyabean meal) with cassava flour, dried ground cassava root or cassava meal, myristic acid increased with 100 per cent

cassava meal; linoleic acid decreased with 100 per cent cassava flour and cassava meal but increased with 50 per cent cassava root in the diet (Barbosa et al., 1986).

Bell et al. (1987) reported that canola seed in the diet of pigs resulted in the decrease of fatty acids myristic, palmitic, palmitoleic, and stearic, and in increase of oleic, linoleic and linolenic in the backfat. Mazhar et al. (1990) found that bacon from pigs fed ground canola had less saturated fatty acids and more monounsaturated fatty acids than bacon from pigs fed intact canola or control diets. Pigs fed intact or ground canola had more polyunsaturated fatty acids in their backfat than those fed the control diet. Busboom et al. (1991) also reported that pigs fed canola had greater proportions of mono and polyunsaturated fatty acids, and less saturated fatty acids in perirenal and subcutaneous fat. The Longissimus muscle of canola-fed pigs had elevated levels of unsaturated fatty acids and less saturated fatty acids, Lamkey et al.,(1990) reported that dietary canola oil reduced total saturated fatty acids and increased mono-and polyunsaturated fatty acids in carcass fat.

2.7.6 Environment and management

Heath (1983) observed that the total amount of body fat was greater in pigs reared in warm (35°C) than those

reared in cold (12°C) environment, and that fat was distributed differentially in the two groups. Warm-reared pigs had more fat in the subcutaneous layer whereas cold-reared pigs had more fat in the abdominal tissues and sheletal muscles.

Grela et al. (1987) reported that the group-housed pigs had a larger carcass fatness and more saturated fatty acids in the fat as compared to those kept individually.

Denton and Lacey (1991) were of the view that intensive methods of rearing of fish, broilers, egg-layers and pigs could reduce the proportion of cis-polyunsaturated fatty acids in the food. It was suggested that changes in the methods of feeding food animals might be partly responsible for continued high incidence of coronary heart disease.

Lefaucheur et al. (1991) reported that the percentage of unsaturated fatty acids in backfat were higher in pigs kept at 12°C than those kept at 28°C. There was no effect of temperature on leaf fat.

Materials and Methods

MATERIALS AND METHODS

3.1 Location

The study "Influence of Chitin on growth and fatty acid composition in growing pigs" was undertaken by the department of Livestock Production Management, College of Veterinary and Animal Sciences, Kerala Agricultural University, Mannuthy. The experimental animals were reared at the University Pig Breeding Farm, Mannuthy under the prevailing managemental conditions of the farm.

The geographical location of Mannuthy is as follows:

Longitude - 76, 16"E

Latitude - 10, 32"N

Altitude - 22.25 mt above MSL

The mean climatological variables of the location are as follows:

Average atmospheric temperature:

Minimum - 20.9-24.8°C

Maximum - 28.2-36.9°C

Average relative humidity - 36-95%

3.2 Experimental programme

Twenty-four weaned female piglings of Large White Yorkshire breed having an average body weight of 9.5 kg were

randomly assigned to three groups of eight each, maintaining uniformity of body weight between the groups.

The pigs of one group were given chitin in the feed at 0.5 per cent level (group 1). The pigs of the second group were given chitin at 1 per cent level in the feed (group 2). The third group of pigs which served as controls were given only the standard farm ration without addition of chitin (group 3). Chitin was mixed with the feed thoroughly by an electrically operated mixer. The chitin (purity >99 per cent), prepared from prawn waste, was obtained from the Central Institute of Fisheries Technology (CIFT), Cochin.

The standard farm ration for the pigs contained 18 per cent crude protein until the animals attained the age of 5 months, after which it contained a lower level of 14 per cent crude protein. The percentage composition of the ration is given below.

Ingredients	Parts	
	Weaning to 5 months of age	Above 5 months of age
Maize	40	30
Wheat bran	34	56
Fish meal	10	5
Groundnut cake	15	8
Mineral mixture	0.5	0.5
Common salt	0.5	0.5

The ration was provided freely based on consumption in one-hour period twice daily at 9.00 hours in the morning and at 15.00 hours in the afternoon.

Clean drinking water was made available to the animals at all times of the day.

The animals in each group were housed individually in open-front, concrete-floor pens providing a covered area of 6.15 m^2 per pen, and having access to concrete-floor open exercise yards with wallowing tanks.

The piglings were injected with Imferon* (1 ml intra-muscularly) at 5 days and at the time of weaning. They were regularly dewormed with Helatac** every two months. The animals and their premises were sprayed with malathion (0.5 per cent v/v) once in every month for control of ectoparasites.

The following observations were made and procedures followed during the course of the experiment.

3.2.1 Digestibility of chitin

The total quantity of faeces excreted in 24 hours was collected individually from three animals in each chitin-fed

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* Iron dextran 50 mg/ml (Rallis India Ltd., Bombay)
** Parbendazole 4% (Eskay Laboratories Ltd., Bombay)

group at 3, 5 and 7 months of age. The faeces of individual animals was kept in separate polythene bags and weighed. The faecal matter was carried in an ice box to the CIFT, Cochin for determination of digestibility of chitin.

The faeces was oven-dried at 100°C for 5 hours followed by drying in a vaccum oven over phosphorus pentoxide (P_2O_5) at 100°C for 24 hours. A portion (20 mg) of dry faeces was suspended in 4 ml of 6 N Hcl in a sealed glass tube under nitrogen gas, kept at 50-60°C for 6 hours, and then heated at 100°C for 10 hours. The hydrolysates were used for analysis for hexosamine by the method of Elson and Morgan (1933) with D-glucosamine hydrochloride as a standard. The digestibility was calculated by the equation [(D-glucosamine calculated from chitin added to the diet - hexosamine excreted in faeces/D-glucosamine calculated from chitin added to the diet)] x 100.

3.2.2 Growth pattern and efficiency

Daily feed intake of individual animals in each group was recorded during the period of experiment. Bodyweight as well as body measurements including length, height, girth (front) and girth (hind) were recorded at the beginning of experiment (pre-treatment) and at fortnightly intervals over the entire experimental period. The observations were utilised to findout the following:

(i) Total feed consumption

(ii) Daily feed intake

(iii) Feed conversion efficiency

(iv) Rate of growth

a. Average daily gain and peak growth period for body weight and body measurements

b. Percentage rate of gain in body weight

Body weight was recorded in the morning before feeding the animals, by using a platform balance with a built-in cage.

Body measurements were taken with a measuring tape. Body length was measured from apex of shoulder to base of tail. Height was measured from hoof to withers. Girth (front) was measured just behind the forelegs, and girth (hind) just in front of the hind legs.

Average daily gain in weight was calculated by the formula,

$$R_1 = \frac{W_2 - W_1}{t_2 - t_1}$$

where,

R_1 = Average daily gain

$W_2 - W_1$ = Gain during a period

$t_2 - t_1$ = Period of gain in days

Percentage rate of gain in body weight was calculated by the formula,

$$R_2 = \frac{W_2 - W_1}{W_1} \times 100$$

where,

R_2 = Growth rate expressed as percentage of previous month's weight

W_1 = Previous month's weight

W_2 = Present month's weight

Average daily gain in respect of body measurements was calculated in the same manner as in the case of body weight.

3.2.3 Carcass characteristics

Three animals, one from each group, were slaughtered at 5, 7 and 9 months of age to study the following:

(i) Live weight at slaughter

(ii) Carcass length

(iii) Weight of ham

(iv) Backfat thickness

(v) Eye-muscle area

(vi) Weight of leaf fat

(vii) Dressing percentage

(viii) Weight of internal organs

The experimental animals were slaughtered in the university slaughter house located near the farm where the animals were reared. The animals were kept off-fed for 18 hours before slaughter.

The weight of individual animals was recorded just before the slaughter at the slaughter house.

The warm carcass weight with head was recorded. After removing the head at the atlanto-occipital joint the carcass weight without head was recorded. The carcass was then split in to two halves through the vertibral column.

The length of the carcass was measured from the anterior aspect of the aitch bone to the anterior edge of the first rib and next to the vertibra.

The weight of ham was recorded after culling at a point of 2.5 inch from the most anterior part of the aitch bone by sawing through the sacral vertibra and shaft of the ileum.

The thickness of backfat was measured at the sites of first rib, last rib and last lumbar vertibrae. The mean of the three measurements was taken as the average backfat thickness.

The eye-muscle was cut through at the 10th rib, and

the cross-sectional impressions of both sides were taken on tissue paper, from which the area of eye-muscle was determined. The average of the areas of the two impressions was taken as the eye-muscle area.

The weight of leaf fat was recorded by separating and weighing it.

The carcass dressing percentage with head and without head was calculated.

The weight of internal organs (heart, liver, kidney, lyngs and spleen) was recorded by weighing each of the organs separately.

3.2.4 Blood analysis

Blood was collected from six animals in each group at the beginning of the experiment (pre-treatment) and subsequently at 5, 7 and 9 months of age, for determination of haematological parameters, and serum cholesterol and triglyceride levels. Blood was collected from anterior venacava in the young piglets at the pre-treatment stage, and from ear vein during subsequent stages.

A portion of the collected blood was immediately subjected to centrifugation for separation of serum to be used for analysis of cholesterol and triglyceride. Serum was

transferred into plastic store vials which were carried in an ice box to CIFT, Cochin and kept at -20°C until analysis was over.

3.2.4.1 Haematology

Blood haemoglobin concentration, total erythrocyte count (TEC), total leukocyte count (TLC) and differential leukocyte count (DLC) were determined by the methods described by Jain (1986).

3.2.4.2 Serum cholesterol concentration

Serum (1 ml) was dried on anhydrous sodium sulphate and extracted with chloroform. Total cholesterol of the lipid extract was determined colorimetrically by Liebermann-Burchard reaction with acetic anhydride and sulphuric acid (Hawk et al., 1954).

3.2.4.3 Serum triglyceride concentration

Serum (1 ml) was dried on anhydrous sodium sulphate and extracted with chloroform. Separation of triglyceride from the extracted lipid was done by column chromatography on silicic acid. Silicic acid was heated at 100°C for 24 hours and cooled by keeping in a dessicator. Columns were prepared with 100 g of activated silicic acid (Silica gel for column chromatography , BDH 60-100 mesh). The activated adsorbant

was made into a slurry in chloroform and poured into a glass column of 2-3 cm inner diameter to a height of 25 cm (after settling). Lipid extract of known quantity (10 ml) was applied to the column, and the neutral lipids were eluted with 100 ml chloroform, evaporated and weighed to find out the triglyceride concentration.

3.2.5 Fatty acid profile of meat

3.2.5.1 Sampling

Samples of muscle and backfat were collected at the time of slaughter for determination of fatty acid profile. Muscle samples were collected from the regions of ham, shoulder, loin-eye and side, and were pooled for analysis. Samples were kept in polythene bags and carried in an ice box to CIFT, Cochin and stored at -20°C.

Sampling of tissues was done as per AOAC (1980). Equal quantities of muscle tissue from ham, shoulder, loin-eye and side were pooled before analysis. The representative samples of muscle and backfat were minced, homogenised and kept at -20°C till completion of analysis.

3.2.5.2 Determination of fatty acid composition

The whole lipids of pooled muscle and backfat samples were extracted by the method of Bligh and Dyer (1959). Fatty

acids in the lipids were converted to their methyl esters and analysed by gas-liquid chromatography.

Whole lipids were saponified with alcoholic potash in an atmosphere of nitrogen and the unsaponifiable fractions were extracted with peroxide-free diethylether (AOAC, 1980). The remaining solutions were acidified with hydrochloric acid, dried over anhydrous sodium sulphate and evaporated in a current of nitrogen to dryness. The fatty acids thus obtained were esterified with 14 per cent (w/v) methanolic-boron trifluoride according to the method of AOAC (1980).

The methyl esters were analysed by gas chromatograph (Varian 3,300) using flame ionisation detector and strip-chart recorder with computerised area integrator. The column was of glass (180 cm x 2 mm i.d) filled with support gas chrom Q (80-150 mesh) coated with 10 per cent silar 10 C (Applied Science Laboratories, USA). The operating conditions were as follows:

Column temperature	-	120-5-200-35 min.
Injection port temperature	-	210°C
Detector temperature	-	230°C
Carrier gas	-	Nitrogen, 25 ml/min.
Sample size	-	1-2 microlitre

The following standards were used in the gas-liquid chromatograph:

Saturated acids - Methyl esters of C_{12}, C_{13}, C_{14}, C_{15}, C_{16}, C_{17}, C_{18} and C_{20} acids (E.Merck).

Unsaturated acids - Methyl esters of oleic, linoleic, arachidonic, erucic and docosahexaenoic ($C_{22:6}$) (Sigma 99%), 5, 8, 11, 14, 17, eicosapentaenoic acids ($C_{20:5}$) (94.6%; NIH standard).

The efficiency of the column and detector was checked periodically by injecting mixtures of standards (Horning et al., 1964).

3.3 Statistical analysis

Statistical significance of difference between the treatment groups was tested using analysis of variance, as one-way classified data, according to the method suggested by Snedecor and Cochran (1967).

RESULTS

4.1 Digestibility of chitin

The digestibility percentages of chitin, determined at different ages of pigs, are shown in Table 1.

For the groups of pigs fed chitin at levels of 0.5 per cent (group 1) and 1.0 per cent (group 2) respectively, the digestibility percentages recorded were 80.49 ± 1.55 and 79.37 ± 1.55 at 3 months of age, 95.36 ± 1.13 and 96.54 ± 1.05 at 5 months of age, and 95.77 ± 1.57 and 95.35 ± 1.33 at 7 months of age. The digestibility percentages were similar for both the groups of pigs at each stage of determination.

Digestibility increased with age from 3 months to 5 months, and thereafter did not show any appreciable change at the subsequent age of 7 months.

Table 1. Digestibility of chitin in pigs

Age	Digestibility (percentage)	
	Group 1 (0.5% chitin)	Group 2 (1% chitin)
3 months	80.49 ± 1.55	79.37 ± 1.55
5 months	95.36 ± 1.13	96.54 ± 1.05
7 months	95.77 ± 1.57	95.35 ± 1.33

4.2 Patterns of growth in pigs

4.2.1 Body weight

4.2.1.1 Fortnightly body weight

The average fortnightly body weights for the three groups of pigs, from weaning to 40 weeks of age, are presented in Table 2 and Fig.1.

The body weight of pigs in all the groups increased progressively as age advanced.

For the pigs in group 1, the body weight increased from 10.00 $\pm$ 0.69 kg at weaning to 107.04 $\pm$ 4.86 kg at 40th week of age.

The pigs in group 2 showed an increase in body weight from 9.68 $\pm$ 0.82 kg at weaning to 108.30 $\pm$ 3.29 kg at 40th week of age.

In the case of the pigs in group 3, the body weight increased from 9.00 $\pm$ 0.34 kg at weaning to 95.36 $\pm$ 1.37 kg at 40th week of age.

The three groups of pigs did not show any significant difference in body weight upto 16th week of age. Thereafter, the differences in body weight between the control and Chitin-fed groups were found to be significant ($P<0.05$) at all stages from 18th to 40th week, except for the differences which were

Table 2. Fortnightly body weight of pigs from weaning to 40 weeks

Age in weeks	Body weight (kg)		
	Group 1 (0.5% chitin)	Group 2 (1% chitin)	Group 3 (Control)
8	10.00 ± 0.69	9.68 ± 0.82	9.00 ± 0.34
10	12.06 ± 0.92	11.62 ± 0.78	10.85 ± 0.36
12	14.96 ± 1.22	14.32 ± 0.80	13.47 ± 0.48
14	20.12 ± 1.60	19.18 ± 1.05	17.37 ± 0.61
16	25.95 ± 1.67	24.21 ± 1.33	21.96 ± 0.79
18	33.37 ± 1.73^{a}	31.97 ± 1.02^{a}	27.95 ± 0.76^{b}
20	40.11 ± 1.90^{A}	39.05 ± 0.87^{a}	34.10 ± 0.69^{Bb}
22	48.26 ± 2.37^{a}	47.06 ± 1.11^{a}	42.15 ± 0.89^{b}
24	55.50 ± 2.36^{a}	54.97 ± 0.86^{a}	49.58 ± 1.11^{b}
26	63.38 ± 2.75^{a}	62.88 ± 1.15^{a}	56.54 ± 1.14^{b}
28	70.75 ± 2.91^{a}	69.98 ± 1.46^{a}	62.54 ± 0.77^{b}
30	77.85 ± 2.63^{A}	76.71 ± 1.39^{A}	68.68 ± 1.01^{B}
32	84.87 ± 3.07^{a}	83.52 ± 1.84^{a}	74.98 ± 1.34^{b}
34	87.40 ± 3.74^{a}	88.21 ± 2.42^{a}	78.41 ± 1.78^{b}
36	94.30 ± 3.68^{a}	95.20 ± 2.28^{a}	85.38 ± 1.62^{b}
38	100.30 ± 3.86^{a}	101.13 ± 2.70^{a}	89.50 ± 1.70^{b}
40	107.04 ± 4.86^{a}	108.30 ± 3.29^{a}	95.36 ± 1.37^{b}

A,B Means in the same row bearing different higher case superscripts differ significantly ($P<0.01$)

a,b Means in the same row bearing different lower case superscripts differ significantly ($P<0.05$)

ANOVA

Age in weeks	Source	DF	MS	F value
8	Treatment	2	2.0937	0.6152 NS
	Error	21	3.4032	
10	Treatment	2	3.0164	0.7045 NS
	Error	21	4.2815	
12	Treatment	2	4.4550	0.6966 NS
	Error	21	6.3946	
14	Treatment	2	15.6352	1.4450 NS
	Error	21	10.8199	
16	Treatment	2	31.9751	2.3086 NS
	Error	21	13.8499	
18	Treatment	2	63.4560	5.1357 *
	Error	21	12.3556	
20	Treatment	2	82.3750	6.1259 **
	Error	21	13.4469	
22	Treatment	2	83.9121	4.1072 *
	Error	21	20.4302	
24	Treatment	2	74.9707	4.2400 *
	Error	18	17.6816	
26	Treatment	2	101.8633	4.2107 *
	Error	18	24.1914	
28	Treatment	2	144.0469	5.5089 *
	Error	18	26.1475	
30	Treatment	2	174.8594	7.5654 **
	Error	18	23.1128	
32	Treatment	2	201.2500	5.8733 *
	Error	18	34.2647	
34	Treatment	2	177.4141	3.8347 *
	Error	15	46.2645	
36	Treatment	2	176.6797	4.1249 *
	Error	15	42.8322	
38	Treatment	2	252.6641	5.0195 *
	Error	15	50.3364	
40	Treatment	2	254.5469	4.5759 *
	Error	12	55.6276	

NS, Non-significant (P>0.05)

* Significant (P<0.05)
** Highly significant (P<0.01)

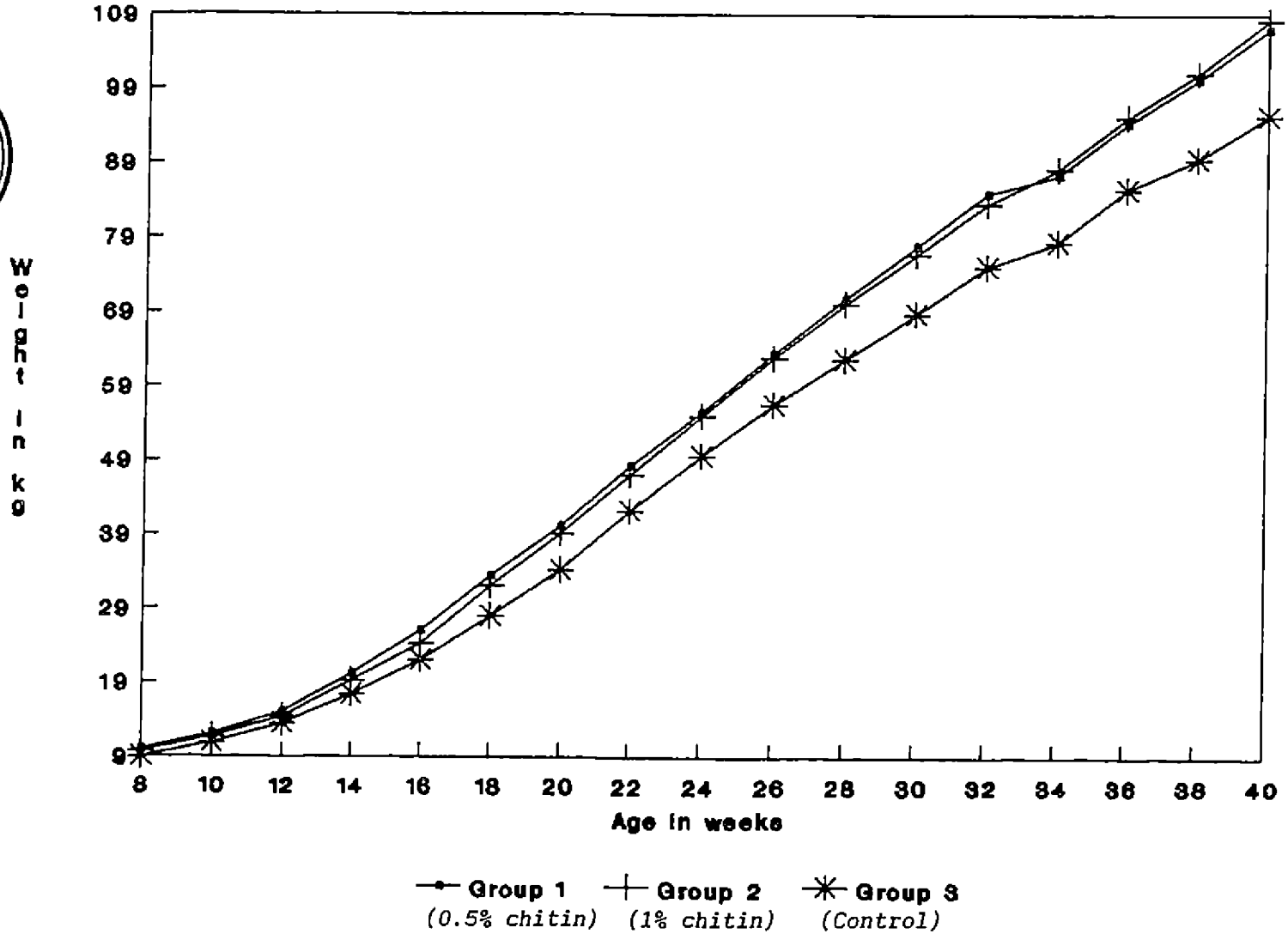

Fig.1 Fortnightly body weight of pigs from weaning to 40 weeks

found to be highly significant ($P<0.01$) at 20th week between group 1 and group 3, and at 30th week between the control and either of the chitin-fed groups. The differences noticed between the two chitin-fed groups were not found to be significant at any stage.

4.2.1.2 Daily gain in body weight

The average daily gains in weight at fortnightly intervals from weaning to 40 weeks of age, for the pigs in the three groups, are presented in Table 3 and Fig.2.

For the pigs in group 1 the daily gain increased from 148.62 $\pm$ 24.02 g at 10th week to a peak of 444.14 $\pm$ 15.19 g at 32nd week, and thereafter declined to 430.00 $\pm$ 17.01 g at 40th week of age.

The pigs in group 2 averaged a daily gain of 138.00 $\pm$ 22.85 g at 10th week to a peak of 439.28 $\pm$ 9.94 g at 32nd week, thereafter showing a decline to 437.40 $\pm$ 12.31 g at 40th week of age.

In the case of the pigs in group 3, the daily gain in weight increased from 131.62 $\pm$ 17.38 g at 10th week to a peak of 392.28 $\pm$ 9.34 g at 32nd week, thereafter declining to 384.60 $\pm$ 6.98 g at 40th week of age.

Table 3. Daily gain in weight of pigs at fortnightly intervals

Age in weeks	Daily gain in weight (g)		
	Group 1 (0.5% chitin)	Group 2 (1% chitin)	Group 3 (Control)
10	148.62 ± 24.02	138.00 ± 22.85	131.62 ± 17.38
12	176.87 ± 25.30	165.00 ± 15.77	159.50 ± 16.46
14	240.75 ± 28.70	225.75 ± 24.27	198.87 ± 14.92
16	284.37 ± 21.61	259.12 ± 22.55	231.12 ± 15.81
18	333.62 ± 18.81^{a}	318.00 ± 16.23^{a}	270.37 ± 13.15^{b}
20	357.87 ± 16.02^{A}	349.12 ± 10.05^{a}	298.12 ± 9.84^{Bb}
22	390.12 ± 20.56^{a}	381.00 ± 10.44^{a}	337.87 ± 9.53^{b}
24	404.28 ± 15.40^{a}	403.85 ± 8.79^{a}	361.71 ± 9.87^{b}
26	422.14 ± 18.75^{a}	421.57 ± 9.48^{a}	376.71 ± 9.63^{b}
28	432.57 ± 17.29^{a}	430.14 ± 9.49^{a}	382.14 ± 6.35^{b}
30	439.00 ± 14.16^{A}	434.71 ± 8.83^{A}	387.16 ± 6.87^{B}
32	444.14 ± 15.19^{a}	439.28 ± 9.94^{a}	392.28 ± 9.34^{b}
34	422.50 ± 16.69^{a}	430.16 ± 11.68^{a}	381.33 ± 11.03^{b}
36	427.50 ± 14.61^{a}	434.16 ± 10.22^{a}	389.50 ± 9.20^{b}
38	429.16 ± 14.06^{a}	434.33 ± 10.96^{a}	383.33 ± 9.51^{b}
40	430.00 ± 17.01^{a}	437.40 ± 12.31^{a}	384.60 ± 6.98^{b}

A,B Means in the same row bearing different higher case superscripts differ significantly ($P<0.01$)

a,b Means in the same row bearing different lower case superscripts differ significantly ($P<0.05$)

ANOVA

Age in weeks	Source	DF	MS	F value
10	Treatment	2	590.0469	0.1578 NS
	Error	21	3737.9880	
12	Treatment	2	630.8750	0.2038 NS
	Error	21	3094.5180	
14	Treatment	2	3601.0630	0.8253 NS
	Error	21	4362.8510	
16	Treatment	2	5676.1880	1.7361 NS
	Error	21	3269.4110	
18	Treatment	2	8683.7500	4.2263 *
	Error	21	2054.6550	
20	Treatment	2	8330.2500	6.4054 **
	Error	21	1300.5000	
22	Treatment	2	6230.6250	3.7356 *
	Error	21	1667.9050	
24	Treatment	2	4186.6250	4.3530 *
	Error	18	961.7639	
26	Treatment	2	4755.6250	3.8150 *
	Error	18	1246.5560	
28	Treatment	2	5661.8750	5.6457 *
	Error	18	1002.8610	
30	Treatment	2	5799.0000	7.6210 **
	Error	18	760.9167	
32	Treatment	2	5742.2500	5.8983 *
	Error	18	973.5278	
34	Treatment	2	4138.1250	3.8521 *
	Error	15	1074.2500	
36	Treatment	2	3483.5000	4.3255 *
	Error	15	805.3333	
38	Treatment	2	4728.3750	5.7891 *
	Error	15	816.7667	
40	Treatment	2	4086.375	5.0044 *
	Error	12	816.5417	

NS, Non-significant (P>0.05)

* Significant (P<0.05)

** Highly significant (P<0.01)

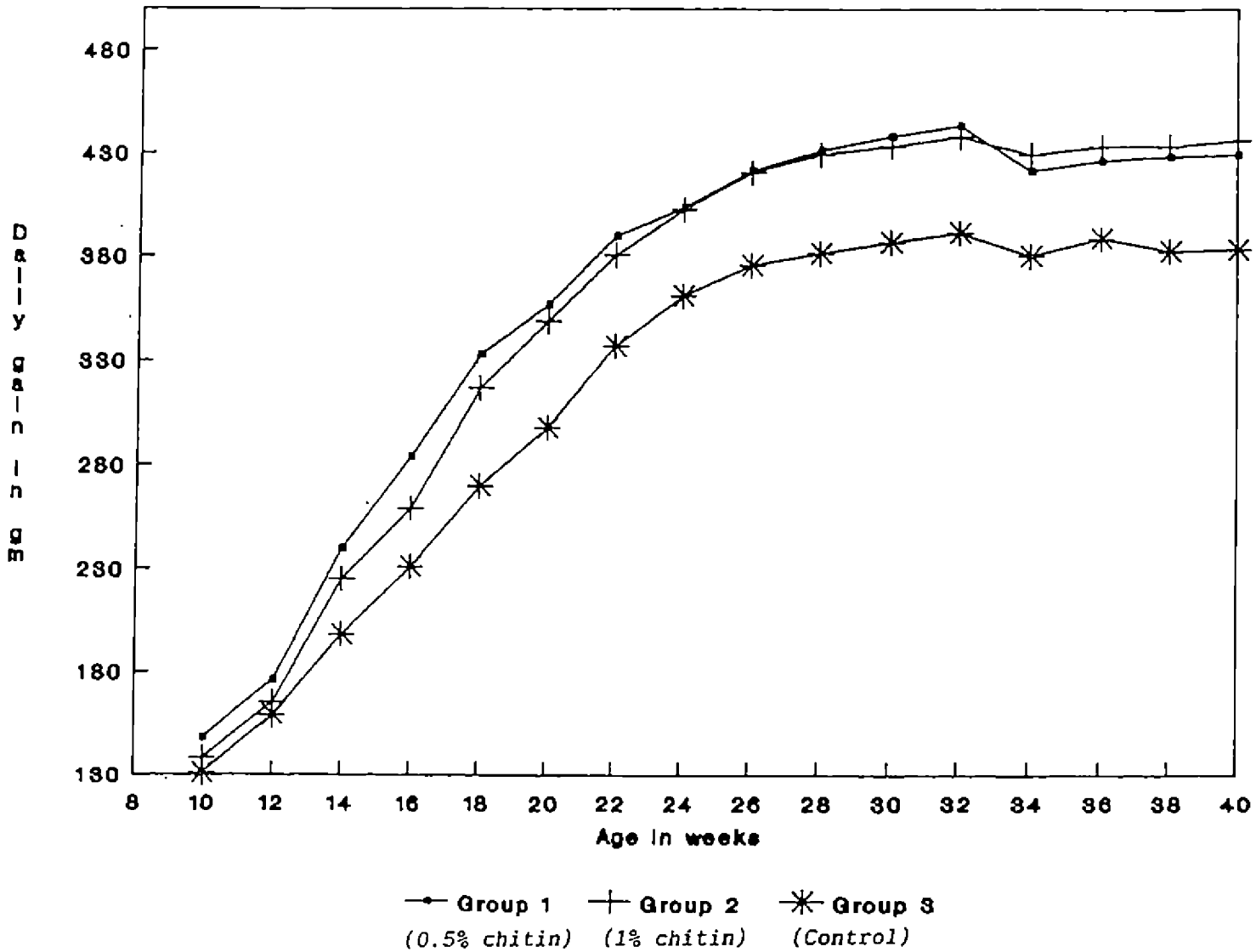

Fig.2 Daily gain in weight of pigs at fortnightly invervals

The rate of gain reached a peak at 32nd week of age for all the three groups of pigs.

The differences in average daily gain observed between the control and chitin-fed groups were found to be significant ($P<0.05$) at all stages from 18th to 40th week of age, except for the differences which were found to be highly significant ($P<0.01$) at 20th week between group 1 and group 2, and at 30th week between the control and either of the chitin-fed groups.

The pattern of rate of gain showed a similar trend for all the three groups upto 16th week of age, thereafter showing considerable differences between the control and chitin-fed groups.

The trend in the rate of gain between the two chitin-fed groups continued identically till the recording of the peak rate of gain at 32nd week. Thereafter, the pigs in group 2 showed higher rates of gain than the pigs in group 1, but these differences were found to be non-significant.

4.2.1.3 Percentage rate of gain in weight

The percentage rates of gain in body weight, for the three groups of pigs, are presented in Table 4 and Fig.3.

The growth rate based on the previous month's weight, for the pigs in group 1, increased from 49.60 per cent at 12th

Table 4. Percentage rate of gain in weight of pigs based on previous month's weight

Age in weeks	Percentage gain in weight		
	Group 1 (0.5% chitin)	Group 2 (1% chitin)	Group 3 (Control)
12	49.60	47.93	49.66
16	73.46	69.06	63.02
20	54.56	61.29	55.28
24	38.36	40.76	45.39
28	27.47	27.30	26.13
32	19.95	19.34	19.89
36	11.11	13.98	13.87
40	13.51	13.76	11.68

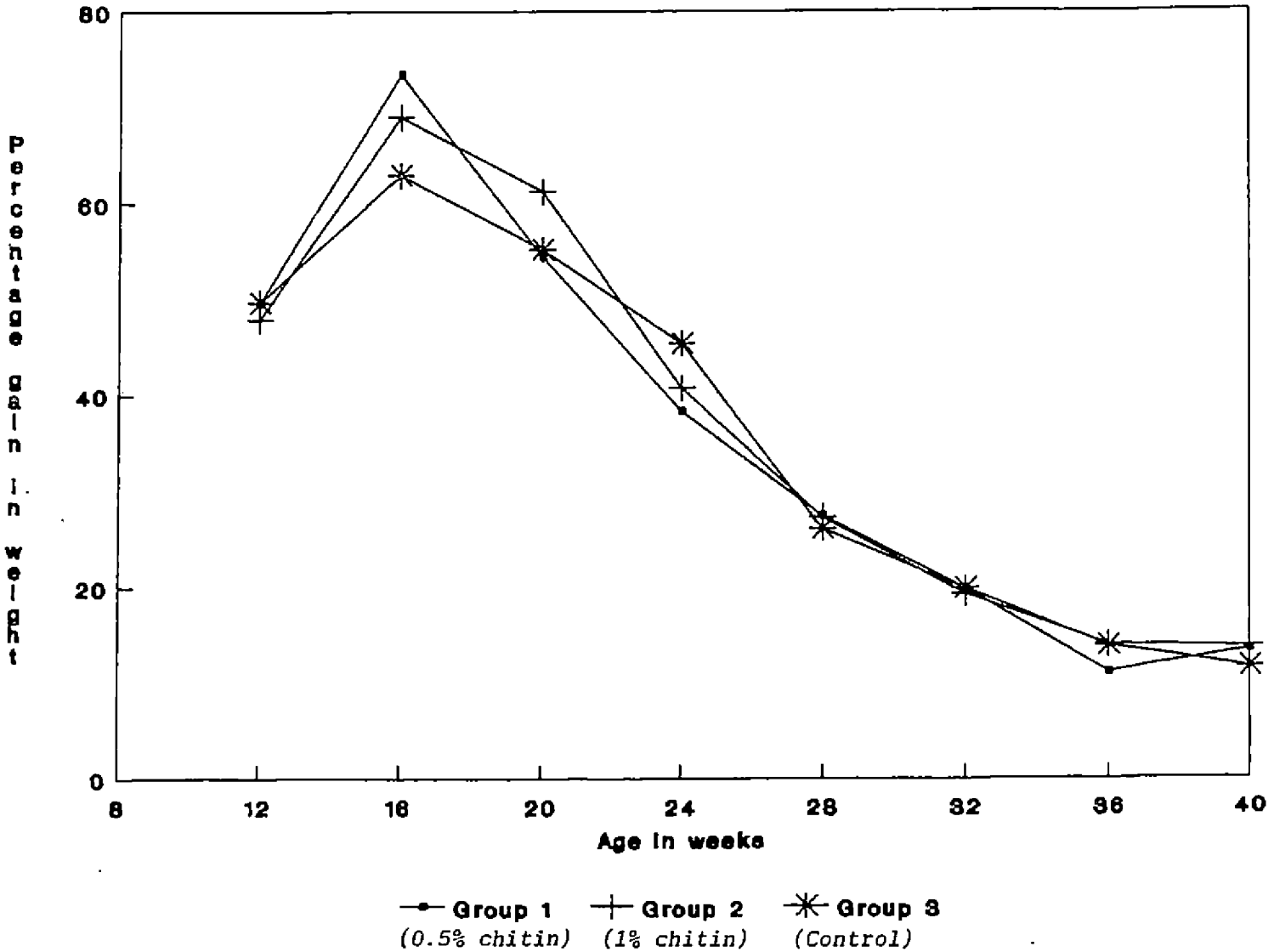

Fig.3 Percentage rate of gain weight of pigs based on previous month's weight

week to 73.46 per cent at 16th week, thereafter followed by a gradual decrease to 13.51 per cent at 40th week of age.

In the case of the pigs in group 2, this showed an increasing trend from 47.93 per cent at 12th week to 69.06 per cent at 16th week, followed by a gradual decline to 13.76 per cent at 40th week.

The pigs in group 3 showed an increase from 49.66 per cent at 12th week to 63.02 per cent at 16th week, thereafter showing a gradual decline to 11.68 per cent at 40th week of age.

4.2.2 Body length

4.2.2.1 Fortnightly body length

The average fortnightly body lengths from weaning to 40 weeks of age, for the three groups of pigs, are presented in Table 5 and Fig.4.

The body length of pigs in all the groups increased progressively as age advanced.

For the pigs in group 1, the body length increased from 41.87 $\pm$ 0.95 cm at weaning to 92.60 $\pm$ 1.02 cm at 40th week of age.

Table 5. Fortnightly body length of pigs from weaning to 40 weeks

Age in weeks	Body length (cm)		
	Group 1 (0.5% chitin)	Group 2 (1% chitin)	Group 3 (Control)
8	41.87 ± 0.95	41.50 ± 1.48	41.62 ± 0.90
10	43.12 ± 1.09	42.87 ± 1.67	42.75 ± 0.97
12	47.25 ± 1.19	47.00 ± 1.38	46.25 ± 1.04
14	52.12 ± 1.64	51.25 ± 1.16	51.25 ± 0.83
16	57.12 ± 1.23	54.62 ± 1.26	53.87 ± 0.83
18	61.25 ± 1.50	59.87 ± 1.40	58.25 ± 1.29
20	64.00 ± 1.38	63.25 ± 1.35	63.00 ± 1.00
22	68.00 ± 1.33	68.87 ± 0.91	65.62 ± 1.53
24	73.71 ± 2.00	74.42 ± 0.94	70.71 ± 0.56
26	79.42 ± 1.41^{A}	77.14 ± 1.14^{A}	72.85 ± 0.85^{B}
28	82.42 ± 1.02^{Aa}	79.14 ± 1.05^{b}	76.85 ± 1.18^{B}
30	83.85 ± 1.31	81.28 ± 0.91	79.85 ± 1.28
32	84.71 ± 1.24	83.00 ± 0.75	80.85 ± 1.10
34	86.50 ± 1.17^{A}	86.16 ± 0.79^{A}	81.66 ± 1.02^{B}
36	87.33 ± 1.02^{A}	88.33 ± 0.84^{A}	83.16 ± 0.98^{B}
38	89.33 ± 1.26^{a}	89.66 ± 0.76^{a}	85.50 ± 0.80^{b}
40	92.60 ± 1.02^{A}	90.40 ± 0.39^{a}	87.40 ± 0.87^{Bb}

A,B Means in the same row bearing different higher case superscripts differ significantly ($P < 0.01$)

a,b Means in the same row bearing different lower case superscripts differ significantly ($P < 0.05$)

ANOVA

Age in weeks	Source	DF	MS	F value
8	Treatment	2	0.1660	0.0211 NS
	Error	21	7.8571	
10	Treatment	2	0.2910	0.0220 NS
	Error	21	13.2023	
12	Treatment	2	2.1660	0.1826 NS
	Error	21	11.8571	
14	Treatment	2	2.0410	0.1588 NS
	Error	21	12.8511	
16	Treatment	2	23.1679	2.2774 NS
	Error	21	10.1726	
18	Treatment	2	18.0429	1.1417 NS
	Error	21	15.8035	
20	Treatment	2	2.1679	0.1701 NS
	Error	21	12.7381	
22	Treatment	2	22.6250	1.7044 NS
	Error	21	13.2738	
24	Treatment	2	15.8593	1.2942 NS
	Error	18	12.2539	
26	Treatment	2	77.9062	8.2770 **
	Error	18	9.4123	
28	Treatment	2	54.9062	6.6142 **
	Error	18	8.3012	
30	Treatment	2	28.7656	2.9229 NS
	Error	18	9.8411	
32	Treatment	2	26.1484	3.3552 NS
	Error	18	7.7934	
34	Treatment	2	43.7265	7.1560 **
	Error	15	6.1104	
36	Treatment	2	45.0546	8.2922 **
	Error	15	5.4333	
38	Treatment	2	32.1718	5.7343 *
	Error	15	5.6104	
40	Treatment	2	34.0703	10.3259 **
	Error	12	3.2994	

NS, Non-significant (P>0.05)

* Significant (P<0.05)

** Highly significant (P<0.01)

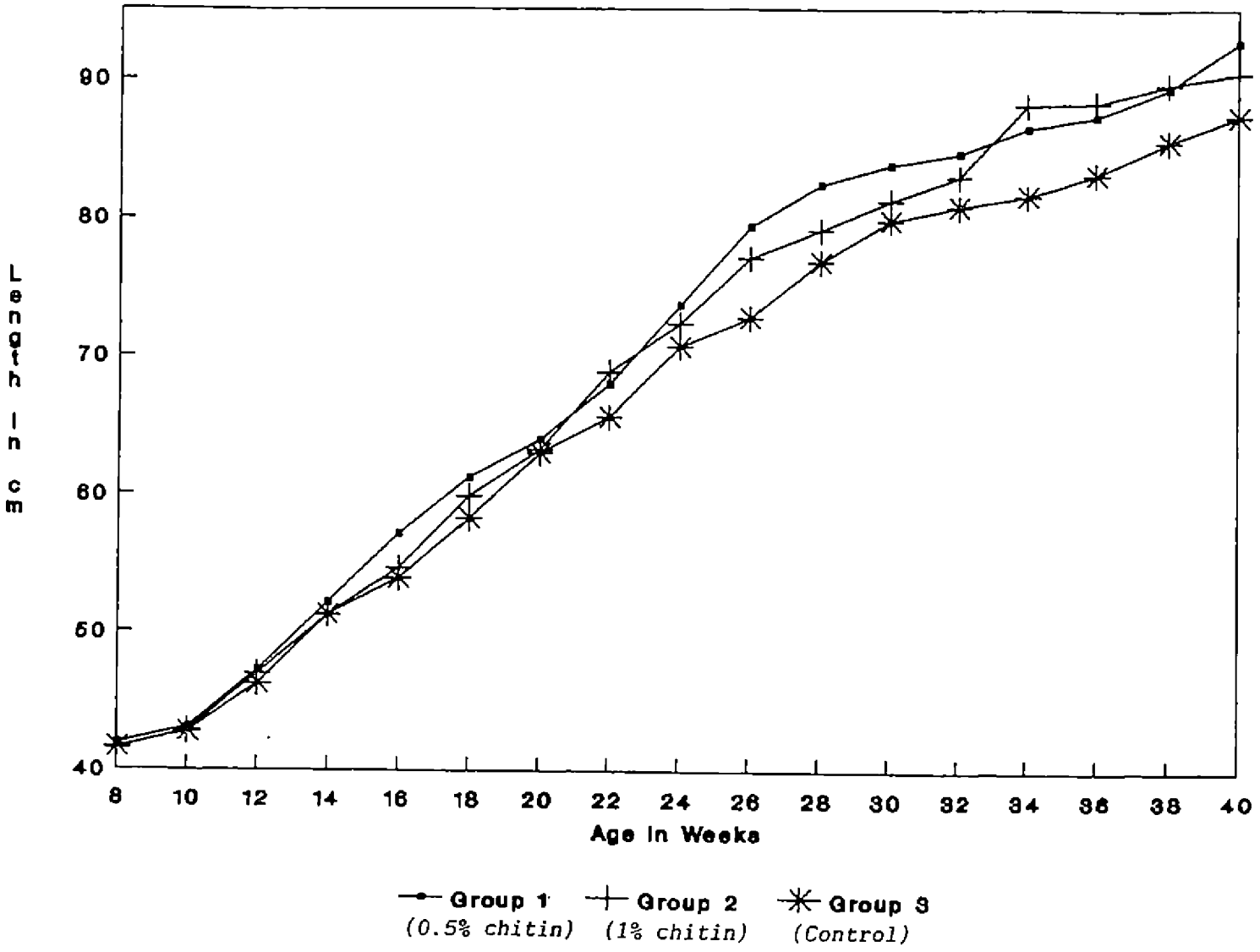

Fig.4 Fortnightly body length of pigs from weaning to 40 weeks

In the case of the pigs in group 2, the body length increased from 41.50 ± 1.48 cm at weaning to 90.40 ± 0.39 cm at 40th week of age.

The pigs in group 3 showed an increase in body length from 41.62 ± 0.90 cm at weaning to 87.40 ± 0.87 cm at 40th week of age.

The differences in body length between the control and chitin-fed groups were found to be highly significant ($P<0.01$) at 26th week. The differences were highly significant ($P<0.01$) between the pigs in group 1 and group 3, and significant ($P<0.05$) between the pigs in group 1 and group 2 at 28th week. The differences between the control and either of the chitin-fed groups were found to be highly significant ($P<0.01$) at 34th and 36th week, and significant ($P<0.05$) at 38th week. At 40th week, the differences were found to be highly significant ($P<0.01$) between the pigs in group 1 and group 3, and significant ($P<0.05$) between the pigs in group 2 and group 3.

4.2.2.2 Daily gain in length

The average daily gains in body length at fortnightly intervals from weaning to 40 weeks of age, for the three groups of pigs, are presented in Table 6 and Fig.5.

Table 6. Daily gain in body length of pigs at fortnightly intervals

Age in weeks	Daily gain in length (cm)		
	Group 1 (0.5% chitin)	Group 2 (1% chitin)	Group 3 (Control)
10	0.089 ± 0.011	0.098 ± 0.018	0.080 ± 0.014
12	0.192 ± 0.013	0.196 ± 0.016	0.165 ± 0.025
14	0.226 ± 0.034	0.232 ± 0.016	0.229 ± 0.022
16	0.272 ± 0.022	0.234 ± 0.020	0.218 ± 0.019
18	0.276 ± 0.020	0.262 ± 0.020	0.237 ± 0.020
20	0.263 ± 0.019	0.258 ± 0.019	0.254 ± 0.019
22	0.266 ± 0.018	0.285 ± 0.018	0.250 ± 0.018
24	0.284 ± 0.019	0.280 ± 0.010	0.263 ± 0.008
26	0.296 ± 0.006^{A}	0.286 ± 0.009^{a}	0.251 ± 0.009^{Bb}
28	0.289 ± 0.009^{a}	0.272 ± 0.009	0.255 ± 0.009^{b}
30	0.272 ± 0.009	0.261 ± 0.009	0.251 ± 0.009
32	0.255 ± 0.009	0.249 ± 0.009	0.238 ± 0.009
34	0.244 ± 0.010	0.244 ± 0.010	0.224 ± 0.010
36	0.230 ± 0.005	0.238 ± 0.011	0.216 ± 0.004
38	0.225 ± 0.004	0.228 ± 0.010	0.212 ± 0.003
40	0.217 ± 0.005	0.215 ± 0.006	0.205 ± 0.004

A,B Means in the same row bearing different higher case superscripts differ significantly ($P < 0.01$)

a,b Means in the same row bearing different lower case superscripts differ significantly ($P < 0.05$)

ANOVA

Age in weeks	Source	DF	MS	F value
10	Treatment	2	0.0006	0.4228 NS
	Error	21	0.0015	
12	Treatment	2	0.0022	0.6978 NS
	Error	21	0.0032	
14	Treatment	2	0.00006	0.0155 NS
	Error	21	0.0044	
16	Treatment	2	0.0060	3.1729 NS
	Error	21	0.0019	
18	Treatment	2	0.0031	0.8742 NS
	Error	21	0.0035	
20	Treatment	2	0.0001	0.0852 NS
	Error	21	0.0019	
22	Treatment	2	0.0025	1.7642 NS
	Error	21	0.0014	
24	Treatment	2	0.0008	1.0722 NS
	Error	18	0.0007	
26	Treatment	2	0.0041	7.7781 **
	Error	18	0.0005	
28	Treatment	2	0.0020	3.7001 *
	Error	18	0.0005	
30	Treatment	2	0.0007	1.9940 NS
	Error	18	0.0003	
32	Treatment	2	0.0005	1.7518 NS
	Error	18	0.0002	
34	Treatment	2	0.0008	2.0035 NS
	Error	15	0.0003	
36	Treatment	2	0.0007	2.2160 NS
	Error	15	0.0003	
38	Treatment	2	0.0004	1.3425 NS
	Error	15	0.0003	
40	Treatment	2	0.0002	0.9920 NS
	Error	12	0.0002	

NS, Non-significant (P>0.05)

* Significant (P<0.05)

** Highly significant (P<0.01)

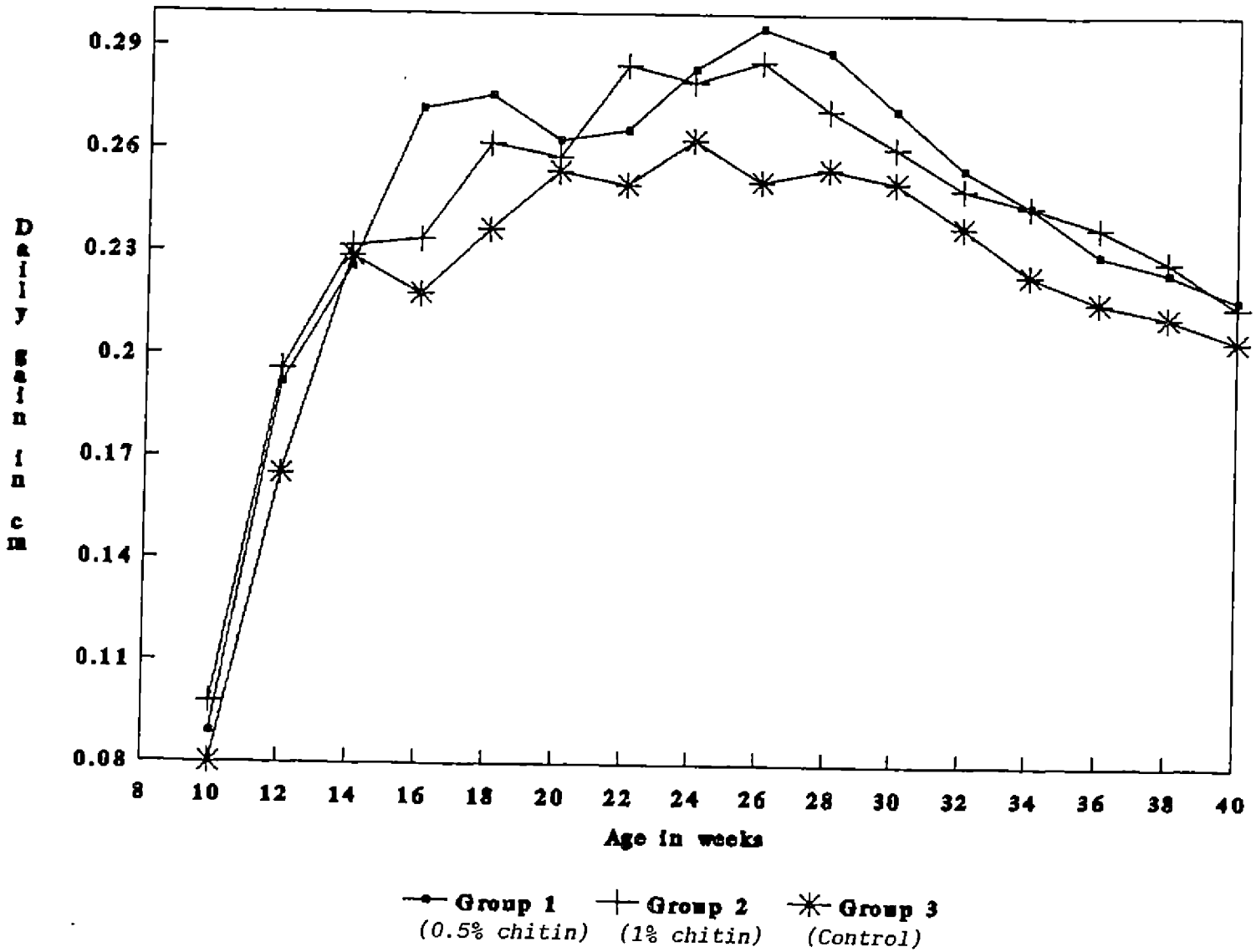

Fig.5 Daily gain in body length of pigs at fortnightly intervals

The pigs in group 1 averaged a daily gain of 0.089 ± 0.011 cm at 10th week, increasing to a peak of 0.296 ± 0.006 cm at 26th week, and thereafter showing a gradual decrease to 0.217 ± 0.005 cm at 40th week.

For the pigs in group 2, the daily gain increased from 0.098 ± 0.018 cm at 10th week to a peak of 0.286 ± 0.009 cm at 26th week, thereafter followed by a gradual decline to 0.215 ± 0.006 cm at 40th week.

In the case of the pigs in group 3, the daily gain in length increased from 0.080 ± 0.014 cm at 10th week to a peak of 0.263 ± 0.008 cm at 24th week, thereafter declining gradually to 0.205 ± 0.004 cm at 40th week.

The highest rate of gain in body length was recorded at 26th week for the pigs in both group 1 and group 2, and at 24th week for the pigs in group 3.

The differences in the rate of gain were found to be highly significant ($P < 0.01$) between the pigs in group 1 and group 3, and significant ($P < 0.05$) between the pigs in group 2 and group 3 at 26th week of age. Significant difference ($P < 0.05$) was also noticed between the pigs in group 1 and group 3 at 28th week of age.

4.2.3 Height at withers

4.2.3.1 Fortnightly height

The average fortnightly heights for the three groups of pigs, from weaning to 40 weeks of age, are presented in Table 7 and Fig.6.

The height of pigs in all the groups increased progressively as age advanced.

For the pigs in group 1, the height increased from 37.75 ± 0.67 cm at weaning to 66.40 ± 0.92 cm at 40th week of age.

The pigs in group 2 showed an increase in height from 36.75 ± 1.03 cm at weaning to 66.00 ± 1.30 cm at 40th week of age.

The height, in the case of the pigs in group 3, increased from 36.37 ± 0.49 cm at weaning to 64.20 ± 0.91 cm at 40th week of age.

The differences in height were found to be significant ($P<0.05$) between the pigs in group 1 and group 3 at 12th and 16th week of age.

Table 7. Fortnightly height of pigs from weaning to 40 weeks

Age in weeks	Height (cm)		
	Group 1 (0.5% chitin)	Group 2 (1% chitin)	Group 3 (Control)
8	37.75 ± 0.67	36.75 ± 1.03	36.37 ± 0.49
10	39.00 ± 0.65	37.87 ± 1.02	37.50 ± 0.46
12	40.75 ± 0.86[a]	38.87 ± 1.00	37.75 ± 0.45[b]
14	42.62 ± 0.73	40.87 ± 1.40	39.50 ± 0.53
16	45.87 ± 0.61[a]	42.62 ± 1.22	42.50 ± 0.46[b]
18	48.12 ± 0.61	47.00 ± 0.80	46.37 ± 0.65
20	51.87 ± 0.22	50.75 ± 1.03	49.62 ± 0.59
22	53.00 ± 0.65	52.62 ± 0.77	51.37 ± 0.32
24	54.57 ± 0.86	54.42 ± 0.84	53.00 ± 0.43
26	55.28 ± 0.68	55.00 ± 1.04	54.57 ± 0.61
28	56.42 ± 0.52	55.85 ± 1.03	55.71 ± 0.86
30	57.42 ± 0.48	57.00 ± 0.75	56.71 ± 0.94
32	59.85 ± 0.67	58.57 ± 0.78	57.85 ± 0.85
34	61.33 ± 0.88	61.00 ± 0.85	59.66 ± 0.80
36	62.50 ± 0.76	62.66 ± 0.66	60.66 ± 0.49
38	64.83 ± 0.79	64.33 ± 0.91	62.16 ± 0.47
40	66.40 ± 0.92	66.00 ± 1.30	64.20 ± 0.91

a,b Means in the same row bearing different lower case superscripts differ significantly ($P < 0.05$)

ANOVA

Age in weeks	Source	DF	MS	F value
8	Treatment	2	1.1250	0.2530 NS
	Error	21	4.4464	
10	Treatment	2	4.8750	1.0790 NS
	Error	21	4.5178	
12	Treatment	2	18.3750	3.5119 *
	Error	21	5.2321	
14	Treatment	2	19.6250	2.6291 NS
	Error	21	7.4642	
16	Treatment	2	29.2910	5.2686 *
	Error	21	5.5595	
18	Treatment	2	6.2910	1.6360 NS
	Error	21	3.8452	
20	Treatment	2	10.1250	2.5851 NS
	Error	21	3.9166	
22	Treatment	2	5.7929	1.9082 NS
	Error	21	3.0357	
24	Treatment	2	5.2851	1.3702 NS
	Error	18	3.8572	
26	Treatment	2	0.9042	0.2005 NS
	Error	18	4.5080	
28	Treatment	2	1.0000	0.2045 NS
	Error	18	4.8888	
30	Treatment	2	0.9062	0.2292 NS
	Error	18	3.9522	
32	Treatment	2	7.1914	1.7161 NS
	Error	18	4.1905	
34	Treatment	2	4.6640	1.081 NS
	Error	15	4.3114	
36	Treatment	2	7.3867	2.9026 NS
	Error	15	2.5447	
38	Treatment	2	12.0546	3.5454 NS
	Error	15	3.4000	
40	Treatment	2	6.8671	1.2118 NS
	Error	12	5.6666	

NS, Non-significant (P>0.05)

* Significant (P<0.05)

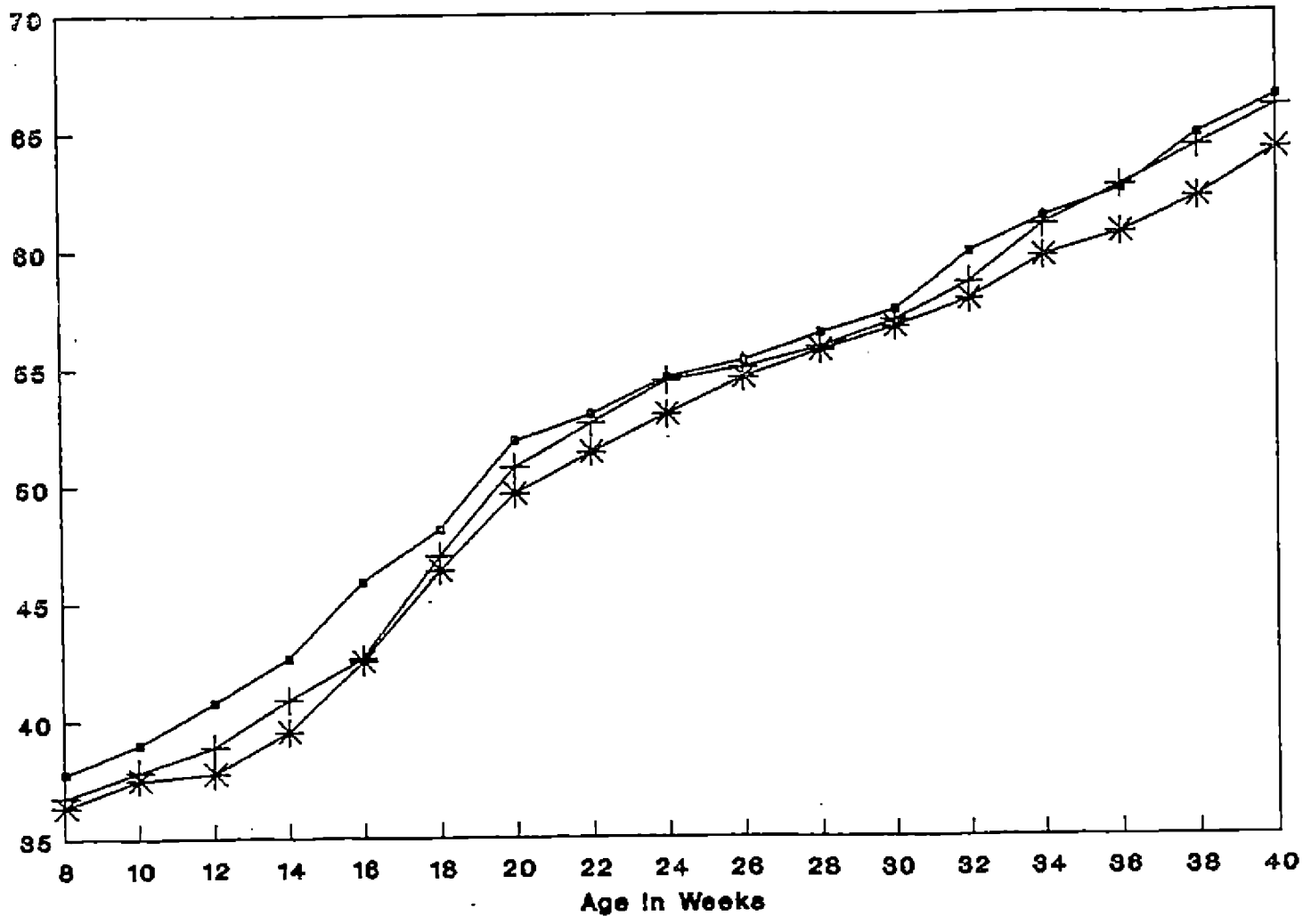

Fig.6 Fortnightly height of pigs from weaning to 40 weeks

4.2.3.2 Daily gain in height

The average daily gains in height at fortnightly intervals from weaning to 40 weeks of age, for the three groups of pigs, are presented in Table 8 and Fig.7.

For the pigs in group 1, the average daily gain in height increased from 0.089 ± 0.011 cm at 10th week to a peak of 0.168 ± 0.006 cm at 20th week, thereafter gradually declining to 0.126 ± 0.002 cm at 40th week of age.

The pigs in group 2 showed an increase in daily gain in height from 0.081 ± 0.011 cm at 10th week to a peak of 0.167 ± 0.009 cm at 20th week, and thereafter a gradual decline to 0.129 ± 0.005 cm at 40th week of age.

In the case of the pigs in group 3, the daily gain in height increased from 0.080 ± 0.009 cm at 10th week to a peak of 0.157 ± 0.008 cm at 20th week, thereafter followed by a gradual decline to 0.122 ± 0.002 cm at 40th week of age.

The highest rate of gain in body height was recorded at 20th week of age for all groups of pigs.

The difference in the rate of gain between the pigs in group 1 and group 3 was found to be significant ($P<0.01$) at 12th week of age.

	Group 1 (0.5% chitin)	Group 2 (1% chitin)	Group 3 (Control)
10	0.089 ± 0.011	0.081 ± 0.011	0.080 ± 0.009
12	0.107 ± 0.008[A]	0.075 ± 0.017	0.050 ± 0.006[B]
14	0.116 ± 0.010	0.098 ± 0.024	0.074 ± 0.011
16	0.145 ± 0.010	0.105 ± 0.017	0.109 ± 0.012
18	0.148 ± 0.007	0.146 ± 0.007	0.137 ± 0.012
20	0.168 ± 0.006	0.167 ± 0.009	0.157 ± 0.008
22	0.159 ± 0.004	0.165 ± 0.006	0.156 ± 0.006
24	0.148 ± 0.007	0.158 ± 0.010	0.131 ± 0.008
26	0.137 ± 0.006	0.145 ± 0.008	0.143 ± 0.006
28	0.132 ± 0.005	0.136 ± 0.008	0.137 ± 0.006
30	0.126 ± 0.003	0.132 ± 0.006	0.131 ± 0.004
32	0.130 ± 0.005	0.130 ± 0.007	0.127 ± 0.003
34	0.127 ± 0.004	0.133 ± 0.006	0.125 ± 0.003
36	0.124 ± 0.004	0.132 ± 0.007	0.121 ± 0.003
38	0.127 ± 0.004	0.131 ± 0.004	0.121 ± 0.010
40	0.126 ± 0.002	0.129 ± 0.005	0.122 ± 0.002

A,B Means in the same row bearing different higher case superscripts differ significantly ($P < 0.01$)

ANOVA

Age in weeks	Source	DF	MS	F value
10	Treatment	2	0.0002	0.2692 NS
	Error	21	0.0008	
12	Treatment	2	0.0067	5.8910 **
	Error	21	0.0011	
14	Treatment	2	0.0034	1.5311 NS
	Error	21	0.0022	
16	Treatment	2	0.0039	2.4685 NS
	Error	21	0.0015	
18	Treatment	2	0.0002	0.3713 NS
	Error	21	0.0007	
20	Treatment	2	0.0002	0.3785 NS
	Error	21	0.0006	
22	Treatment	2	0.0001	0.5673 NS
	Error	21	0.0003	
24	Treatment	2	0.0012	1.8667 NS
	Error	18	0.0006	
26	Treatment	2	0.0001	0.2311 NS
	Error	18	0.0004	
28	Treatment	2	0.00006	0.1809 NS
	Error	18	0.0003	
30	Treatment	2	0.0060	0.3769 NS
	Error	18	0.0001	
32	Treatment	2	0.00005	0.1355 NS
	Error	18	0.0002	
34	Treatment	2	0.00008	0.4910 NS
	Error	15	0.0001	
36	Treatment	2	0.0001	0.9270 NS
	Error	15	0.0001	
38	Treatment	2	0.0001	2.0631 NS
	Error	15	0.00008	
40	Treatment	2	0.00005	0.6889 NS
	Error	12	0.00007	

NS, Non-significant (P>0.05)

** Highly significant (P<0.01)

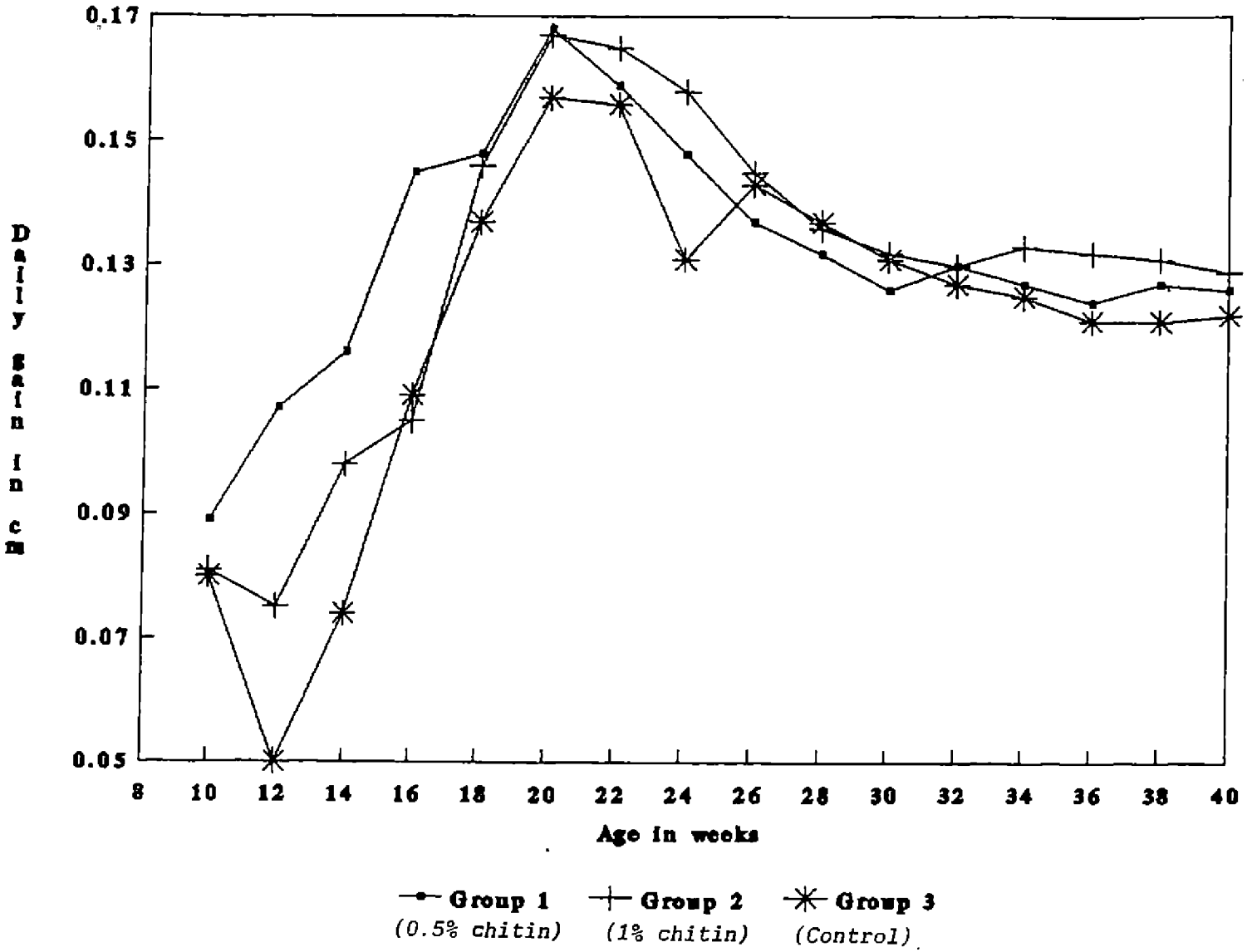

Fig.7 Daily gain in height of pigs at fortnightly intervals

4.2.4 Body girth (front)

4.2.4.1 Fortnightly body girth (front)

The average fortnightly body girths (front) for the three groups of pigs, from weaning to 40 weeks of age, are presented in Table 9 and Fig.8.

The body girth (front) of pigs in all the groups increased progressively as age advanced.

For the pigs in group 1, the girth (front) increased from 47.75 $\pm$ 1.68 cm at weaning to 109.40 $\pm$ 2.54 cm at 40 weeks of age.

The pigs in group 2 showed an increase in girth (front) from 47.75 $\pm$ 1.49 cm at weaning to 109.80 $\pm$ 3.02 cm at 40 weeks of age.

In the case of the pigs in group 3, the girth (front) increased from 47.87 $\pm$ 0.85 cm at weaning to 107.00 $\pm$ 1.09 cm at 40 weeks of age.

The differences in body girth (front) were found to be significant ($P<0.05$) between the pigs in group 1 and group 3 at 30th week. The differences between the pigs in group 1 and group 2, and between the pigs in group 1 and group 3 were found to be significant ($P<0.05$) at 32nd week of age.

Table 9. Fortnightly body girth (front) of pigs from weaning to 40 weeks

Age in weeks	Body girth(front) (cm)		
	Group 1 (0.5% chitin)	Group 2 (1% chitin)	Group 3 (Control)
8	47.75 ± 1.68	47.75 ± 1.49	47.87 ± 0.85
10	50.12 ± 1.74	50.25 ± 1.46	50.25 ± 0.88
12	55.50 ± 1.89	55.25 ± 1.33	53.50 ± 0.73
14	60.62 ± 1.66	59.87 ± 1.32	57.87 ± 0.69
16	65.25 ± 1.68	63.25 ± 1.22	62.87 ± 1.30
18	70.62 ± 1.37	69.00 ± 1.00	67.75 ± 0.81
20	77.37 ± 1.89	74.87 ± 1.32	72.25 ± 0.94
22	80.75 ± 1.73	77.62 ± 1.10	76.75 ± 0.70
24	85.28 ± 1.93	82.85 ± 1.81	82.57 ± 0.48
26	89.42 ± 1.83	87.28 ± 1.65	85.42 ± 0.75
28	91.42 ± 2.12	89.85 ± 1.50	88.57 ± 0.78
30	96.42 ± 1.32[a]	94.00 ± 1.21	92.00 ± 0.65[b]
32	99.42 ± 1.19[a]	96.57 ± 0.99[b]	95.14 ± 0.63[b]
34	103.16 ± 2.32	102.33 ± 1.47	99.00 ± 1.12
36	104.83 ± 2.28	104.66 ± 1.42	102.50 ± 0.84
38	108.16 ± 2.34	107.66 ± 2.13	105.16 ± 0.70
40	109.40 ± 2.54	109.80 ± 3.02	107.00 ± 1.09

a,b Means in the same row bearing different lower case superscripts differ significantly ($P < 0.05$)

ANOVA

Age in weeks	Source	DF	MS	F value
8	Treatment	2	0.0410	0.0026 NS
	Error	21	15.3273	
10	Treatment	2	0.0410	0.0025 NS
	Error	21	15.8988	
12	Treatment	2	9.5000	0.6018 NS
	Error	21	15.7857	
14	Treatment	2	16.1679	1.2056 NS
	Error	21	13.4107	
16	Treatment	2	13.0429	0.8106 NS
	Error	21	16.0892	
18	Treatment	2	16.6250	1.7510 NS
	Error	21	9.4940	
20	Treatment	2	52.5390	3.1500 NS
	Error	21	16.6785	
22	Treatment	2	35.3750	2.8046 NS
	Error	21	12.6131	
24	Treatment	2	15.5703	0.9159 NS
	Error	18	17.0000	
26	Treatment	2	28.0468	1.7974 NS
	Error	18	15.6033	
28	Treatment	2	14.3359	0.8316 NS
	Error	18	17.2378	
30	Treatment	2	34.4296	4.0316 *
	Error	18	8.5399	
32	Treatment	2	33.3359	5.0730 *
	Error	18	6.5711	
34	Treatment	2	29.1718	1.6440 NS
	Error	15	17.7437	
36	Treatment	2	10.1640	0.6361 NS
	Error	15	15.9781	
38	Treatment	2	15.5000	0.7334 NS
	Error	15	21.1333	
40	Treatment	2	11.4687	0.4095 NS
	Error	12	28.0000	

NS, Non-significant (P>0.05)

* Significant (P<0.05)

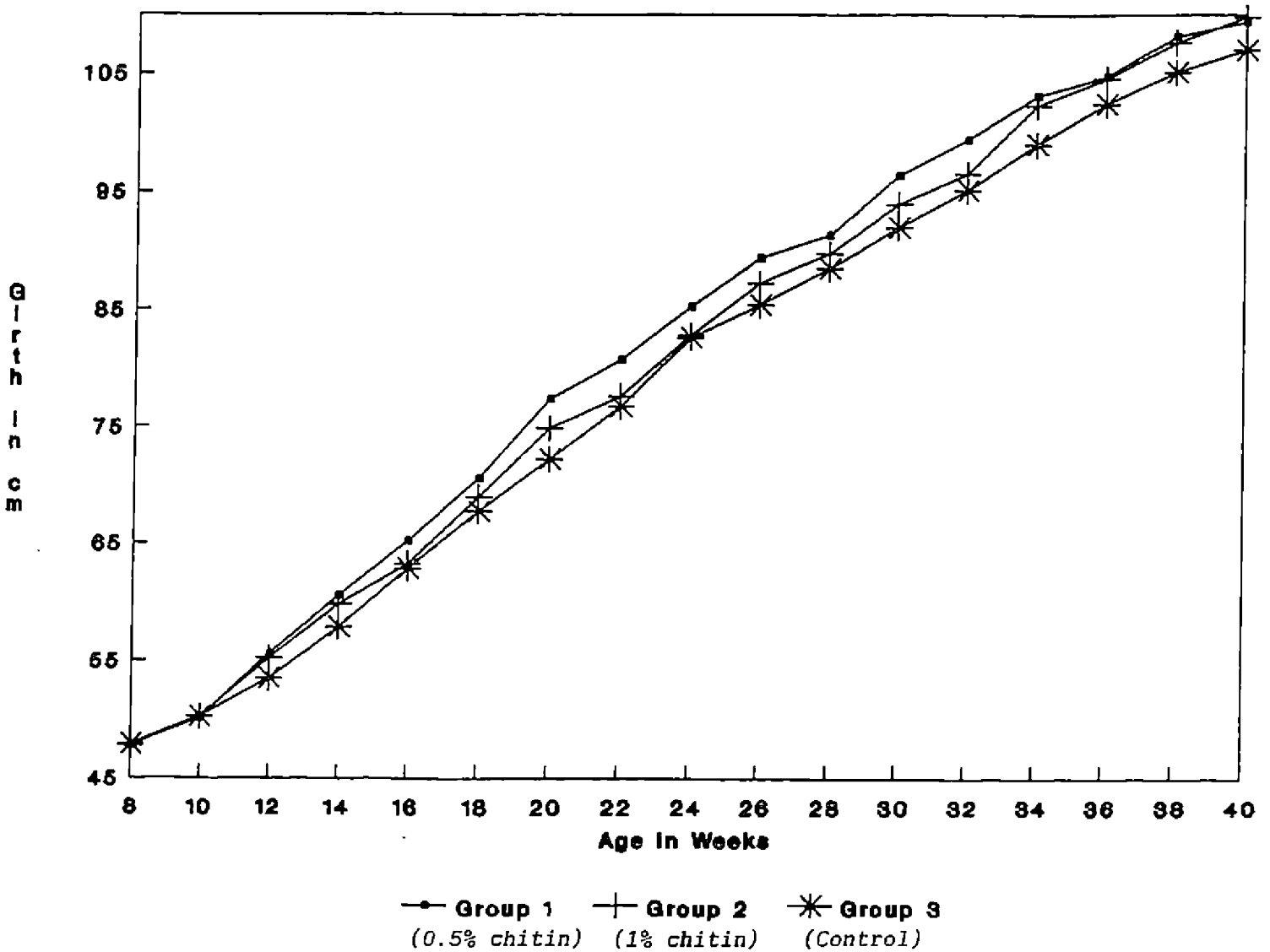

Fig.8 Fortnightly body girth (front) of pigs from weaning to 40 weeks

4.2.4.2. Daily gain in body girth (front)

The average daily gains in girth (front) at fortnightly intervals from weaning to 40 weeks of age, for the three groups of pigs, are presented in Table 10 and Fig.9.

For the pigs in group 1, the daily gain in girth (front) increased from 0.170 $\pm$ 0.023 cm at 10th week to a peak of 0.353 $\pm$ 0.01 cm at 20th week, and declined thereafter to 0.276 $\pm$ 0.006 cm at 40th week of age.

The pigs in group 2 showed an increase in daily gain in girth (front) from 0.178 $\pm$ 0.019 cm at 10th week to a peak of 0.323 $\pm$ 0.012 cm at 20th week, followed by a gradual decline to 0.277 $\pm$ 0.009 cm at 40th week.

In the case of the pigs in group 3, the daily gain in girth (front) increased from 0.170 $\pm$ 0.023 cm at 10th week to a peak of 0.313 $\pm$ 0.008 cm at 24th week, thereafter gradually declining to 0.260 $\pm$ 0.004 cm at 40th week.

The maximum rate of gain in girth (front) was recorded at 20th week for the pigs in group 1 and group 2, and at 24th week for the pigs in group 3.

The differences in the rate of gain between the pigs in group 1 and group 3 were found to be significant ($P<0.05$) at 14th, 26th and 34th week, and highly significant ($P<0.01$)

Table 10. Daily gain in body girth (front) of pigs at fortnightly intervals

Age in weeks	Daily gain in girth(front) (cm)		
	Group 1 (0.5% chitin)	Group 2 (1% chitin)	Group 3 (Control)
10	0.170 ± 0.023	0.178 ± 0.019	0.170 ± 0.023
12	0.277 ± 0.030	0.268 ± 0.013	0.200 ± 0.019
14	0.307 ± 0.018^{a}	0.289 ± 0.015^{a}	0.238 ± 0.010^{b}
16	0.313 ± 0.015	0.277 ± 0.018	0.268 ± 0.017
18	0.327 ± 0.012	0.304 ± 0.010	0.284 ± 0.016
20	0.353 ± 0.010^{A}	0.323 ± 0.012^{a}	0.290 ± 0.008^{Bb}
22	0.344 ± 0.011^{Aa}	0.312 ± 0.011^{b}	0.301 ± 0.006^{B}
24	0.338 ± 0.008	0.319 ± 0.013	0.313 ± 0.008
26	0.333 ± 0.007^{a}	0.319 ± 0.007	0.301 ± 0.008^{b}
28	0.314 ± 0.008	0.305 ± 0.008	0.293 ± 0.007
30	0.318 ± 0.009	0.304 ± 0.007	0.288 ± 0.007
32	0.310 ± 0.006	0.294 ± 0.009	0.283 ± 0.006
34	0.303 ± 0.006^{a}	0.304 ± 0.005^{a}	0.278 ± 0.008^{b}
36	0.290 ± 0.006	0.294 ± 0.008	0.278 ± 0.008
38	0.286 ± 0.006	0.289 ± 0.007	0.271 ± 0.004
40	0.276 ± 0.006	0.277 ± 0.009	0.260 ± 0.004

A,B Means in the same row bearing different higher case superscripts differ significantly ($P < 0.01$)

a,b Means in the same row bearing different lower case superscripts differ significantly ($P < 0.05$)

ANOVA

Age in weeks	Source	DF	MS	F value
10	Treatment	2	0.0002	0.0532 NS
	Error	21	0.0038	
12	Treatment	2	0.0137	3.4674 NS
	Error	21	0.0039	
14	Treatment	2	0.0101	5.5589 *
	Error	21	0.0018	
16	Treatment	2	0.0044	1.8814 NS
	Error	21	0.0023	
18	Treatment	2	0.0036	2.5029 NS
	Error	21	0.0014	
20	Treatment	2	0.0077	8.2118 **
	Error	21	0.0009	
22	Treatment	2	0.0040	7.0496 **
	Error	21	0.0005	
24	Treatment	2	0.0012	1.5525 NS
	Error	18	0.0007	
26	Treatment	2	0.0018	4.3182 *
	Error	18	0.0004	
28	Treatment	2	0.0008	1.6892 NS
	Error	18	0.0004	
30	Treatment	2	0.0015	3.1725 NS
	Error	18	0.0004	
32	Treatment	2	0.0012	3.1529 NS
	Error	18	0.0003	
34	Treatment	2	0.0012	4.3868 *
	Error	15	0.0002	
36	Treatment	2	0.0004	1.2303 NS
	Error	15	0.0003	
38	Treatment	2	0.0006	2.5976 NS
	Error	15	0.0002	
40	Treatment	2	0.0004	1.7661 NS
	Error	12	0.0002	

NS, Non-significant (P>0.05)

* Significant (P<0.05)

** Highly significant (P<0.01)

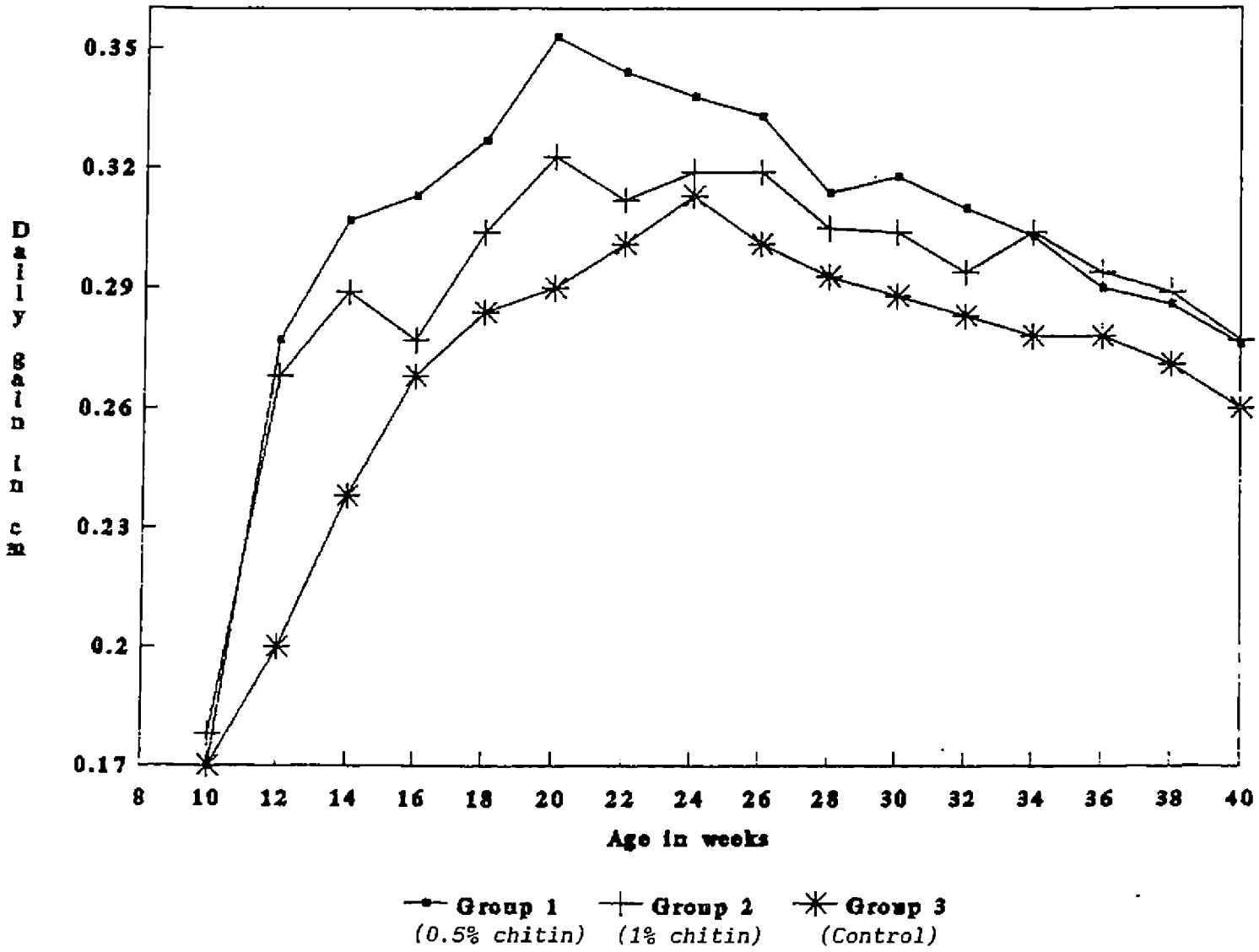

Fig.9 Daily gain in body girth (front) of pigs at fortnightly intervals

at 20th and 22nd week. Significant differences ($P<0.05$) were noticed between the pigs in group 2 and group 3 at 14th, 20th and 34th week of age.

4.2.5 Body girth (hind)

4.2.5.1 Fortnightly body girth (hind)

The average fortnightly body girths (hind) for the three groups of pigs, from weaning to 40 weeks of age, are presented in Table 11 and Fig.10.

The body girth (hind) of pigs in all the groups increased progressively as age advanced.

For the pigs in group 1, the girth (hind) increased from 50.62 $\pm$ 1.51 cm at weaning to 115.0 $\pm$ 2.40 cm at 40th week of age.

For the pigs in group 2, the girth (hind) increased from 52.75 $\pm$ 1.56 cm at weaning to 116.40 $\pm$ 2.31 cm at 40th week of age.

In the case of the pigs in group 3, the hind girth increased from 53.12 $\pm$ 1.45 cm at weaning to 112.80 $\pm$ 1.31 cm at 40th week of age.

The differences observed in hind girth between the groups of pigs were not found to be statistically significant.

Table 11. Fortnightly body girth (hind) of pigs from weaning to 40 weeks

Age in weeks	Body girth(hind) (cm)		
	Group 1 (0.5% chitin)	Group 2 (1% chitin)	Group 3 (Control)
8	50.62 ± 1.51	52.75 ± 1.56	53.12 ± 1.45
10	51.75 ± 1.55	54.00 ± 1.67	54.50 ± 1.37
12	55.00 ± 1.79	57.87 ± 1.74	58.00 ± 1.08
14	61.25 ± 2.05	61.50 ± 1.50	62.62 ± 1.13
16	66.37 ± 2.33	66.62 ± 0.88	66.50 ± 1.21
18	72.50 ± 2.37	71.00 ± 1.25	70.00 ± 0.84
20	77.12 ± 2.29	74.87 ± 2.04	74.87 ± 1.10
22	81.87 ± 2.68	78.75 ± 1.87	77.00 ± 0.86
24	88.85 ± 3.68	85.42 ± 1.63	83.85 ± 0.79
26	93.28 ± 3.12	91.14 ± 2.08	85.28 ± 0.94
28	95.42 ± 2.67	93.71 ± 1.82	89.42 ± 0.97
30	99.00 ± 2.30	96.71 ± 2.11	92.57 ± 0.86
32	102.00 ± 2.68	98.85 ± 1.48	98.14 ± 0.63
34	105.00 ± 2.87	104.83 ± 1.62	102.50 ± 1.56
36	107.00 ± 2.39	108.33 ± 2.24	103.83 ± 1.27
38	112.00 ± 2.23	114.00 ± 2.38	108.66 ± 1.52
40	115.00 ± 2.40	116.40 ± 2.31	112.80 ± 1.31

ANOVA

Age in weeks	Source	DF	MS	F value
8	Treatment	2	14.5429	0.8985 NS
	Error	21	16.1845	
10	Treatment	2	17.1679	0.9024 NS
	Error	21	19.0238	
12	Treatment	2	23.0429	1.1607 NS
	Error	21	19.8511	
14	Treatment	2	4.2929	0.2080 NS
	Error	21	20.6369	
16	Treatment	2	0.1250	0.0060 NS
	Error	21	20.5595	
18	Treatment	2	12.6679	0.5991 NS
	Error	21	21.1428	
20	Treatment	2	13.5000	0.4735 NS
	Error	21	28.5059	
22	Treatment	2	48.7890	1.5949 NS
	Error	21	30.5892	
24	Treatment	2	45.7656	1.1644 NS
	Error	18	39.3012	
26	Treatment	2	120.0469	3.4314 NS
	Error	18	34.9843	
28	Treatment	2	66.8593	2.5131 NS
	Error	18	26.6033	
30	Treatment	2	74.3281	3.0190 NS
	Error	18	24.6197	
32	Treatment	2	29.4765	1.2886 NS
	Error	18	22.8732	
34	Treatment	2	11.7187	0.4390 NS
	Error	15	26.6895	
36	Treatment	2	32.0546	1.2919 NS
	Error	15	24.8114	
38	Treatment	2	44.6562	1.7233 NS
	Error	15	25.9125	
40	Treatment	2	16.4687	0.7659 NS
	Error	12	21.5000	

NS, Non-significant (P>0.05)

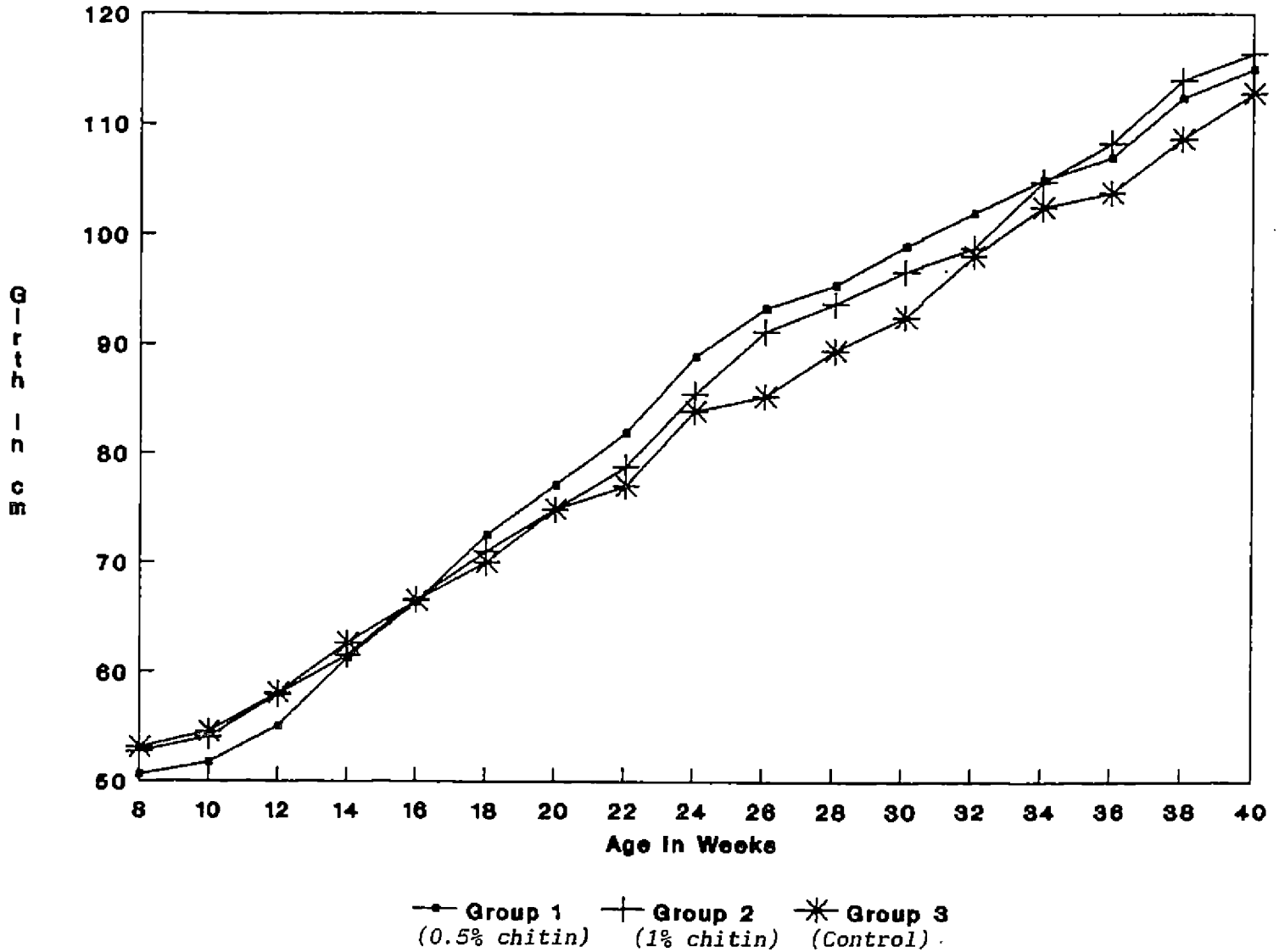

Fig.10 Fortnightly body girth (hind) of pigs from weaning to 40 weeks

4.2.5.2 Daily gain in body girth (hind)

The average daily gains in girth (hind) at fortnightly intervals from weaning to 40 weeks of age, for the three groups of pigs, are presented in Table 12 and Fig.11.

The daily gain for the pigs in group 1 increased from 0.080 ± 0.009 cm at 10th week to a peak of 0.341 ± 0.023 cm at 24th week, thereafter declining gradually to 0.281 ± 0.008 cm at 40th week.

For the pigs in group 2, the daily gain increased from 0.089 ± 0.011 cm at 10th week to a peak of 0.307 ± 0.011 cm at 26th week, thereafter gradually decreasing to 0.290 ± 0.008 cm at 40th week.

In the case of the pigs in group 3, the daily gain increased from 0.098 ± 0.013 cm at 10th week to a peak of 0.278 ± 0.016 cm at 24th week, thereafter gradually declining to 0.261 ± 0.008 cm at 40th week.

The maximum rate of gain in girth (hind) was recorded at 24th week for the pigs in group 1 and group 3, and at 26th week for the pigs in group 2.

The differences between the pigs in group 1 and group 3 were found to be significant ($P<0.05$) at 18th, 22nd, 28th and 30th week, and highly significant ($P<0.01$) at 26th

Table 12. Daily gain in body girth (hind) of pigs at fortnightly intervals

Age in weeks	Daily gain in girth(hind) (cm)		
	Group 1 (0.5% chitin)	Group 2 (1% chitin)	Group 3 (Control)
10	0.080 ± 0.009	0.089 ± 0.011	0.098 ± 0.013
12	0.156 ± 0.021	0.183 ± 0.017	0.174 ± 0.014
14	0.253 ± 0.029	0.208 ± 0.016	0.226 ± 0.014
16	0.281 ± 0.025	0.248 ± 0.022	0.239 ± 0.017
18	0.313 ± 0.020^{a}	0.261 ± 0.014	0.241 ± 0.023^{b}
20	0.315 ± 0.014	0.266 ± 0.019	0.259 ± 0.016
22	0.326 ± 0.022^{a}	0.271 ± 0.014^{b}	0.262 ± 0.012^{b}
24	0.341 ± 0.023	0.295 ± 0.015	0.278 ± 0.016
26	0.338 ± 0.018^{A}	0.307 ± 0.011^{a}	0.259 ± 0.016^{Ab}
28	0.319 ± 0.015^{a}	0.295 ± 0.011	0.262 ± 0.013^{b}
30	0.314 ± 0.011^{a}	0.287 ± 0.013	0.259 ± 0.012^{b}
32	0.305 ± 0.012	0.276 ± 0.008	0.269 ± 0.010
34	0.294 ± 0.010	0.290 ± 0.008	0.271 ± 0.013
36	0.284 ± 0.113	0.287 ± 0.114	0.259 ± 0.011
38	0.290 ± 0.006	0.296 ± 0.008	0.264 ± 0.010
40	0.281 ± 0.008	0.290 ± 0.008	0.261 ± 0.008

A,B Means in the same row bearing different higher case superscripts differ significantly ($P < 0.01$)

a,b Means in the same row bearing different lower case superscripts differ significantly ($P < 0.05$)

ANOVA

Age in weeks	Source	DF	MS	F value
10	Treatment	2	0.0006	0.6176 NS
	Error	21	0.0010	
12	Treatment	2	0.0014	0.5939 NS
	Error	21	0.0025	
14	Treatment	2	0.0040	1.1129 NS
	Error	21	0.0036	
16	Treatment	2	0.0040	1.0165 NS
	Error	21	0.0039	
18	Treatment	2	0.0109	3.4905 *
	Error	21	0.0031	
20	Treatment	2	0.0073	3.0535 NS
	Error	21	0.0024	
22	Treatment	2	0.0096	3.9341 *
	Error	21	0.0024	
24	Treatment	2	0.0073	3.3961 NS
	Error	18	0.0021	
26	Treatment	2	0.0111	6.6287 **
	Error	18	0.0016	
28	Treatment	2	0.0057	4.4651 *
	Error	18	0.0012	
30	Treatment	2	0.0053	4.9369 *
	Error	18	0.0010	
32	Treatment	2	0.0026	3.2165 NS
	Error	18	0.0008	
34	Treatment	2	0.0009	1.2275 NS
	Error	15	0.0007	
36	Treatment	2	0.0015	2.8002 NS
	Error	15	0.0005	
38	Treatment	2	0.0016	2.5562 NS
	Error	15	0.0006	
40	Treatment	2	0.0010	3.3149 NS
	Error	12	0.0003	

NS, Non-significant (P>0.05)

* Significant (P<0.05)

** Highly significant (P<0.01)

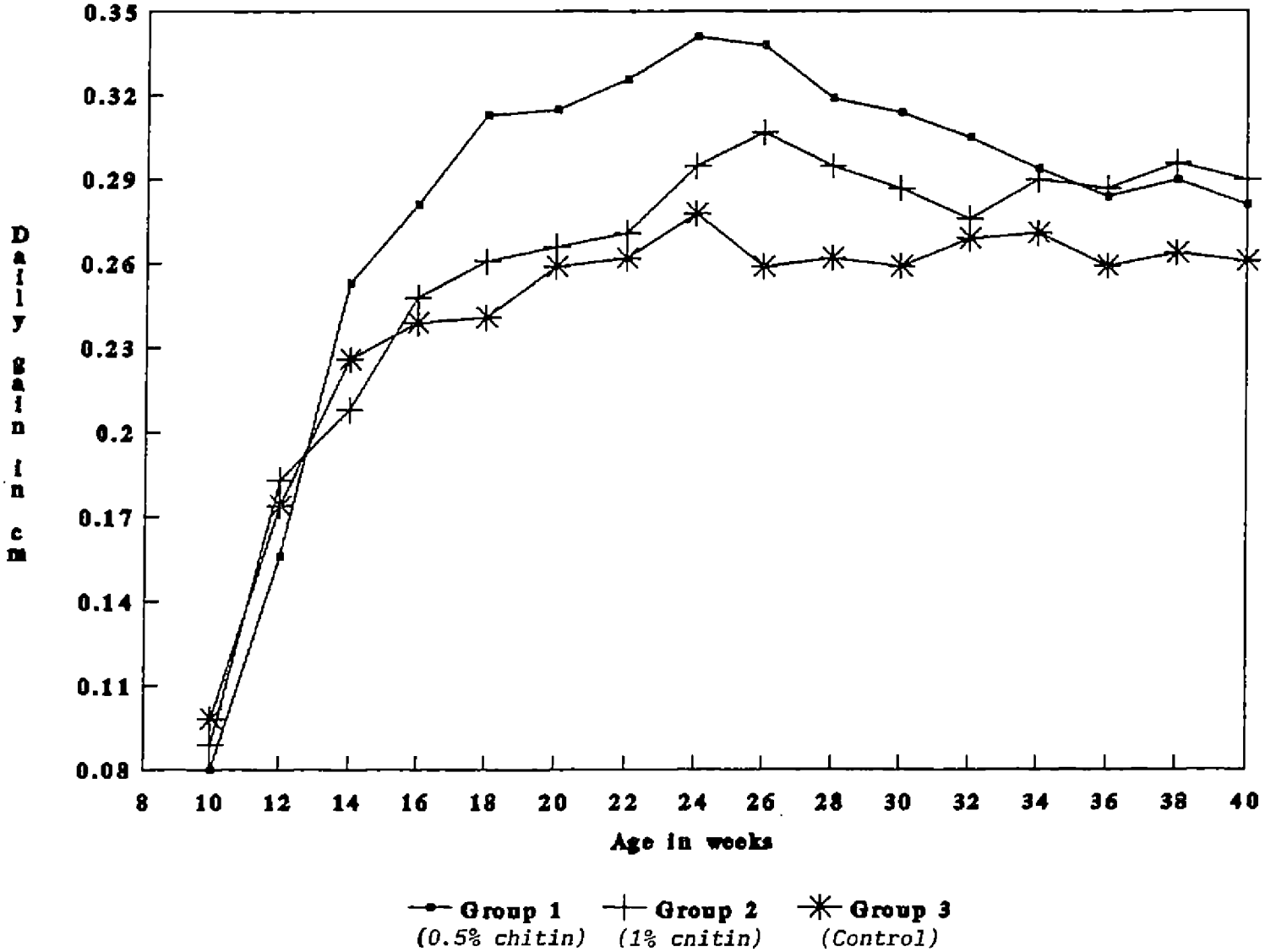

Fig.11 Daily gain in body girth (hind) of pigs at fortnightly intervals

week. Significant differences ($P<0.05$) were observed between the pigs in group 1 and group 2 at 22nd week, and between the pigs in group 2 and group 3 at 26th week.

4.2.6 Feed intake

4.2.6.1 Total feed consumption

The average feed consumptions at fortnightly intervals from weaning to 40 weeks of age, for the three groups of pigs, are presented in Table 13 and Fig.12.

The total feed consumption for the pigs in group 1 averaged 11.51 $\pm$ 0.23 kg at 10th week. The consumption increased gradually to 445.48 $\pm$ 21.97 kg at 40th week of age.

For the pigs in group 2, the feed consumption increased from 11.57 $\pm$ 0.34 kg at 10th week to 462.16 $\pm$ 16.09 kg at 40th week.

In the case of the pigs in group 3, the feed consumption increased from 11.30 $\pm$ 0.23 kg at 10th week to 444.68 $\pm$ 12.58 kg at 40th week of age.

The pigs in the three groups showed differences in feed consumption as age advanced, especially during the later part of the experiment.

Table 13. Total feed consumption of pigs from weaning to 40 weeks

Age in weeks	Feed consumption (kg)		
	Group 1 (0.5% chitin)	Group 2 (1% chitin)	Group 3 (Control)
10	11.51 ± 0.23	11.57 ± 0.34	11.30 ± 0.23
12	24.90 ± 0.52	24.96 ± 0.61	24.61 ± 0.20
14	39.38 ± 0.87	39.37 ± 0.93	39.25 ± 0.52
16	56.32 ± 1.37	55.82 ± 1.36	55.61 ± 1.09
18	77.16 ± 1.93	76.80 ± 1.69	74.48 ± 1.67
20	100.92 ± 2.87	99.91 ± 1.81	95.81 ± 2.29
22	128.25 ± 4.34	126.53 ± 2.37	120.00 ± 2.95
24	157.10 ± 6.29	154.55 ± 2.75	146.97 ± 4.09
26	190.01 ± 7.78	187.11 ± 3.86	177.02 ± 4.63
28	224.27 ± 9.31	221.22 ± 5.21	208.64 ± 5.23
30	260.11 ± 11.19	258.10 ± 6.84	241.95 ± 5.84
32	297.68 ± 12.78	297.35 ± 8.22	277.34 ± 6.39
34	330.36 ± 14.56	337.18 ± 10.87	317.98 ± 7.80
36	369.78 ± 15.12	379.61 ± 12.07	358.66 ± 8.70
38	409.86 ± 15.27	421.98 ± 12.89	401.40 ± 9.90
40	445.48 ± 21.97	462.16 ± 16.09	444.68 ± 12.58

ANOVA

Age in weeks	Source	DF	MS	F value	
10	Treatment	2	0.1661	0.2674	NS
	Error	21	0.6211		
12	Treatment	2	0.2778	0.1482	NS
	Error	21	0.8736		
14	Treatment	2	0.0468	0.0092	NS
	Error	21	5.0915		
16	Treatment	2	1.0664	0.0809	NS
	Error	21	13.1711		
18	Treatment	2	16.8515	0.6709	NS
	Error	21	25.1175		
20	Treatment	2	58.6328	1.3096	NS
	Error	21	44.7700		
22	Treatment	2	151.6406	1.7162	NS
	Error	21	88.3541		
24	Treatment	2	194.3594	1.3027	NS
	Error	18	149.1962		
26	Treatment	2	325.2188	1.4370	NS
	Error	18	226.3056		
28	Treatment	2	480.5625	1.4568	NS
	Error	18	329.8611		
30	Treatment	2	693.3750	1.4396	NS
	Error	18	481.6250		
32	Treatment	2	950.3750	1.4965	NS
	Error	18	635.0556		
34	Treatment	2	562.5000	0.7262	NS
	Error	15	782.8417		
36	Treatment	2	659.2500	0.7319	NS
	Error	15	900.7000		
38	Treatment	2	642.2500	0.6450	NS
	Error	15	995.6500		
40	Treatment	2	889.5000	0.5926	NS
	Error	12	1500.7920		

NS, Non-significant (P>0.05)

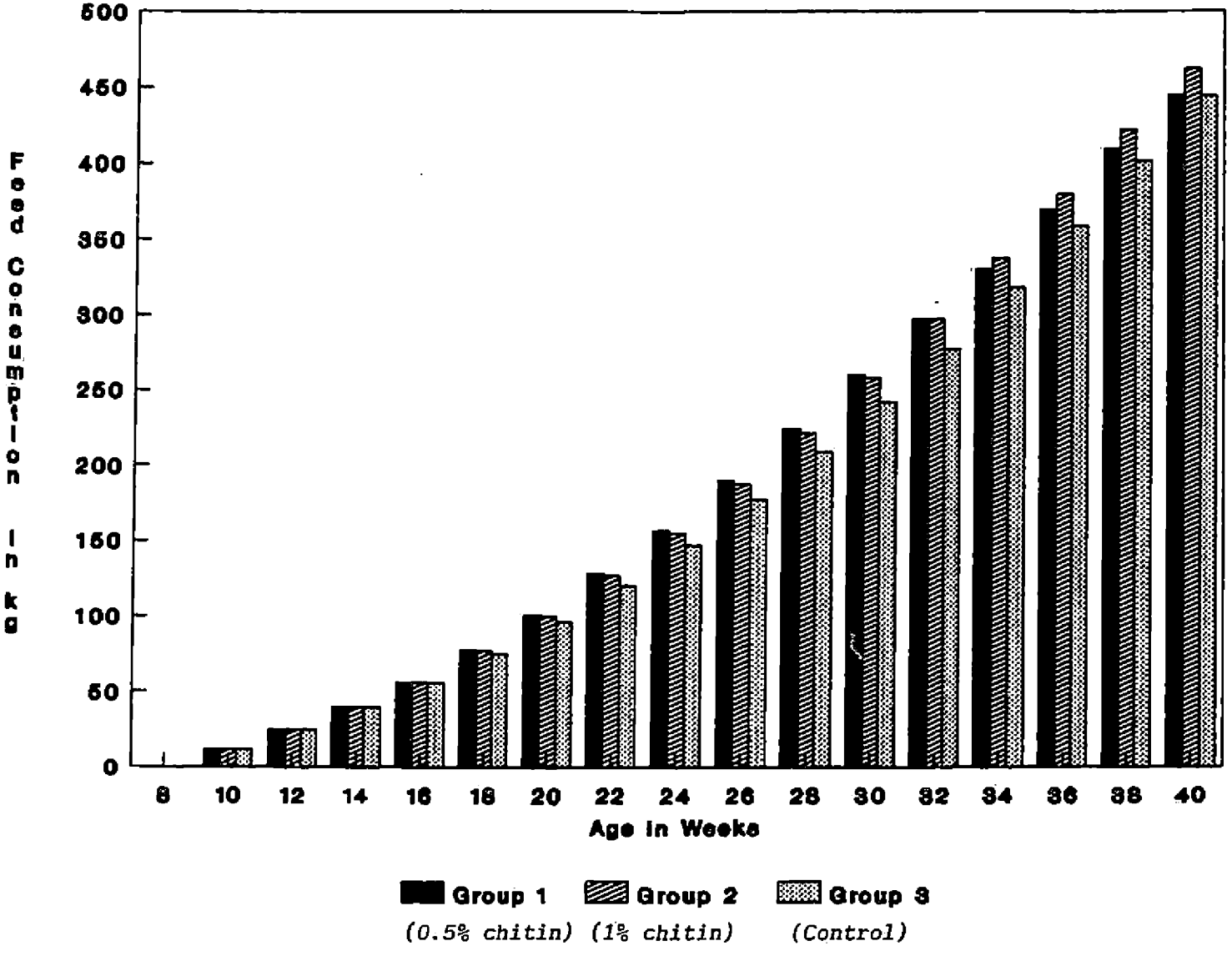

Fig.12 Total feed consumption of pigs from weaning to 40 weeks

The differences observed in feed consumption between the control and chitin-fed groups, and between the two chitin-fed groups were found to be non-significant.

4.2.6.2 Daily feed intake

The average daily feed intakes at different ages of fortnightly intervals from weaning to 40 weeks of age, for the three groups of pigs, are presented in Table 14 and Fig.13.

The daily feed intake of pigs increased with increase in age and weight of animals in all the groups.

The daily feed intake for the pigs in group 1 increased from 0.821 $\pm$ 0.015 kg at 10th week to 1.988 $\pm$ 0.098 kg at 40th week of age.

For the pigs in group 2, the daily feed intake increased from 0.827 $\pm$ 0.025 kg at 10th week to 2.062 $\pm$ 0.071 kg at 40th week of age.

In the case of the pigs in group 3, the daily feed intake increased from 0.807 $\pm$ kg 0.016 at 10th week to 1.985 $\pm$ 0.056 kg at 40th week of age.

Eventhough differences were observed in daily feed intake between the control and chitin-fed groups, and between

Table 14. Daily feed intake of pigs from weaning to 40 weeks

Age in weeks	Daily feed intake (kg)		
	Group 1 (0.5% chitin)	Group 2 (1% chitin)	Group 3 (Control)
10	0.821 ± 0.015	0.827 ± 0.025	0.807 ± 0.016
12	0.887 ± 0.019	0.891 ± 0.021	0.878 ± 0.007
14	0.937 ± 0.020	0.936 ± 0.022	0.934 ± 0.012
16	1.005 ± 0.024	0.996 ± 0.024	0.992 ± 0.019
18	1.102 ± 0.027	1.096 ± 0.024	1.063 ± 0.024
20	1.201 ± 0.034	1.188 ± 0.020	1.140 ± 0.027
22	1.308 ± 0.044	1.290 ± 0.024	1.224 ± 0.030
24	1.402 ± 0.056	1.379 ± 0.024	1.311 ± 0.036
26	1.507 ± 0.061	1.484 ± 0.030	1.404 ± 0.036
28	1.601 ± 0.066	1.580 ± 0.037	1.490 ± 0.037
30	1.688 ± 0.072	1.675 ± 0.044	1.570 ± 0.037
32	1.771 ± 0.076	1.769 ± 0.044	1.650 ± 0.038
34	1.814 ± 0.080	1.852 ± 0.059	1.746 ± 0.042
36	1.886 ± 0.076	1.936 ± 0.069	1.829 ± 0.044
38	1.951 ± 0.072	2.008 ± 0.601	1.910 ± 0.047
40	1.988 ± 0.098	2.062 ± 0.071	1.985 ± 0.056

ANOVA

Age in weeks	Source	DF	MS	F value
10	Treatment	2	0.0008	0.2703 NS
	Error	21	0.0031	
12	Treatment	2	0.0003	0.1380 NS
	Error	21	0.0023	
14	Treatment	2	0.00002	0.0088 NS
	Error	21	0.0029	
16	Treatment	2	0.0003	0.0805 NS
	Error	21	0.0041	
18	Treatment	2	0.0034	0.6778 NS
	Error	21	0.0051	
20	Treatment	2	0.0081	1.3071 NS
	Error	21	0.0062	
22	Treatment	2	0.0157	1.7137 NS
	Error	21	0.0092	
24	Treatment	2	0.0155	1.3052 NS
	Error	18	0.0119	
26	Treatment	2	0.0204	1.4328 NS
	Error	18	1.4250	
28	Treatment	2	0.0244	1.4511 NS
	Error	18	0.0168	
30	Treatment	2	0.0291	1.4348 NS
	Error	18	0.0203	
32	Treatment	2	0.0336	1.4950 NS
	Error	18	0.0225	
34	Treatment	2	0.0171	0.7272 NS
	Error	15	0.0236	
36	Treatment	2	0.0171	0.7300 NS
	Error	15	0.0234	
38	Treatment	2	0.0145	0.6455 NS
	Error	15	0.0225	
40	Treatment	2	0.0177	0.5918 NS
	Error	12	0.0299	

NS, Non-significant (P>0.05)

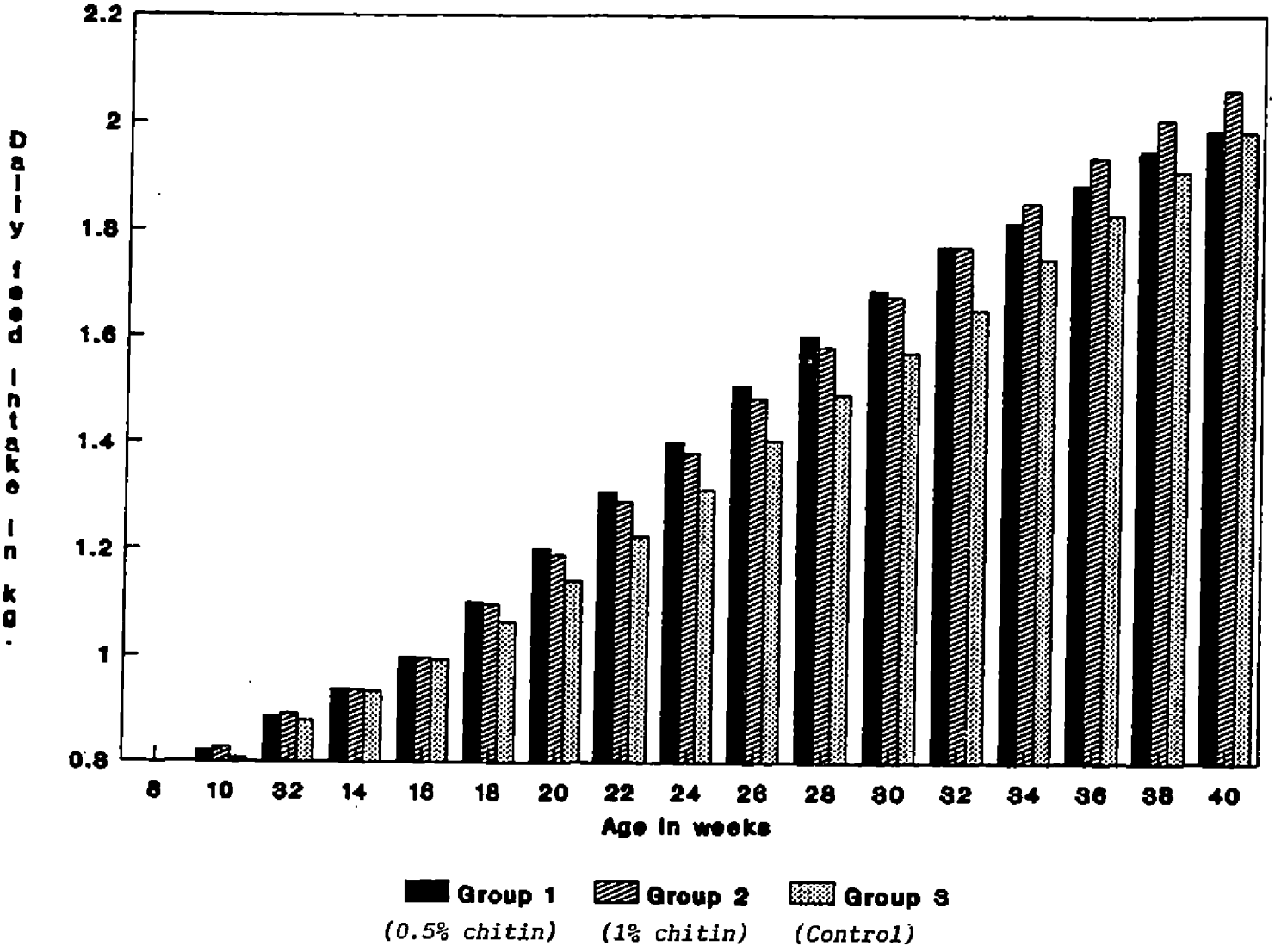

Fig.13 Daily feed intake of pigs from weaning to 40 weeks

the two chitin-fed groups, these differences were found to be non-significant.

4.2.7 Feed conversion efficiency

The average feed conversion efficiencies, calculated at fortnightly intervals from weaning to 40 weeks of age, for the three groups of pigs, are presented in Table 15 and Fig.14.

The average feed conversion efficiency for the pigs in group 1 was the lowest at 10th week (6.66 $\pm$ 1.07), gradually improving the 4.33 $\pm$ 0.58 at 14th week. Thereafter, the feed conversion efficiency was seen steady at 3.33 $\pm$ 0.14 to 3.83 $\pm$ 0.07 from 16th to 30th week, and then gradually decreasing to 4.52 $\pm$ 0.21 at 40th week of age. The highest feed conversion efficiency of 3.33 $\pm$ 0.14 was observed at 18th week for this group of animals.

In the case of the pigs in group 2, the lowest feed conversion efficiency of 7.02 $\pm$ 1.02 was noticed at 10th week, gradually improving to 4.36 $\pm$ 0.31 at 14th week. Thereafter, it kept steady from 16th to 30th week (3.39 $\pm$ 0.08 to 3.98 $\pm$ 0.25), and then gradually decreased to 4.70 $\pm$ 0.04 at 40th week. The maximum efficiency of 3.39 $\pm$ 0.08 was observed at 22nd week for this group of animals.

Table 15. Feed conversion efficiency of pigs from weanings to 40 weeks

Age in weeks	Feed conversion efficiency		
	Group 1 (0.5% chitin)	Group 2 (1% chitin)	Group 3 (Control)
10	6.66 ± 1.07	7.02 ± 1.02	6.92 ± 0.97
12	5.87 ± 0.98	5.59 ± 0.34	5.99 ± 0.71
14	4.33 ± 0.58	4.36 ± 0.31	4.88 ± 0.39
16	3.63 ± 0.21	3.98 ± 0.25	4.43 ± 0.32
18	3.33 ± 0.14^{a}	3.47 ± 0.09^{a}	3.99 ± 0.21^{b}
20	3.37 ± 0.09^{A}	3.40 ± 0.03^{A}	3.86 ± 0.15^{B}
22	3.37 ± 0.08	3.39 ± 0.08	3.63 ± 0.11
24	3.42 ± 0.04	3.40 ± 0.09	3.62 ± 0.10
26	3.56 ± 0.04	3.53 ± 0.09	3.73 ± 0.14
28	3.69 ± 0.04	3.64 ± 0.09	3.89 ± 0.10
30	3.83 ± 0.07	3.84 ± 0.10	4.05 ± 0.09
32	3.97 ± 0.06	4.01 ± 0.08	4.21 ± 0.12
34	4.28 ± 0.05	4.29 ± 0.05	4.58 ± 0.16
36	4.39 ± 0.06	4.44 ± 0.06	4.69 ± 0.12
38	4.50 ± 0.05^{a}	4.61 ± 0.06^{a}	4.98 ± 0.13^{b}
40	4.52 ± 0.21^{a}	4.70 ± 0.04^{a}	5.19 ± 0.09^{b}

A,B Means in the same row bearing different higher case superscripts differ significantly ($P<0.01$)

a,b Means in the same row bearing different lower case superscripts differ significantly ($P<0.05$)

ANOVA

Age in weeks	Source	DF	MS	F value
10	Treatment	2	0.2762	0.0327 NS
	Error	21	8.4319	
12	Treatment	2	0.3390	0.0788 NS
	Error	21	4.3016	
14	Treatment	2	0.7680	0.4821 NS
	Error	21	1.5931	
16	Treatment	2	1.2985	2.2678 NS
	Error	21	0.5725	
18	Treatment	2	0.9516	4.7438 *
	Error	21	0.2006	
20	Treatment	2	0.5908	6.8345 **
	Error	21	0.0864	
22	Treatment	2	0.1691	2.3271 NS
	Error	21	0.0726	
24	Treatment	2	0.1071	2.0601 NS
	Error	18	0.0520	
26	Treatment	2	0.0809	1.1393 NS
	Error	18	0.0710	
28	Treatment	2	0.1250	2.4296 NS
	Error	18	0.0514	
30	Treatment	2	0.1109	1.8624 NS
	Error	18	0.0595	
32	Treatment	2	0.1153	1.7750 NS
	Error	18	0.0649	
34	Treatment	2	0.1781	2.7026 NS
	Error	15	0.0659	
36	Treatment	2	0.1486	3.2274 NS
	Error	15	0.0460	
38	Treatment	2	0.3248	6.1088 *
	Error	15	0.0531	
40	Treatment	2	0.6050	6.5220 *
	Error	12	0.0927	

NS, Non-significant (P>0.05)

* Significant (P<0.05)

** Highly significant (P<0.01)

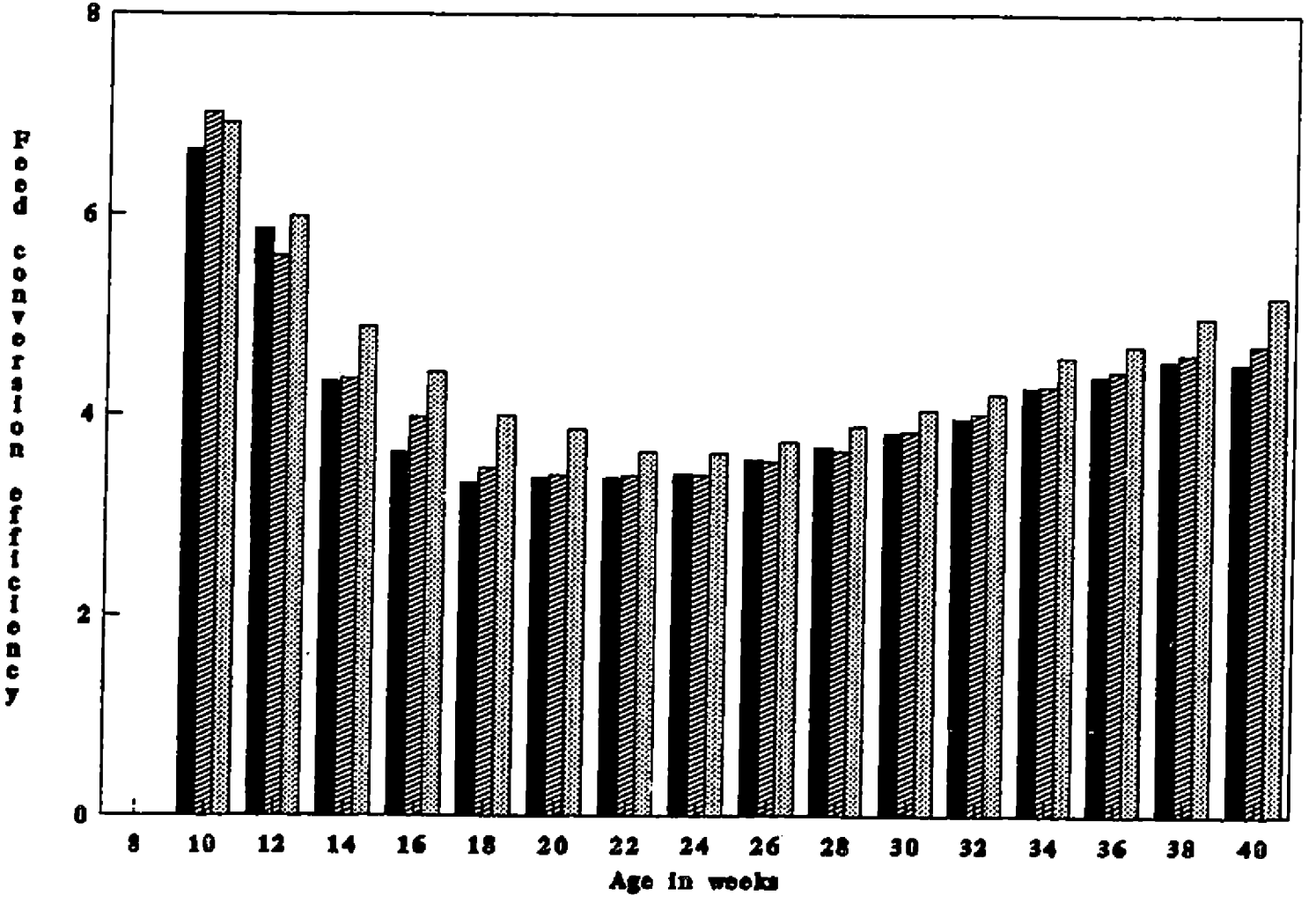

Fig.14 Feed conversion efficiency of pigs from weaning to 40 weeks

For the pigs in group 3, the lowest feed conversion efficiency of 6.92 ± 0.97 was noticed at 10th week, gradually improving to 4.88 ± 0.39 at 14th week. The feed conversion efficiency thereafter kept steady at 3.62 ± 0.10 to 4.43 ± 0.32 from 16th to 30th week, followed by a gradual decline to 5.19 ± 0.09 at 40th week of age. The maximum feed conversion efficiency of 3.62 ± 0.10 was recorded at 24th week of age for this group of animals.

For all the three groups, the peak feed conversion efficiency was recorded between 18th and 24th week. However, a trend of high feed conversion efficiency was observed between 16th and 30th week of age.

The differences in feed conversion efficiency observed between the control and chitin-fed groups were found to be significant ($P < 0.05$) at 18th, 38th and 40th week, and highly significant ($P < 0.01$) at 20th week of age. The differences observed between the two chitin-fed groups were not found to be significant at any stage.

4.3 Carcass characteristics

The carcass characteristics of pigs, slaughtered at 5, 7 and 9 months of age, are presented in Table 16.

Table 16. Effect of chitin on carcass characteristics of pigs

Carcass characteristics	Slaughter age								
	5 months			7 months			9 months		
	Group 1	Group 2	Group 3	Group 1	Group 2	Group 3	Group 1	Group 2	Group 3
Live weight at slaughter (kg)	56.8	56.2	44.7	88.0	82.5	71.5	99.5	101.5	93.0
Carcass length (cm)	64.0	65.0	62.0	79.0	77.0	74.0	80.0	89.0	77.0
Weight of ham (kg)	9.0	9.1	6.44	13.44	13.0	10.14	14.9	15.3	13.26
Ham percentage	25.35	26.0	25.25	24.66	25.0	24.43	21.59	21.42	21.38
Backfat thickness (cm)	0.9	1.10	1.13	2.40	2.23	2.46	2.56	2.90	3.16
Eye-muscle area (cm^2)	24.56	23.22	18.43	34.43	34.73	31.18	37.75	40.88	33.30
Weight of leaf fat (kg)	Nil	Nil	Nil	0.55	0.50	0.525	1.60	1.75	1.60
Leaf fat percentage	--	--	--	0.625	0.606	0.734	1.67	1.69	1.72
Dressing percentage with head	68.62	68.77	63.57	70.11	70.37	66.44	79.47	77.09	74.08
Dressing percentage without head	62.50	62.27	57.04	63.06	63.03	58.04	72.25	70.34	66.66

4.3.1 Live weight at slaughter

The live weights at slaughter recorded for the pigs in group 1 were 56.8, 88.0 and 99.5 kg at 5, 7 and 9 months of age respectively. The same for the pigs in group 2 were 56.2, 82.5 and 101.5 kg, and for the pigs in group 3, 44.7, 71.5 and 93.0 kg, at 5, 7 and 9 months of age respectively.

4.3.2 Carcass length

The carcass lengths recorded for the pigs in group 1 were 64, 79 and 80 cm at 5, 7 and 9 months of age respectively. The carcass lengths recorded at 5, 7 and 9 months of age, respectively, were 65, 77 and 89 cm for pigs in group 2, and 62, 74 and 77 cm for the pigs in group 3.

4.3.3 Weight of ham

The weights of ham recorded at ages 5, 7 and 9 months respectively were 9.0, 13.44 and 14.9 kg for the pigs in group 1; 9.1, 13.0 and 15.3 kg for the pigs in group 2; and 6.44, 10.14 and 13.26 kg for the pigs in group 3.

The weights of ham as percentage of carcass weight without head recorded for the pigs in group 1 were 25.35, 24.66 and 21.59 at 5, 7 and 9 months of age respectively. The ham percentages for the pigs in group 2 were 26.00, 25.00 and

21.42, and for the pigs in group 3 25.25, 24.43 and 21.38, at 5, 7 and 9 months of age respectively.

4.3.4 Backfat thickness

The pigs in group 1 had 0.9, 2.40 and 2.56 cm of backfat thickness at 5, 7 and 9 months of age respectively. The pigs in group 2 had 1.10, 2.23 and 2.9 cm, and the pigs in group 3, 1.13, 2.46 and 3.16 cm of backfat thickness at 5, 7 and 9 months of age respectively.

4.3.5 Eye-muscle area

At ages 5, 7 and 9 months respectively, the pigs in group 1 had eye-muscle areas of 24.56, 34.43 and 37.75 cm^2; the pigs in group 2, 23.22, 34.73 and 40.88 cm^2; and the pigs in group 3, 18.43, 31.18 and 33.30 cm^2.

4.3.6 Weight of leaf fat

Leaf fat was not found to any appreciable quantity in any group of pigs at 5 months of age. At ages 7 and 9 months respectively, the quantities of leaf fat recorded were 0.55 and 1.6 kg for the pigs in group 1, 0.50 and 1.75 kg for the pigs in group 2, and 0.525 and 1.6 kg for the pigs in group 3.

The weights of leaf fat as percentage of live weight at 7 and 9 months of age, respectively, were found to be 0.625

and 1.67 for the pigs in group 1, 0.606 and 1.69 for the pigs in group 2, and 0.734 and 1.72 for the pigs in group 3.

4.3.7 Dressing percentage

4.3.7.1 Dressing percentage (with head)

For the pigs in group 1, the dressing percentages recorded at 5, 7 and 9 months of age were recorded at 68.22, 70.11 and 79.47 respectively. The dressing percentages for the pigs in group 2 were 68.77, 70.37 and 77.09, and for the pigs in group 3, 63.57, 66.44 and 74.08, at 5, 7 and 9 months of age respectively. The dressing percentage increased with increase in body weight as age of animals advanced from 5 to 9 months.

4.3.7.2 Dressing percentage (without head)

The dressing percentages recorded at 5, 7 and 9 months of age respectively were 62.5, 63.06 and 72.25 for the pigs in group 1; 62.27, 63.03 and 70.34 for the pigs in group 2; and 57.04, 58.04 and 66.66 for the pigs in group 3. The dressing percentage increased with increase in slaughter weight of animals as age advanced from 5 to 9 months.

4.4 Weight of internal organs

The weights of internal organs for the three groups of

Table 17. Weight of internal organs of pigs at different ages

Internal organs	Slaughter age								
	5 months			7 months			9 months		
	Group 1	Group 2	Group 3	Group 1	Group 2	Group 3	Group 1	Group 2	Group 3
Heart (g)	245	215	215	290	310	270	300	320	300
% of live wt.	0.43	0.38	0.48	0.33	0.37	0.38	0.30	0.31	0.32
Liver (kg)	1.27	1.21	1.165	2.07	1.97	1.75	2.15	2.30	2.10
% of live wt.	2.23	2.15	2.60	2.35	2.38	2.44	2.16	2.22	2.25
Kidney (g)	190	215	180	270	250	220	290	300	280
% of live wt.	0.33	0.38	0.40	0.30	0.30	0.30	0.29	0.28	0.30
Lungs (g)	450	470	420	660	550	475	550	675	650
% of live wt.	0.79	0.83	0.93	0.75	0.66	0.66	0.55	0.65	0.69
Spleen (g)	90	105	85	150	130	110	125	150	135
% of live wt.	0.15	0.18	0.19	0.17	0.15	0.15	0.12	0.14	0.14
Total weight of organs (kg)	2.245	2.215	2.065	3.44	3.21	2.82	3.48	3.745	3.465
% of live wt.	3.95	3.94	4.61	3.90	3.90	3.94	3.49	3.68	3.72

pigs, slaughtered at 5, 7 and 9 months of age, are presented in Table 17.

4.4.1 Heart

For the pigs in group 1, slaughtered at 5, 7 and 9 months of age respectively, the weights of heart recorded were 245, 290 and 300 g, and the percentages of heart weight to live weight 0.43, 0.33 and 0.30.

For the pigs in group 2, slaughtered at 5, 7 and 9 months of age respectively, the weights of heart recorded were 215, 310 and 320 g, and the percentages of heart weight to live weight 0.38, 0.37 and 0.31.

In the case of the pigs in group 3, the weights of heart recorded were 215, 270 and 300 g, and the percentages of heart weight to live weight 0.48, 0.38 and 0.32 for the pigs slaughtered at 5, 7 and 9 months of age respectively.

It was observed that while the weight of heart increased with increase in age and weight of animals, the percentage of heart weight to live weight decreased, for all the groups of pigs.

4.4.2 Liver

The weights of liver observed for the pigs in group 1

were 1.27, 2.07 and 2.15 kg, and liver weights as percentage of live weight 2.23, 2.35 and 2.16, at 5, 7 and 9 months of age respectively.

For the pigs in group 2, the weights of liver recorded were 1.21, 1.97 and 2.30 kg, and liver weights as percentage of live weight 2.15, 2.38 and 2.22, at 5, 7 and 9 months of age respectively.

In the case of the pigs in group 3, the weights of liver were 1.165, 1.75 and 2.10 kg, and liver weights as percentage of liver weight 2.60, 2.44 and 2.25, at 5, 7, and 9 months of age respectively.

It was observed that weight of liver increased with increase in body weight as age advanced from 5 to 9 months, for all the groups.

4.4.3 Kidney

For the pigs in group 1, the weights of kidney recorded were 190, 270 and 290 g, and weights of kidney as percentage of live weight 0.33, 0.30 and 0.29, at 5, 7 and 9 months of age respectively.

For the pigs in group 2, slaughtered at 5, 7 and 9 months of age respectively, the weights of kidney recorded

were 215,250 and 300 g, and kidney weights as percentage of live weight 0.38, 0.30 and 0.28.

In the case of the pigs in group 3, the weights of kidney recorded were 180, 220 and 280 g, and percentages of kidney weight to live weight 0.40, 0.30 and 0.30, at 5, 7 and 9 months of age respectively.

It was observed that the weight of kidney increased with increase in age and weight of animals, while the weight of kidney as percentage of live weight decreased, for all the groups of pigs.

4.4.4 Lungs

The weights of lungs observed for the pigs in group 1 were 450, 660 and 550 g, and lungs weights as percentage of live weight 0.79, 0.75 and 0.55, at 5, 7 and 9 months of age respectively.

For the pigs in group 2, the weights of lungs recorded were 470, 550 and 675 g, and lungs weights as percentage of live weight 0.83, 0.66 and 0.65, at 5, 7 and 9 months of age respectively.

In the case of the pigs in group 3, the weights of lungs recorded were 420, 475 and 650 g, and weights of lungs

as percentage of live weight 0.93, 0.66 and 0.69, at 5, 7 and 9 months of age respectively.

4.4.5 Spleen

The weights of spleen observed for the pigs in group 1 were 90, 150 and 125 g, and weights of spleen as percentage of live weight 0.15, 0.17 and 0.12, at 5, 7 and 9 months of age respectively.

For the pigs in group 2, the weights of spleen recorded were 105, 130 and 150 g, and weights of spleen as percentage of live weight 0.18, 0.15 and 0.14, at 5, 7 and 9 months of age respectively.

In the case of the pigs in group 3, the weights of spleen recorded were 85, 110 and 135 g, and weights of spleen as percentage of live weight 0.19, 0.15 and 0.14, at 5, 7 and 9 months of age respectively.

4.4.6 Total weight of organs

The total weights of internal organs recorded for the pigs in group 1 were 2.245, 3.44 and 3.48 kg at 5, 7 and 9 months of age respectively. The total weights of internal organs as percentage of live weight were 3,95, 3.90 and 3.49 at 5, 7 and 9 months of age respectively.

For the pigs in group 2, the total organ weights were 2.215, 3.21 and 3.745 kg at 5, 7 and 9 months of age respectively. The total organ weights as percentage of live weight were 3.94, 3.90 and 3.68 at 5, 7 and 9 months of age respectively.

In the case of the pigs in group 3, the total organ weights recorded at 5, 7 and 9 months of age were 2.065, 2.820 and 3.465 kg respectively. The total organ weights as percentage of live weight were 4.61, 3.94 and 3.72 at 5, 7 and 9 months of age respectively.

4.5 Haematological studies

4.5.1 Haemoglobin concentration

The average haemoglobin concentrations at different ages, for the three groups of pig, are shown in Table 18 and Fig.15.

For the pigs in group 1, the haemoglobin concentration was 8.16 $\pm$ 0.39 g per dl at the pre-treatment stage. The haemoglobin concentrations recorded at 5, 7 and 9 months of age were 13.53 $\pm$ 0.48, 13.00 $\pm$ 0.30 and 12.93 $\pm$ 0.39 g per dl respectively.

The haemoglobin concentration, for the pigs in group 2, was found to be 8.38 $\pm$ 0.45 g per dl at the

Table 18. Haemoglobin concentration of pigs at different ages

Age	Haemoglobin concentration (g per dl)		
	Group 1 (0.5% chitin)	Group 2 (1% chitin)	Group 3 (Control)
Pre-treatment	8.16 ± 0.39	8.38 ± 0.45	8.26 ± 0.53
5 months	13.53 ± 0.48	13.00 ± 0.31	12.73 ± 0.41
7 months	13.00 ± 0.30	13.20 ± 0.37	12.53 ± 0.35
9 months	12.93 ± 0.39	13.30 ± 0.29	13.06 ± 0.34

ANOVA

Age	Source	DF	MS	F value
Pre-treatment	Treatment	2	0.0705	0.0602 NS
	Error	15	1.1703	
5 months	Treatment	2	0.9954	0.9950 NS
	Error	15	1.0004	
7 months	Treatment	2	0.7022	0.9759 NS
	Error	15	0.7195	
9 months	Treatment	2	0.2064	0.2902 NS
	Error	15	10.6667	

NS, Non-significant (P>0.05)

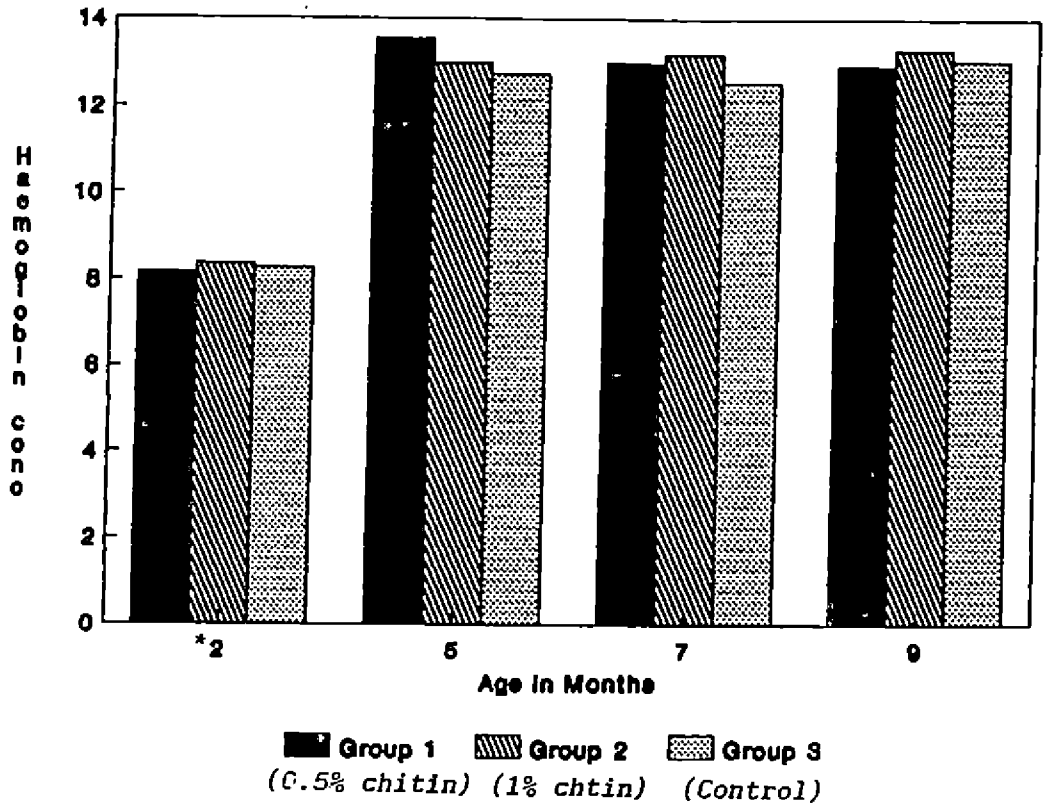

Fig.15 Haemoglobin concentration of pigs at different ages

* *Pre-treatment stage*

pre-treatment stage. The haemoglobin concentration recorded thereafter were 13.00 ± 0.31, 13.20 ± 0.37 and 13.30 ± 0.29 g per dl at 5, 7 and 9 months of age respectively.

In the case of the pigs in group 3, the concentration of haemoglobin was 8.26 ± 0.53 g per dl at the pre-treatment stage. Thereafter, the concentrations of haemoglobin were found to be 12.73 ± 0.41, 12.53 ± 0.35 and 13.06 ± 0.34 g per dl at 5, 7 and 9 months of age respectively.

The differences observed in haemoglobin concentration between the groups of pigs were not found to be significant at any stage.

4.5.2 Total erythrocyte count (TEC)

The total erythrocyte counts at different ages, for the pigs in the three groups, are shown in Table 19 and Fig.16.

The TEC for the pigs in group 1 was $5.56 \pm 0.20 \times 10^6$ per cu mm at the pre-treatment stage. Thereafter, the TEC values recorded were $6.91 \pm 0.11 \times 10^6$, $6.94 \pm 0.12 \times 10^6$ and $7.03 \pm 0.07 \times 10^6$ per cu mm at 5, 7 and 9 months of age respectively.

For the pigs in group 2, the TEC was found to be $5.73 \pm 0.17 \times 10^6$ per cu mm at the pre-treatment stage. The TEC

Table 19. Total erythrocyte count (TEC) of pigs at different ages

Age	TEC (10^6 per cu mm)		
	Group 1 (0.5% chitin)	Group 2 (1% chitin)	Group 3 (Control)
Pre-treatment	5.56 ± 0.20	5.73 ± 0.17	5.60 ± 0.13
5 months	6.91 ± 0.11	6.88 ± 0.13	6.85 ± 0.10
7 months	6.94 ± 0.12	7.00 ± 0.08	6.79 ± 0.14
9 months	7.03 ± 0.07	7.10 ± 0.11	6.83 ± 0.13

ANOVA

Age	Source	DF	MS	F value
Pre-treatment	Treatment	2	0.0451	0.2459 NS
	Error	15	0.1835	
5 months	Treatment	2	0.0051	0.0590 NS
	Error	15	0.0878	
7 months	Treatment	2	0.0716	0.9593 NS
	Error	15	0.0747	
9 months	Treatment	2	0.1155	1.3512 NS
	Error	15	0.0855	

NS, Non-significant (P>0.05)

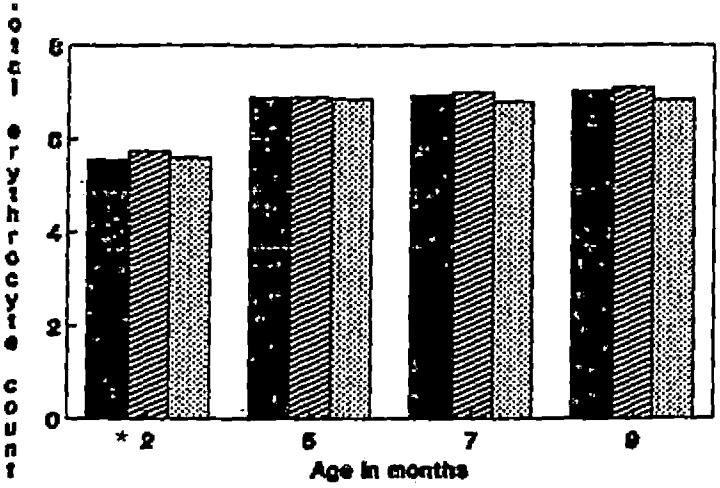

Fig.16 Total erythrocyte count of pigs at different ages

* *Pre-treatment stage*

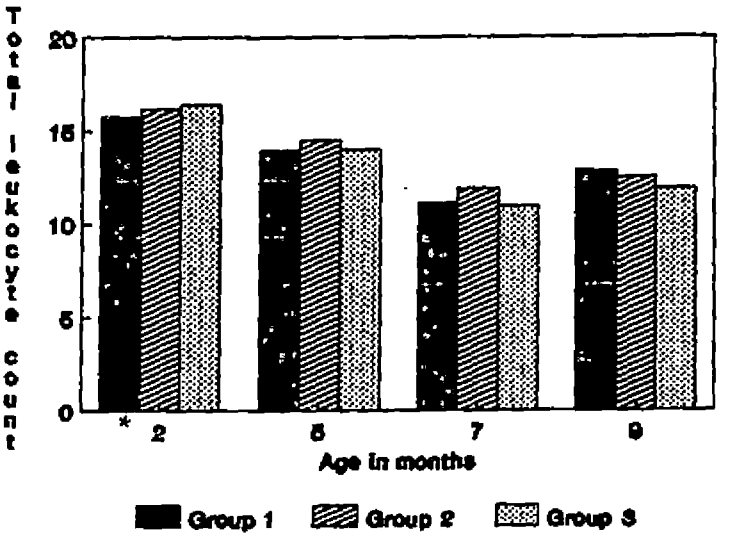

Fig.17 Total leukocyte count of pigs at different ages

* Pre-treatment stage

values recorded at 5, 7 and 9 months of age, respectively, were $6.88 \pm 0.13 \times 10^6$, $7.00 \pm 0.08 \times 10^6$ and $7.10 \pm 0.11 \times 10^6$ per cu mm.

In the case of the pigs in group 3, the TEC was $5.60 \pm 0.13 \times 10^6$ per cu mm at the pre-treatment stage. The TEC values recorded thereafter were $6.85 \pm 0.10 \times 10^6$, $6.79 \pm 0.14 \times 10^6$ and $6.83 \pm 0.13 \times 10^6$ per cu mm at 5, 7 and 9 months of age respectively.

The differences observed in total erythrocyte count between the groups were not found to be significant at any stage.

4.5.3 Total leukocyte count (TLC)

The total leukocyte counts at different ages, for the three groups of pigs, are shown in Table 20 and Fig.17.

The TLC for the pigs in group 1 was $15.78 \pm 0.59 \times 10^3$ per cu mm at the pre-treatment stage. The TLC values at 5, 7 and 9 months of age were $13.98 \pm 0.67 \times 10^3$, $11.15 \pm 0.39 \times 10^3$ and $12.88 \pm 0.90 \times 10^3$ per cu mm respectively.

For the pigs in group 2, the TLC was $16.20 \pm 0.64 \times 10^3$ per cu mm at the pre-treatment stage. The TLC values at 5, 7 and 9 months of age were $14.51 \pm 0.69 \times 10^3$, $11.90 \pm 0.39 \times 10^3$ and $12.50 \pm 0.16 \times 10^3$ per cu mm respectively.

Table 20. Total leukocyte count (TLC) of pigs at different ages

Age	TLC (10^3 per cu mm)		
	Group 1 (0.5% chitin)	Group 2 (1% chitin)	Group 3 (Control)
Pre-treatment	15.78 ± 0.59	16.20 ± 0.64	16.39 ± 0.40
5 months	13.98 ± 0.67	14.51 ± 0.69	14.01 ± 0.95
7 months	11.15 ± 0.39	11.90 ± 0.39	10.95 ± 0.58
9 months	12.88 ± 0.90	12.50 ± 0.16	11.90 ± 0.16

ANOVA

Age	Source	DF	MS	F value
Pre-treatment	Treatment	2	0.5839	0.3183 NS
	Error	15	1.8341	
5 months	Treatment	2	0.5451	0.1767 NS
	Error	15	3.0837	
7 months	Treatment	2	1.5050	1.2366 NS
	Error	15	1.2170	
9 months	Treatment	2	1.4737	0.8166 NS
	Error	15	1.8045	

NS, Non-significant (P>0.05)

In the case of the pigs in group 3, a TLC value of $16.39 \pm 0.40 \times 10^3$ per cu mm was recorded at the pre-treatment stage. The TLC values recorded at 5, 7 and 9 months of age were $14.01 \pm 0.95 \times 10^3$, $10.95 \pm 0.58 \times 10^3$ and $11.90 \pm 0.16 \times 10^3$ per cu mm respectively.

The differences in total leukocyte count between the groups were not found to be significant at any stage.

4.5.4 Differential leukocyte count

The differential leukocyte counts at different ages, for the three groups of pigs,are shown in Table 21.

4.5.4.1 Neutrophil

The pigs in group 1 showed a neutrophil count of 34.5 ± 1.31 per cent at the pre-treatment stage. The percentages of neutrophil at the subsequent ages of 5, 7 and 9 months were 27.33 ± 1.938, 38.5 ± 1.258 and 28.330 ± 1.810 respectively.

The neutrophil count observed for the pigs in group 2 was 34.0 ± 1.19 per cent at the pre-treatment stage. At the subsequent ages of 5, 7 and 9 months, the neutrophil counts recorded were 27.16 ± 1.979, 37.33 ± 1.134 and 27.5 ± 1.607 per cent respectively.

For the pigs in group 3, a neutrophil count of $36.0 \pm$

Table 21. Differential leukocyte count (DLC) of pigs at different ages

Age	Group	DLC (percentage)			
		Neutrophil	Eosinophil	Lymphocyte	Monocyte
Pre-treatment	1	34.5 ±1.310	3.66±0.333	58.0 ±1.390	3.83±0.435
	2	34.0 ±1.190	3.50±0.367	58.5 ±1.565	4.0 ±0.446
	3	36.0 ±1.144	3.0 ±0.274	56.66±1.283	4.33±0.457
5 months	1	27.33±1.938	2.50±0.393	67.00±2.258	3.16±0.456
	2	27.16±1.979	2.66±0.40	66.83±2.304	3.33±0.464
	3	28.83±1.855	2.50±0.408	65.66±2.184	3.0 ±0.468
7 months	1	38.5 ±1.258	2.50±0.412	55.83±1.851	3.16±0.513
	2	37.33±1.134	3.0 ±0.425	56.33±2.333	3.33±0.513
	3	38.33±1.183	2.66±0.422	55.0 ±2.278	4.0 ±0.519
9 months	1	28.33±1.810	2.33±0.415	65.33±2.531	4.0 ±0.480
	2	27.5 ±1.607	2.16±0.420	66.5 ±1.176	3.83±0.488
	3	28.16±1.346	2.33±0.413	66.0 ±0.966	3.50±0.504

NB: No basophil noticed

ANOVA

Age	Source	DF	MS	F value
Neutrophil				
Pre-treatment	Treatment	2	2.3710	0.7106 NS
	Error	15	3.3365	
5 months	Treatment	2	2.1064	0.6784 NS
	Error	15	3.1046	
7 months	Treatment	2	0.8242	0.2560 NS
	Error	15	3.2188	
9 months	Treatment	2	4.7363	0.6021 NS
	Error	15	7.8652	
Lymphocyte				
Pre-treatment	Treatment	2	1.8378	0.4581 NS
	Error	15	4.0111	
5 months	Treatment	2	1.1679	0.4287 NS
	Error	15	2.7242	
7 months	Treatment	2	0.9042	0.1640 NS
	Error	15	5.5122	
9 months	Treatment	2	0.7480	0.2576 NS
	Error	15	2.9033	
Eosinophil				
Pre-treatment	Treatment	2	1.9571	0.8889 NS
	Error	15	2.2017	
5 months	Treatment	2	0.1508	0.0440 NS
	Error	15	3.4216	
7 months	Treatment	2	0.9726	0.2000 NS
	Error	15	4.8627	
9 months	Treatment	2	0.2835	0.0769 NS
	Error	15	3.6865	
Monocyte				
Pre-treatment	Treatment	2	0.9464	0.6545 NS
	Error	15	1.4459	
5 months	Treatment	2	0.5727	0.1129 NS
	Error	15	5.0721	
7 months	Treatment	2	3.6368	0.5401 NS
	Error	15	6.7324	
9 months	Treatment	2	1.3708	0.2252 NS
	Error	15	6.0865	

NS, Non-significant (P>0.05)

1.144 per cent was recorded at the pre-treatment stage. The percentages of neutrophil at 5, 7 and 9 months of age were 28.83 ± 1.855, 38.33 ± 1.183 and 28.16 ± 1.346 respectively.

The differences in neutrophil count between groups were found to be non-significant.

4.5.4.2 Eosinophil

The pigs in group 1 showed an eosinophil count of 3.66 ± 0.333 per cent at the pre-treatment stage. The counts of eosinophil at the subsequent ages of 5, 7 and 9 months were 2.50 ± 0.393, 2.50 ± 0.412 and 2.33 ± 0.415 per cent respectively.

The pigs in group 2 showed an eosinophil count of 3.50 ± 0.367 per cent at the pre-treatment stage. The eosinophil counts at the subsequent ages of 5, 7 and 9 months were 2.66 ± 0.40, 3.0 ± 0.425 and 2.16 ± 0.42 per cent respectively.

The eosinophil count for the pigs in group 3 was 3.0 ± 0.274 per cent at the pre-treatment stage. At the subsequent ages of 5, 7 and 9 months, the eosinophil counts recorded were 2.50 ± 0.408, 2.66 ± 0.422 and 2.33 ± 0.413 per cent respectively.

The differences between the groups in eosinophil count were found to be non-significant.

4.5.4.3 Lymphocyte

The pigs in group 1 showed a lymphocyte count of 58.0 ± 1.39 per cent at the pre-treatment stage. The counts of lymphocyte at the subsequent ages of 5, 7 and 9 months were 67.0 ± 2.258, 55.83 ± 1.851 and 65.33 ± 2.531 per cent respectively.

The pigs in group 2 showed a lymphocyte count of 58.5 ± 1.565 per cent at the pre-treatment stage. The lymphocyte counts recorded at the subsequent ages of 5, 7 and 9 months were 66.83 ± 2.304, 56.33 ± 2.333 and 66.50 ± 1.176 per cent respectively.

The pigs in group 3 showed a lymphocyte count of 56.66 ± 1.283 per cent at the pre-treatment stage. The lymphocyte counts recorded at 5, 7 and 9 months of age were 65.66 ± 2.184, 55.0 ± 2.278 and 66.0 ± 0.966 per cent respectively.

The differences in lymphocyte count between the groups were found to be non-significant at all stages.

4.5.4.4 Monocyte

The pigs in group i showed a monocyte count of 3.83 ± 0.435 per cent at the pre-treatment stage. The monocyte counts at the subsequent ages of 5, 7 and 9 months were 3.16 ± 0.456, 3.16 ± 0.513 and 4.0 ± 0.48 per cent respectively.

The pigs in group 2 showed a monocyte count of 4.0 ± 0.446 at the pre-treatment stage. The monocyte counts at the subsequent ages of 5, 7 and 9 months were 3.33 ± 0.464, 3.33 ± 0.513 and 3.83 ± 0.488 per cent respectively.

The monocyte count for the pigs in group 3 was 4.33 ± 0.457 per cent at the pre-treatment stage. The monocyte counts recorded at 5, 7 and 9 months of age were 3.0 ± 0.468, 4.0 ± 0.519 and 3.50 ± 0.504 per cent respectively.

The differences noticed in the monocyte count between the groups were found to be non-significant at all stages.

4.6 Serum cholesterol and triglyceride concentrations

4.6.1 Serum cholesterol concentration

The serum cholesterol concentrations at different ages, for the three groups of pigs, are presented in Table 22 and Fig.18.

The serum cholesterol concentration for the pigs in group 1 was 95.73 ± 2.35 mg per 100 ml at the pre-treatment stage. The concentrations at 5, 7 and 9 months of age were 84.25 ± 2.47, 108.79 ± 2.75 and 118.18 ± 2.26 mg per 100 ml respectively.

Table 22. Effect of chitin on serum cholesterol concentration of pigs

Age	Cholesterol concentration (mg per 100 ml)		
	Group 1 (0.5% chitin)	Group 2 (1% chitin)	Group 3 (Control)
Pre-treatment	95.73 ± 2.35	97.33 ± 2.77	94.14 ± 2.66
5 months	84.25 ± 2.47	77.65 ± 2.82	85.28 ± 2.80
7 months	108.79 ± 2.75^{a}	99.50 ± 3.03^{b}	110.70 ± 2.79^{a}
9 months	118.18 ± 2.26^{A}	107.77 ± 2.33^{B}	122.38 ± 2.50^{A}

A,B Means in the same row bearing different higher case superscripts differ significantly (P <0.01)

a,b Means in the same row bearing different lower case superscripts differ significantly (P <0.05)

ANOVA

Age	Source	DF	MS	F value
Pre-treatment	Treatment	2	15.2656	0.3550 NS
	Error	15	42.9979	
5 months	Treatment	2	102.9247	2.4005 NS
	Error	15	42.8776	
7 months	Treatment	2	215.0625	4.3721 *
	Error	15	49.1895	
9 months	Treatment	2	339.5313	10.||713 **
	Error	15	33.7125	

NS, Non-significant (P>0.05)
* Significant (P<0.05) ** Highly significant (P<0.01)

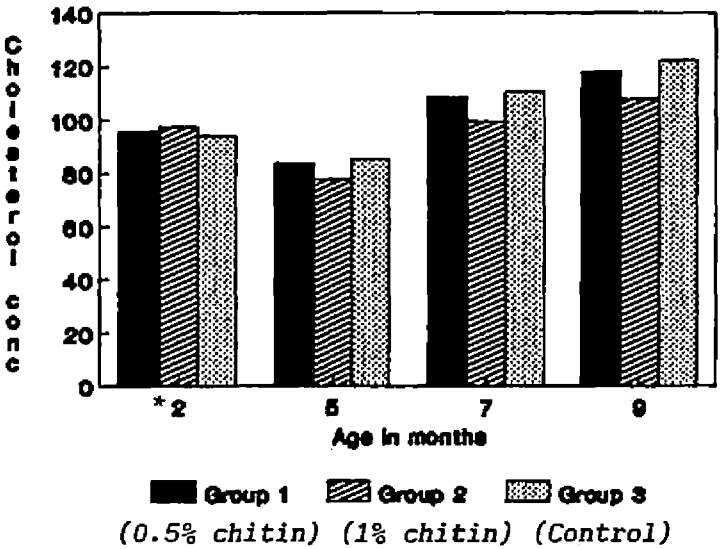

Fig.18 Effect of chitin on serum cholesterol concentration of pigs

* *Pre-treatment stage*

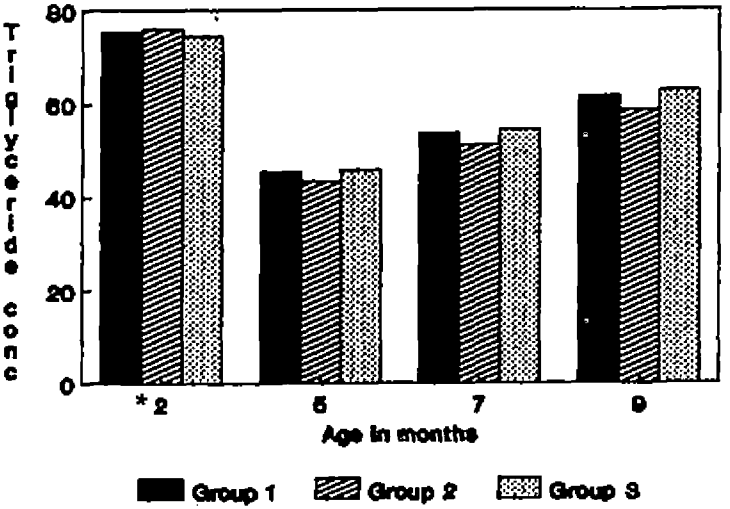

Fig.19 Effect of chitin on serum triglyceride concentration of pigs

* *Pre-treatment stage*

For the pigs in group 2, the serum cholesterol concentration at the pre-treatment stage was 97.33 ± 2.77 mg per 100 ml. The concentrations at 5, 7 and 9 months of age were 77.65 ± 2.82, 99.50 ± 3.03 and 107.77 ± 2.33 mg per 100 ml respectively.

In the case of pigs in group 3, the serum cholesterol concentration was 94.14 ± 2.66 mg per 100 ml of the pre-treatment stage. The concentrations at 5, 7 and 9 months of age were 85.28 ± 2.80, 110.70 ± 2.79 and 122.38 ± 2.50 mg per 100 ml respectively.

When compared between groups, the pigs in group 2 showed lower levels of serum cholesterol than the pigs in group 1 and group 3 at all ages from 5 to 9 months. Eventhough the cholesterol levels appeared to be similar for the pigs in group 1 and group 3, the pigs in group 1 showed slightly lower levels.

The differences in serum cholesterol concentration between the pigs in group 2 and the pigs of either group 1 or group 3 were found to be significant ($P < 0.05$) at 7 months, and highly significant ($P < 0.01$) at 9 months of age.

4.6.2 Serum triglyceride concentration

The serum triglyceride concentrations at different

Table 23. Effect of chitin on serum triglyceride concentration of pigs

Age	Triglyceride concentration (mg per 100 ml)		
	Group 1 (0.5% chitin)	Group 2 (1% chitin)	Group 3 (Control)
Pre-treatment	75.50 ± 3.07	76.03 ± 3.12	74.57 ± 2.50
5 months	45.50 ± 2.32	43.50 ± 2.56	45.82 ± 2.13
7 months	53.95 ± 2.67	51.15 ± 2.30	54.50 ± 2.37
9 months	61.75 ± 2.88	58.50 ± 2.92	62.80 ± 2.88

ANOVA

Age	Source	DF	MS	F value
Pre-treatment	Treatment	2	3.2695	0.0641 NS
	Error	15	50.9906	
5 months	Treatment	2	9.5136	0.2876 NS
	Error	15	33.0747	
7 months	Treatment	2	19.3789	0.5079 NS
	Error	15	38.1479	
9 months	Treatment	2	30.1523	0.5976 NS
	Error	15	50.4515	

NS, Non-significant (P>0.05)

ages, for the three groups of pigs, are presented in Table 23 and Fig.19.

The serum triglyceride concentration, for the pigs in group 1, was 75.50 ± 3.07 mg per 100 ml at the pre-treatment stage. The concentrations at 5, 7 and 9 months of age were 45.50 ± 2.32, 53.95 ± 2.67 and 61.75 ± 2.88 mg per 100 ml respectively.

For the pigs in group 2, the serum triglyceride concentration at the pre-treatment stage was 76.03 ± 3.12 mg per 100 ml. The concentrations at 5, 7 and 9 months of age were 43.50 ± 2.56, 51.15 ± 2.30 and 58.50 ± 2.92 mg per 100 ml respectively.

In the case of the pigs in group 3, the serum triglyceride concentration was 74.57 ± 2.50 mg per 100 ml at the pre-treatment stage. The concentrations at 5, 7 and 9 months of age were 45.82 ± 2.13, 54.50 ± 2.37 and 62.80 ± 2.88 mg per 100 ml respectively.

When compared between groups, the pigs in group 2 showed lower levels of serum triglyceride than the pigs in group 1 and group 3 at all ages from 5 to 9 months. Eventhough the serum triglyceride levels appeared to be similar for the pigs in group 1 and group 3, the pigs in group 1 showed slightly lower levels.

The differences noticed between the groups in serum triglyceride concentration were found to be non-significant.

4.7 Fatty acid composition of muscle and backfat

The fatty acid profiles of muscle and backfat, for the three groups of pigs slaughtered at 5, 7 and 9 months of age, are presented in Table 24.

4.7.1 Muscle

At 5 months of age, the fatty acid composition of muscle for the pigs in group 1 showed 28.12 per cent palmitic, 49.30 per cent stearic and 22.20 per cent oleic acid, giving a total of 77.42 per cent saturated and 22.20 per cent unsaturated fatty acids.

For the pigs in group 2 at the same age, the fatty acids observed were palmitic 24.31 per cent, stearic 54.35 per cent, and oleic 21.30 per cent, giving a total of 78.66 per cent of saturated and 21.30 per cent of unsaturated fatty acids.

In the case of the pigs in group 3, 25.31 per cent palmitic, 52.66 per cent stearic and 22.00 per cent oleic acid were recorded in the muscle of pigs slaughtered at 5 months of age. A total of 77.97 per cent saturated and 22.00 per cent

Table 24. Effect of chitin on fatty acid composition of muscle and backfat of pigs

Age	Tissue	Treatment group	Fatty acid (Percentage)					
			Myristic (C 14:0)	Palmitic (C 16:0)	Stearic (C 18:0)	Oleic (C 18:1)	Saturated	Un-saturated
5 months	Muscle	Group 1		28.12	49.30	22.20	77.42	22.20
		Group 2		24.31	54.35	21.30	78.66	21.30
		Group 3		25.31	52.66	22.00	77.97	22.00
	Backfat	Group 1		22.21	47.91	29.87	70.12	29.87
		Group 2		22.98	47.63	28.51	70.61	28.51
		Group 3		21.89	48.54	29.40	70.43	29.40
7 months	Muscle	Group 1	1.42	23.91	51.47	23.20	76.80	23.20
		Group 2	1.50	20.85	50.50	26.70	72.85	26.70
		Group 3	1.70	41.91	43.64	12.45	87.25	12.45
	Backfat	Group 1	1.17	25.73	52.06	20.47	78.96	20.47
		Group 2	0.78	24.59	50.06	24.33	75.43	24.33
		Group 3	1.46	39.78	43.71	14.10	84.95	14.10
9 months	Muscle	Group 1	0.70	24.05	52.06	22.72	76.81	22.72
		Group 2	--	22.86	52.63	24.50	75.49	24.50
		Group 3	1.0	38.80	45.90	14.20	85.70	14.20
	Backfat	Group 1	0.71	20.61	49.89	28.31	71.21	28.31
		Group 2	--	16.69	55.60	24.69	75.29	24.69
		Group 3	0.60	36.50	49.75	13.10	86.85	13.10

unsaturated fatty acids were recorded for this group of animals.

At 7 months of age, the fatty acid composition of muscle for the pigs in group 1 showed 1.42 per cent myristic, 23.91 per cent palmitic, 51.47 per cent stearic and 23.20 per cent oleic acid. The total percentages of saturated and unsaturated fatty acids recorded were 76.80 and 23.20 respectively.

In the case of the pigs in group 2, slaughtered at 7 months of age, the muscle fatty acid composition showed 1.50 per cent myristic, 20.85 per cent palmitic, 50.50 per cent stearic and 26.70 per cent oleic acid. A total of 72.85 per cent saturated and 26.70 per cent unsaturated fatty acids were recorded.

For the pigs in group 3, slaughtered at the same age, the composition of fatty acid of muscle showed 1.70 per cent myristic, 41.91 per cent palmitic, 43.64 per cent stearic and 12.45 per cent oleic acid, giving a total of 87.25 per cent saturated and 12.45 per cent unsaturated fatty acids.

At 9 months of slaughter age, the fatty acid composition of muscle for the pigs in group 1 showed 0.70 per cent myristic, 24.05 per cent palmitic, 52.06 per cent stearic and 22.72 per cent oleic acid. The total saturated and

unsaturated fatty acids recorded were 76.81 and 22.72 per cent respectively.

For the pigs in group 2, slaughtered at the same age, the composition of fatty acid of muscle showed 22.86 per cent palmitic, 52.63 per cent stearic and 24.50 per cent oleic acid, giving a total of 75.49 per cent of saturated and 24.50 per cent of unsaturated fatty acids.

In the case of the pigs in group 3, slaughtered at 9 months of age the fatty acid composition of muscle showed 1.00 per cent myristic, 38.80 per cent palmitic, 45.90 per cent stearic and 14.20 per cent oleic acid. A total of 85.70 per cent saturated and 14.20 per cent unsaturated fatty acids were recorded.

4.7.2 Backfat

At 5 months of age, the fatty acid composition of backfat for the pigs in group 1 showed 22.21 per cent palmitic, 47.91 per cent stearic and 29.87 per cent oleic acid. The total saturated and unsaturated fatty acids recorded were 70.12 and 29.87 per cent respectively.

For the pigs in group 2, at the same age, the backfat fatty acid composition showed 22.98 per cent palmitic, 47.63 per cent stearic, and 28.51 per cent oleic acid. A total of

70.61 per cent saturated and 28.51 per cent unsaturated fatty acids were recorded.

In the case of the pigs in group 3, the fatty acid composition of backfat at 5 months of age showed 21.89 per cent palmitic, 48.54 per cent stearic, and 29.40 per cent oleic acid. A total of 70.43 per cent saturated and 29.40 per cent unsaturated fatty acids were recorded.

At 7 months of age, the fatty acid composition of backfat for the pigs in group 1 showed 1.17 per cent myristic, 25.73 per cent palmitic, 52.06 per cent stearic, and 20.47 per cent oleic acid, with a total of 78.96 per cent saturated and 20.47 per cent unsaturated fatty acids.

In the case of the pigs in group 2, the fatty acid composition of backfat at 7 months of age showed 0.78 per cent myristic, 24.59 per cent palmitic, 50.06 per cent stearic, and 24.33 per cent oleic acid. A total of 75.43 per cent of saturated and 24.33 per cent of unsaturated fatty acids were recorded.

For the pigs in group 3, the backfat fatty acid profile at 7 months of age comprised 1.46 per cent myristic, 39.78 per cent palmitic, 43.71 per cent stearic, and 14.10 per

cent oleic acid, giving a total of 84.95 per cent saturated and 14.10 per cent unsaturated fatty acids.

At 9 months of age, the backfat fatty acid composition for the pigs in group 1 showed 0.71 per cent myristic, 20.61 per cent palmitic, 49.89 per cent stearic, and 28.31 per cent oleic acid, giving a total of 71.21 per cent saturated and 28.31 per cent unsaturated fatty acids.

For the pigs in group 2, the backfat fatty acid profile at the same age comprised 19.69 per cent palmitic, 55.6 per cent stearic, and 24.69 per cent oleic acid, giving a total of 75.29 per cent saturated and 24.69 per cent unsaturated fatty acids.

In the case of the pigs in group 3, the backfat fatty acid composition at 9 months of age showed 0.60 per cent myristic, 36.50 per cent palmitic, 49.75 per cent stearic, and 13.10 per cent oleic acid. A total of 86.85 per cent saturated and 13.10 per cent unsaturated fatty acids were recorded.

Discussion

DISCUSSION

5.1 Digestibility of chitin

The digestibility of chitin in pigs was found to be about 80 per cent at 3 months of age and above 95 per cent at subsequent ages of 5 and 7 months. Hirano et al. (1990) reported that both chitin and chitosan were digested upto 35 to 83 per cent by rabbits and 88 to 98 per cent by hens and broilers. According to Muzzarelli (1986), mammals in general are able to digest chitin because they possess chitinase in their gastric mucosa and sometimes pancreas. Chitinases are synthesised by bacteria, fungi and the digestive glands of animals whose diet include chitin (Muzzarelli, 1977). The abomasum of ruminants (Lunblad, 1974) and the entrails of chicken (Muzzarelli, 1977) have been found to have significant chitinase activity to degrade chitin. Microbial degradation of chitin, particularly in ruminants, has been reported (Patton and Chandler, 1975; Patton et al., 1975). The observations of Patton (1972), White (1981) and Laflamme (1988) revealed that when animals were first exposed to a chitinous diet, digestion of chitin was poor, but digestion improved after a period of adaptation to chitinous materials. Husby et al. (1981) suggested that this improvement in chitin

digestion could be due to a shift in the ruminal microflora once chitinous material was added to the diet. Another possible explanation was that the microbial chitinase enzyme required chitin to induce its production. Hirano et al. (1990) also observed in rabbits that digestion of chitinous materials increased with adaptation to feeding. In the present experiment it was found that digestibility was low at three months of age, but was found to be appreciably higher at later ages of 5 and 7 months. This trend in digestibility might have been due to a period of adaptability during which there was a shift in the intestinal microflora of pigs or due to the development of stomach and intestine and consequent increase in the chitinase activity.

5.2 Patterns of growth in pigs

5.2.1 Body weight

5.2.1.1 Fortnightly body weight

The body weight of pigs in all the three groups showed considerable increase as age advanced from weaning to 40 weeks.

For the pigs in group 1, the body weight increased from 10.00 $\pm$ 0.69 kg at weaning to 1 7.04 $\pm$ 4.86 kg at 40th week of age, giving a net increase of 97.04 kg.

The pigs in group 2 showed an increase in body weight from 9.68 ± 0.82 kg at weaning to 108.30 ± 3.29 kg at 40th week. An overall gain in body weight of 98.62 kg was recorded for this group of pigs.

In the case of the pigs in group 3, the body weight increased from 9.00 ± 0.34 kg at weaning to 95.36 ± 1.37 kg at 40th week, with a net increase of 86.36 kg.

As compared with the pigs in group 3, the pigs in group 1 and group 2 showed higher total gains in weight by 10.68 and 12.26 kg respectively.

The chitin-fed groups of pigs showed higher body weights than the control group from the first fortnight, and the differences were found to be significant ($P < 0.05$ or 0.01) at all stages from 18th to 40th week of age. The differences observed between the two chitin-fed groups did not follow any definite trend across the ages, and also were not found to be significant at any stage.

The increased weight gain by the chitin-fed groups might be due to the growth-promoting effect of chitin.

According to Brody (1945), the body weight of animals increase from birth in a way characteristic to the species. Growth between 53 and 346 days has been reported to be linear

by Abarca and Tapia (1963). Ittner and Hughes (1938), by plotting live weight against age, obtained a smooth curve with a linear growth between 70 and 168 days with a diminishing increment after 168 days. A similar growth curve was obtained in the present study for pigs in all the three groups.

5.2.1.2 Daily gain in body weight

For the pigs in group 1, the average daily gain in weight increased from 148.62 ± 24.02 g at 10th week to a peak of 444.14 ± 15.19 g at 32nd week, thereafter declining gradually to 430.00 ± 17.01 g at 40th week of age.

The pigs in group 2 showed an increase in the average daily gain in weight from 138.00 ± 22.85 g at 10th week to a peak of 439.28 ± 9.94 g at 32nd week, followed by a gradual decline to 437.40 ± 12.31 g at 40th week of age.

In the case of the pigs in group 3, the average daily gain in weight increased from 131.62 ± 17.38 g at 10th week to a peak of 392.28 ± 9.34 g at 32nd week, and thereafter gradually declined to 384.60 ± 6.98 g at 40th week of age.

For all the groups of pigs, the average daily gain in weight increased progressively with advance in age reaching a peak at 32nd week of age, and thereafter gradually declined.

The finding of the present study is in agreement with that of Brody (1945) who also observed a similar trend in the growth patterns of pigs. However, he recorded a peak rate of gain at 10th month as against 8th month in the present study.

Morrison (1984) reported that the growth rate increased until a weight of about 102 kg and then decreased slightly. Kanis and Koops (1990), on the other hand, observed that the maximum daily gain was at live weight of 77 kg in gilts. The weights at maximum average daily gain observed in the present study were 84.87 ± 0.37 and 83.52 ± 1.84 kg for the pigs in group 1 and group 2 respectively, whereas the weight was considerably low for the pigs in group 3 (74.98 ± 1.34 kg).

The finding of the present study is not in agreement with that of Jung et al. (1989) who reported an age at highest average daily gain of 123.9 days in Large White Yorkshire females. However, they recorded a maximum average daily gain of 824 g as against 392.28 ± 9.34 to 444.15 ± 15.19 g observed in the present study. The higher rate of gain observed in their study may be due to the influence of temperate climate on the growth of pigs.

The finding of the present study is also at variance with that of Pavlik and Pulkrabek (1989), according to whom,

the age at highest average daily gain in Large White pigs averaged 116.7 to 167.1 days. The final body weight at 180 days was recorded at 95.91 ± 2.48 to 104.96 ± 2.94 kg in their study as against 56.54 ± 1.14 to 63.38 ± 2.75 kg at a similar age (26 weeks) in the present study. The reduced rate of gain observed in the present study may probably be due to the influence of tropical warm and humid climate of this location.

The average daily gains recorded for the pigs in group 1 and group 2 were found higher by 45.4 and 52.8 g respectively than that recorded for the pigs in group 3, at the end of the experiment.

The chitin-fed groups of pigs showed higher daily gains than the control group from the first fortnight, and the differences were found to be significant ($P < 0.05$ or 0.01) at all stages from 18th to 40th week of age. The differences observed between the two chitin-fed groups did not follow any definite trend across the ages, and also were not found to be significant at any stage.

The higher daily gains observed for the chitin-fed groups, as compared with that for the control group, indicate that the rate of gain in body weight of pigs was increased by feeding of chitin.

The growth promoting effect of chitin may be due to the glucosamine produced by the hydrolysis of chitin in the intestine of pigs.

Chitin and chitoson have been reported as non-toxic when fed to animals (Arai et al., 1968; Landes and Bough, 1976; Green and Krammer, 1979; Hirano et al., 1990).

N-acetyl glucosamine has been reported to function as a growth factor when added to baby foods (Gyorgy et al., 1955; Kent and Whitehouse, 1955).

Zilliken et al. (1954) postulated that the N-acetyl glucosamine moiety present in human milk and colostrum promoted growth of Bifidobacteria which in turn blocked other types of microorganisms and generated the lactase required for digestion of milk lactose in infants. Kehagias et al. (1977), and Bezkorovainy and Topouzian (1981) also reported that N-acetyl-D-glucosamine (GLc NAC, the monomer of chitin) and some of its derivatives stimulated growth of Bifidobacterium bifidus var. penn.

The promoting effect of N-acetyl-D-glucosamine glycosides on the growth of Bifidobacteria has been reported by Gyorgy et al. (1954) and Poupard et al. (1973). Supplement of N-acetyl- D-glucosamine glycosides in the diet has been

reported to increase lactose tolerance and body weight gain in rats (Zikakis and Austin, 1978; Austin et al., 1979).

Nutritional studies have shown that a combination of chitin and whey in isonitrogenous isocaloric diets enabled broiler chicken to utilise whey more efficiently resulting in higher weight gain and feed efficiency (Austin et al., 1981; Zikakis et al., 1982). This improvement was attributed to the growth of Bifidobacteria in the gut of chicken with concomitant increase in lactolytic activity brought about by addition of chitinous material to the diet. Spreen et al. (1984) also reported that chitinous materials enhanced the growth and proliferation of Bifidobacteria in the intestine of chicken.

Recent works have shown the growth promoting effect of chitin in broiler chicken. Nair et al. (1987) observed that broiler chicken, when fed on a commercial diet containing 0.5 per cent chitin, showed an increase of 10 per cent weight gain and 5 per cent feed intake with increased feed efficiency over the controls the diet of which did not contain chitin. Further, Nair et al. (1993) reported higher weight gain, feed efficiency, feed consumption and dressed weight in broiler chicken when chitin was added at 0.5 per cent level to the ration, as compared to the controls not receiving chitin.

Recently, N-acetyl-D-glucosamine and other amino sugars and glycoconjugates have been suggested for use as chemical probiotics (in place of bacterial probiotics and antibiotics) in the form of feed additives. These chemical substances, which act as competitive carbohydrates, can specifically abolish bacterial adhesion in the small intestine leading to reduction in the number of harmful bacteria to a minimum, while promoting directly or indirectly the proliferation of potentially useful strains (Pusztai et al., 1990).

5.2.1.3 Percentage rate of gain in weight

The percentage growth rate based on the previous month's weight, for all the three groups of pigs, increased from 12 weeks of age to a maximum at 16 weeks of age, rapidly falling thereafter as age of the animals increased. A similar pattern in the percentage rate of gain in body weight was observed by Bhagwat and Sahastrabuddhe (1971) and Saseendran (1979).

The initial increase in the percentage gain was probably due to the lesser gain obtained in the early part of the experiment when the piglings were exposed to the experimental feed. The relative decrease thereafter indicate

that the piglings might have adjusted well to the feeding regime.

5.2.2 Body length

5.2.2.1 Fortnightly body length

The body length of pigs in all the three groups increased with increase in age from weaning to 40th week.

The body length for the pigs in group 1 increased from 41.87 ± 0.95 cm at weaning to 92.60 ± 1.02 cm at 40th week of age, giving a net increase of 50.73 cm.

The body length for the pigs in group 2 increased from 41.50 ± 1.48 cm at weaning to 90.40 ± 0.39 cm at 40th week, showing an overall gain of 48.90 cm.

In the case of the pigs in group 3, the body length increased from 41.62 ± 0.90 cm at weaning to 87.40 ± 0.87 cm at 40th week of age. An overall increase of 45.78 cm was recorded.

The total gains in body length recorded for the pigs in group 1 and group 2 were found to be higher by 4.95 and 3.12 cm respectively as compared to the total gain recorded for the pigs in group 3.

The chitin-fed groups of pigs showed higher body lengths than the controls, and the differences were found to be significant ($P<0.05$ or 0.01) at 26th and 28th week and at all stages from 34th to 40th week of age. The differences observed between the chitin-fed groups did not follow any definite trend across the ages, and also were not found to be significant at any stage.

The higher gain in body length observed for the chitin-fed groups might be due to the effect of chitin on their growth.

The observation made in the present study agrees with that of Bowland et al. (1965) who reported that higher rates of carcass weight gain were associated with longer carcasses. The chitin-fed groups of pigs in the present study showed higher live weight and carcass weight gain than the pigs in the control group.

The finding of the present study also agrees with that of Shields et al. (1983) who reported that body length of pigs increased as body weight increased from birth to 145 kg body weight. Hladky and Fl'ak (1989) reported positive correlations of allometric growth between live weight and body measurements in Large White pigs. In the present study, the

body length of pigs in all the groups increased as live weight of animals increased with advance in age.

5.2.2.2 Daily gain in length

The average daily gain in length, for the pigs in group 1, increased from 0.089 ± 0.011 cm at 10th week, to a peak of 0.296 ± 0.006 cm at 26th week, thereafter declining gradually to 0.217 ± 0.005 cm at 40th week of age.

For the pigs in group 2, the average daily gain in length increased from 0.098 ± 0.018 cm at 10th week to a peak of 0.286 ± 0.009 cm at 26th week, thereafter showing a gradual decline to 0.215 ± 0.006 cm at 40th week.

In the case of the pigs in group 3, the average daily gain in length showed an increase from 0.08 ± 0.014 cm at 10th week to a peak of 0.263 ± 0.008 cm at 24th week followed by a gradual decline to 0.205 ± 0.004 cm at 40th week of age.

The average daily gain in length reached a peak at 26th week for the pigs in group 1 and group 2, and at 24th week for the pigs in group 3.

As compared with the pigs in group 3, the pigs in group 1 and group 2 showed daily gains in length higher by 0.012 and 0.010 cm respectively, at the end of the experiment.

The pigs in both group 1 and group 2 showed higher rates of gain than the pigs in group 3 at all stages. The differences noticed were found to be highly significant ($P<0.01$) between the pigs in group 1 and group 3, and significant ($P<0.05$) between the pigs in group 2 and group 3 at 26th week, and significant ($P<0.05$) between the pigs in group 1 and group 3 at 28th week. The differences noticed between the two chitin-fed groups were not found to be significant, and also did not follow any definite trend across the ages.

The increased rates of average daily gain in length observed for the pigs in group 1 and group 2 might be due to the influence of chitin on growth.

Body length reached the maximum rate of gain at an earlier age of 24 to 26 weeks as compared with body weight which reached the maximum rate of gain at a later age of 32 weeks. This may be due to the fact that length of body is a measure of bone growth (Pomeroy, 1955) and bone is an early maturing tissue making up greater proportion of its growth in earlier life than do muscle or fat which make up the greatest proportion of live weight in full grown animals (Palsson, 1955).

5.2.3 Height at withers

5.2.3.1 Fortnightly height

The height of pigs in all the three groups showed an increase as the animals advanced in age from weaning to 40th week.

The pigs in group 1 showed an increase in height from 37.75 ± 0.67 cm at weaning to 66.40 ± 0.92 cm at 40th week, thereby registering a total gain of 28.65 cm.

In the case of the pigs in group 2, the height increased from 36.75 ± 1.03 cm at weaning to 66.00 ± 1.30 cm at 40th week, giving a net increase of 29.25 cm.

The pigs in group 3 showed an increase in height from 36.37 ± 0.49 cm at weaning to 64.20 ± 0.91 cm at 40th week with an overall gain of 27.83 cm.

The total gains in height recorded for the pigs in group 1 and group 2 were greater than that recorded for the pigs in group 3 by 0.82 and 1.42 cm respectively.

The pigs in both group 1 and group 2 showed consistently greater heights than the pigs in group 3. The differences in height were found to be significant ($P<0.05$) between the pigs in group 1 and group 3 at 12th and 16th week

of age. Eventhough the pigs in group 1 tended to have slightly higher values than the pigs in group 2, these differences were found to be non-significant.

The increased heights observed for the pigs in group 1 and group 2 might be due to the effect of chitin on growth.

Dubreuil *et al*. (1989) reported significant correlation between daily gain in weight and height at withers. In the present study, the animals in group 1 and group 2 showed higher live weights and higher average daily gains in weight than those in group 3.

The increase in height with increase in age and weight of animals in all the groups, as observed in the present studs, follows the findings of Hladky and Fl'ak (1989) who observed positive correlations of allometric growth of body measurements with live weight.

5.2.3.2 Daily gain in height

The average daily gain in height for the pigs in group 1 increased from 0.089 $\pm$ 0.011 cm at 10th week to a peak of 0.168 $\pm$ 0.006 cm at 20th week, and thereafter declined gradually to 0.126 $\pm$ 0.002 cm at 40th week of age.

The pigs in group 2 showed an increase in the average daily gain in height from 0.081 $\pm$ 0.011 cm at 10th week to a

peak of 0.167 ± 0.009 cm at 20th week, followed by a gradual decline to 0.129 ± 0.005 cm at 40th week of age.

In the case of the pigs in group 3, the average daily gain in height increased from 0.080 ± 0.009 cm at 10th week to a peak of 0.157 ± 0.008 cm at 20th week, and gradually declined thereafter to 0.122 ± 0.002 cm at 40th week of age.

For the pigs in all the groups, the average daily gain in height reached a peak at 20th week of age.

Compared with the pigs in group 3, the pigs in group 1 and group 2 showed higher daily gains in height by 0.004 and 0.007 cm respectively, at the end of the experiment.

The pigs in both group 1 and group 2 showed higher rates of gain in height than the pigs in group 3 at all stages. The differences were found to be highly significant ($P<0.01$) between the pigs in group 1 and group 3 at 12th week. The differences noticed between the two chitin-fed groups were not found to be statistically significant, and also did not follow any definite pattern across the ages.

The higher rates of gain in height observed for the pigs in group 1 and group 2 might be due to the influence of chitin on growth.

The pigs in all the groups attained their maximum rate of growth in height at an earlier age of 20 weeks, whereas the maximum rate of growth in body weight was attained at a later age of 32 weeks. This may be attributed to the fact that height is a measure of bone growth (Pomeroy, 1955) and bone is an earlier maturing tissue than muscle and fat which make up the greatest proportion of live weight in full grown animals (Palsson, 1955). Furthermore, limb bones are relatively better developed at birth and hence are early maturing (Palsson, 1955).

5.2.4 Body girth (front)

5.2.4.1 Fortnightly body girth (front)

The body girth (front) of pigs in all the groups showed considerable increase from weaning to 40th week of age.

The pigs in group 1 showed an increase from 47.75 $\pm$ 1.68 cm at weaning to 109.40 $\pm$ 2.54 cm at 40th week of age. A total gain of 61.65 cm was recorded for this group of pigs.

The girth (front) for the pigs in group 2 increased from 47.75 $\pm$ 1.49 cm at weaning to 109.80 $\pm$ 3.02 cm at 40th week, giving a net gain of 62.05 cm.

In the case of the pigs in group 3, the girth (front) increased from 47.87 $\pm$ 0.85 cm at weaning to 107.00 $\pm$ 1.09 cm

at 40th week. An overall gain of 59.13 cm was recorded for this group of pigs.

The total gains in girth (front) recorded for the pigs in group 1 and group 2 were higher by 2.52 and 2.92 cm respectively than that recorded for the pigs in group 3.

The pigs in both group 1 and group 2 had greater girths (front) than the pigs in group 3. The differences observed were found to be significant ($P<0.05$) between the pigs in group 1 and group 3 at 30th and 32nd week. Except at 32nd week when the pigs in group 1 showed significantly higher ($P<0.05$) girth than the pigs in group 2, the differences noticed between these two groups were not found to be significant at any stage, and also did not follow any definite trend across the ages.

The higher girths (front) recorded for the chitin-fed groups might be due to the effect of chitin on their growth.

Dubreuil et al. (1989) reported significant correlation between daily gain in weight and chest circumference. Delate and Basu (1990) reported that chest circumference alone accounted for 79.0 to 96.5 per cent and chest circumference plus body length for 87.5 to 98.5 per cent of the variation in body weight among animals. In the present study, the chitin-fed groups also showed higher body weights

and higher average daily gains in weight as compared with the pigs in the control group.

5.2.4.2 Daily gain in body girth (front)

The pigs in group 1 showed an increase in the average daily gain in body girth (front) from 0.170 ± 0.023 cm at 10th week to a peak of 0.353 ± 0.010 cm at 20th week, followed by a gradual decline to 0.276 ± 0.006 cm at 40th week of age.

For the pigs in group 2, the average daily gain in body girth (front) increased from 0.178 ± 0.019 cm at 10th week to a peak of 0.323 ± 0.012 cm at 20th week, and thereafter declined gradually to 0.277 ± 0.009 cm at 40th week of age.

In the case of the pigs in group 3, the average daily gain in body girth (front) increased from 0.170 ± 0.023 cm at 10th week to a peak of 0.313 ± 0.008 cm at 24th week, and gradually declined thereafter to 0.260 ± 0.004 cm at 40th week of age.

The average daily gain in body girth (front) reached a peak at 20th week for the pigs in group 1 and group 2, and at 24th week for the pigs in group 3.

The pigs in group 1 and group 2 showed higher daily

gains in body girth (front) than the pigs in group 3 by 0.016 and 0.017 cm respectively, at the end of the experiment.

The pigs in both group 1 and group 2 showed higher rates of gain in body girth (front) than the controls at all stages. The differences noticed between the pigs in group 1 and group 3 were found to be significant ($P<0.05$) at 14th, 26th and 34th week, and highly significant ($P<0.01$) at 20th and 22nd week. Similarly, the differences noticed between the pigs in group 2 and group 3 were found to be significant ($P<0.05$) at 14th, 20th and 34th week. Except at 22nd week when the pigs in group 1 showed significantly higher ($P<0.05$) girth (front) than the pigs in group 2, the differences noticed between these two groups were not found significant at any stage. Also, the differences between these two groups of chitin-fed animals did not follow any definite trend across the ages.

The increased rates of gain in body girth (front) recorded for the pigs in group 1 and group 2 might be due to the influence of chitin on growth.

Body girth (front) reached the peak rate of gain at an earlier age of 20 to 24 weeks as compard with body weight which reached the peak rate of gain at a later age of 32 weeks. This is because of the early maturing nature of

Skeleton which contributes, along with muscle and fat, to the development of body girth (front) (Palsson, 1955).

5.2.5 Body girth (hind)

5.2.5.1 Fortnightly body girth (hind)

The average body girth (hind) of the pigs in the three groups increased considerably from weaning to 40th week of age.

The pigs in group 1 showed an increase in body girth (hind) from 50.62 ± 1.51 cm at weaning to 115.0 ± 2.40 cm at 40th week. A total gain of 64.38 cm was recorded for this group of pigs.

In the case of the pigs in group 2, the body girth (hind) increased from 52.75 ± 1.56 cm at weaning to 116.40 ± 2.31 cm at 40th week of age, giving a net increase of 63.65 cm.

In the case of the pigs in group 3, the body girth (hind) increased from 53.12 ± 1.45 cm at weaning to 112.80 ± 1.31 cm at 40th week. An overall increase of 59.68 cm was recorded for this group of pigs.

The pigs in group 1 and group 2 had higher total gains in girth (hind) than the pigs in group 3 by 4.7 and 3.97 cm respectively.

Eventhough the differences noticed between the groups were not found to be statistically significant, the pigs in group 1 and group 2 showed higher values than the pigs in group 3. The differences noticed between the pigs in group 1 and group 2 did not follow any definite trend across the ages.

The increased gains in body girth (hind) observed for the pigs in group 1 and group 2 might be due to the effect of chitin on their growth.

5.2.5.2 Daily gain in body girth (hind)

The pigs in group 1 showed an increase in the average daily gain in body girth (hind) from 0.080 $\pm$ 0.009 cm at 10th week to a peak of 0.341 $\pm$ 0.023 at 24th week, followed by a gradual decline to 0.281 $\pm$ 0.008 cm at 40th week of age.

For the pigs in group 2, the average daily gain in body girth (hind) increased from 0.089 $\pm$ 0.011 cm at 10th week to a peak of 0.307 $\pm$ 0.011 cm at 26th week, and thereafter declined gradually to 0.290 $\pm$ 0.008 cm at 40th week of age.

In the case of the pigs in group 3, the average daily gain in body girth (hind) increased from 0.098 $\pm$ 0.013 cm at 10th week to a peak of 0.278 $\pm$ 0.016 cm at 24th week, and gradually declined thereafter to 0.261 $\pm$ 0.008 cm at 40th week of age.

The average daily gain in body girth (hind) reached a peak at 24th week for the pigs in group 1 and group 3, and at 26th week for the pigs in group 2.

The pigs in group 1 and group 2 showed higher daily gains in body girth (hind) than the pigs in group 3 by 0.020 and 0.029 cm respectively, at the end of the experiment.

The pigs in both group 1 and group 2 showed higher rates of gain in body girth (hind) than the pigs in group 3 from 16th week onwards. The differences noticed between the pigs in group 1 and group 3 were found to be significant ($P<0.05$) at 18th, 22nd, 28th and 30th week and highly significant ($P<0.01$) at 26th week. The differences noticed between the pigs in group 2 and group 3 were found to be significant ($P<0.05$) at 22nd and 26th week. The differences noticed between the two chitin-fed groups were not found to be statistically significant at any stage, and also did not follow any definite trend across the ages.

The increased rates of gain in body girth (hind) observed for the pigs in group 1 and group 2 might be due to the influence of chitin on growth.

5.2.6 Feed intake

Feed intake, in terms of total feed consumption as

well as daily feed intake, increased progressively with increase in age and weight of animals in all the groups.

Eventhough the total feed consumption increased similarly for all the groups, it showed a slight difference in pattern from 18th week onwards. From 18th week, the pigs in group 1 and group 2 showed an increased consumption as compared with the pigs in group 3.

The pigs in group 1 and group 2 showed a similar increasing trend in feed consumption upto 32nd week. Thereafter, the pigs in group 2 showed a sudden increase in consumption in comparison with the pigs in group 1, and at the end of the experiment at 40 weeks, the pigs in group 2 showed a higher consumption by 16.68 and 17.48 kg as compared with the pigs in group 1 and group 3 respectively.

Eventhough the pigs in group 2 showed higher feed consumption than the pigs in group 1 and group 3, the differences were found to be non-significant. The pigs in group 2, however, showed a higher weight (108.30 $\pm$ 3.29 kg) at the end of the experiment as compared with the pigs in group 1 (107.04 $\pm$ 4.86 kg) and group 3 (95.36 $\pm$ 1.37 kg).

The same was the trend in daily feed intake. From 10th to 40th week of age, the daily feed intake showed a progressively increasing trend from 0.821 $\pm$ 0.015 to 1.988 $\pm$

0.098 kg for group 1, 0.827 ± 0.025 to 2.062 ± 0.071 kg for group 2, and 0.807 ± 0.016 to 1.985 ± 0.056 kg for group 3.

The differences in daily feed intake observed between the groups were found to be non-significant.

5.2.7 Feed conversion efficiency

The animals in all the groups showed a poor feed conversion efficiency upto 14th week of age (4.33 ± 0.58 to 6.66 ± 1.07 for group 1, 4.36 ± 0.31 to 7.02 ± 1.02 for group 2 and 4.88 ± 0.39 to 6.92 ± 0.97 for group 3). The feed conversion efficiency improved thereafter and was kept stabilised from 16th to 30th week for all the groups (3.33 ± 0.14 to 3.83 ± 0.07 for group 1, 3.39 ± 0.08 to 3.98 ± 0.25 for group 2, and 3.62 ± 0.10 to 4.43 ± 0.32 for group 3). The feed conversion efficiency was found to be poor from 32nd to 40th week (3.97 ± 0.06 to 4.52 ± 0.21 for group 1, 4.01 ± 0.08 to 4.70 ± 0.04 for group 2, and 4.21 ± 0.12 to 5.19 ± 0.09 for group 3).

The chitin-fed groups showed higher feed conversion efficiencies than the control group. The differences observed were found to be significant ($P<0.05$) at 18th week and highly significant ($P<0.01$) at 20th week. The differences were also found to be significant ($P<0.05$) at 38th and 40th week of age.

There was no significant difference in feed conversion efficiency between the chitin-fed groups.

The better feed conversion efficiency shown by the chitin-fed groups may be due to the effect of chitin on feed utilisation and growth rate in pigs.

An increased feed conversion efficiency noticed between 16th and 30th week was due to the higher rate of weight gain during this period.

Rate of growth has been reported to be highly correlated with feed efficiency (Robison, 1976). Kastarov (1989) reported that the correlation of feed conversion ratio with average daily gain was -0.79 in Large White pigs finished from 30 to 90 kg body weight.

A decrease in feed efficiency with increase in age and body weight has been reported. Brooks et al. (1964) reported that from weaning to 220 lb live weight the feed efficiency decreased at successive weight intervals of 50 lb. A similar study by Koinarski (1983) revealed that the feed efficiency from birth to 40, 60, 80, 90, 100, 120 and 130 kg decreased as the weight of the animals increased. Bittante et al. (1989a) reported that the feed efficiency decreased in the successive age periods of 10-22 weeks, 22-34 weeks and 34-42 weeks. Kumar and Barsaul (1987) observed a higher daily consumption

and feed conversion ratio for the period from 126 to 159 days than for the period from 1 to 126 days of age. A similar pattern of decreasing feed conversion efficiency with increasing age and weight of animals was observed in the present study.

A poor feed conversion efficiency from weaning to 14th week, as observed in the present study, may be due to the lesser body weight gained during this period because of stress due to weaning of the piglets and their exposure to the experimental diet. The feed efficiency improved when the piglings were adapted to the new environment and diet.

5.3 Carcass characteristics

5.3.1 Live weight at slaughter

The animals in group 1 showed an average weaning weight of 10 kg at the beginning of the experiment. This group of animals showed an average weight of 56.8 kg at 5 months, 88.0 kg at 7 months, and 99.5 kg at 9 months of age. The pigs in this group showed an increase of 46.8 kg at 5 months, 78.0 kg at 7 months and 89.5 kg at 9 months of age from weaning weight. From 5 to 7 months of age, these animals showed 54.9 per cent increase in weight. The increase in weight between 7 and 9 months was 13.06 per cent. An overall

increase of 75.17 per cent was recorded between 5 and 9 months of age.

The animals in group 2 showed an average weight of 9.68 kg at weaning, 56.2 kg at 5 months, 82.5 kg at 7 months, and 101.5 kg at 9 months of age. This group of animals showed an increase in weight of 46.5 kg from weaning to 5 months, 72.8 kg from weaning to 7 months and 91.8 kg from weaning to 9 months of age. The increase in weight recorded from 5 to 7 month and from 7 to 9 month were recorded at 46.8 and 23.03 per cent respectively. The overall increase from 5 to 9 month was found to be 80.60 per cent.

The pigs in group 3 recorded an average weight of 9 kg at weaning, 44.7 kg at 5 months, 71.5 kg at 7 months, and 93.0 kg at 9 months of age. From weaning to 5, 7 and 9 months of age, the gains in body weight averaged 35.7, 62.5 and 84.0 kg, respectively. The increase in body weight was 59.95 per cent from 5 to 7 months and 30.06 per cent from 7 to 9 months of age. An overall increase of 108 per cent could be observed between 5 and 9 months of age.

The animals in all the groups showed a higher gain in live weight between 5 and 7 months of age. The rate of growth noted between 7 and 9 months of age was poor in all the groups.

The increase in live weight recorded between 5 and 7 months of age for animals in all the three groups may be due to the higher rate of growth attained during this period.

The finding closely follows the observation of Bywaters and Willham (1935) who reported linear growth in weight of pigs between about 70 and 168 days of age with a diminishing increment after 168 days. Matousek et al. (1989) also reported that the point of inflection of growth curve occurred at 169.5 days of age. These ages (168 or 169.1 days) at which maximum growth rate is attained fall in the range of 5 to 7 months during which the pigs in the present study showed a higher gain in weight, and as expected, showed a lower gain at the subsequent age period of 7 to 9 months.

The observation made in the present study closely agrees with that of Brody (1945) who reported a higher increment in body weight between 6 and 8 months than between 8 and 10 months of age.

The finding of the present study also closely follows the observation made by Hwang et al. (1984), according to whom, lean steadily increased in the fattening period, but decreased after 80 kg slaughter weight. In the present study, maximum rate of growth was noticed between 5 and 7 months during which weight increased from 44.7 to 56.5 kg at 5 months

to 71.5 to 88.0 kg at 7 months of age, registering a gain of 46.8 to 59.95 per cent, whereas the gain was noticed to decrease between 7 and 9 months during which the weight increased from 71.5 to 88.0 kg at 7 months to 93.0 to 101.5 kg at 9 months of age, registering a gain of only 13.06 to 30.06 per cent.

Matousek et al. (1990) observed that while the average daily gain was similar from 30 days to slaughter at 6, 7 and 8 months of age, it showed a decrease at 9 months of age.

The highest overall increase of 91.8 kg from weaning to 9 months of age was observed for the animals in group 2 followed by 89.5 kg for those in group 1. The lowest gain in weight (84.0 kg) from weaning to 9 months was recorded for the pigs in group 3.

The increased gain in weight observed for the chitin-fed groups may be due to the effect of chitin on growth of pigs. Chitin, when fed at 1 per cent level in the feed, effected the maximum gain in weight of pigs.

This finding of increased weight gain due to feeding of chitin is in agreement with that of Zikakis and Austin (1978) and Austin et al. (1979) who observed higher body weight gain in rats fed N-acetyl-D-glucosamine glycosides. Addition of chitin in ration containing whey has been reported

to have effected higher weight gain and feed efficiency in poultry (Austin et al., 1981; Zikakis et al., 1982).

The finding of the present study is in agreement with those of Nair et al. (1987) and Nair et al. (1993) who observed higher weight gain and feed efficiency in broiler chicken when chitin was added to the ration at 0.5 per cent level.

5.3.2 Carcass length

The carcass length for the animals in group 1 increased from 64 cm at 5 months to 79 cm at 7 months and to 80 cm at 9 months of age. An increase of 25 per cent could be observed in the carcass length from 5 to 9 months. Maximum growth in carcass length was observed between 5 and 7 months (23.43 per cent) and very little (1.26 per cent) between 7 and 9 months of age.

In the case of the animals in group 2, the carcass length increased from 65 cm at 5 months to 77 cm at 7 months and to 89 cm at 9 months of age. An increase of 36.9 per cent in carcass length was observed between 5 and 9 months of age. An increase of 18.46 per cent was observed between 5 and 7 months, and 15.6 per cent between 7 and 9 months of age.

The carcass length for the animals in group 3 showed

an increase from 62 cm at 5 months to 74 cm at 7 months and to 77 cm at 9 months of age. The maximum increase of 19.35 per cent could be observed between 5 and 7 months of age, whereas this increase was only 4 per cent between 7 and 9 months. The overall increase in carcass length recorded between 5 and 9 months was 24.2 per cent.

The trend in the gain in carcass length was similar to that of live weight gain. The maximum increase was observed between 5 and 7 months, thereafter decreasing considerably. The maximum increase in carcass length between 5 and 7 months may be due to the maximum rate of growth of animals during this period.

The increase in carcass length through the successive stages of slaughter indicate that body length continued to increase with age of the animals as was found in the present study. This is supported by Shields et al. (1983) who reported that body length increased as weight of the pigs increased.

The finding of the present study is in agreement with that of Bowland et al. (1965) who reported that higher rates of carcass weight gain were associated with longer carcasses. In the present study, the chitin-fed groups, as compared with

the controls, had higher rates of weight gain associated with greater body length.

5.3.3 Weight of ham

The weight of ham showed an increase from 9 kg at 5 months to 13.44 kg at 7 months and to 14.9 kg at 9 months of age, for the pigs in group 1. The percentage increase noted was 49.33 per cent from 5 to 7 months and 10.86 per cent from 7 to 9 months of age. An overall increase of 65.55 per cent was noted from 5 to 9 months of age.

In the case of the animals in group 2, the weight of ham showed an increase from 5 months (9.1 kg) to 7 months (13.0 kg) and to 9 months (15.3 kg). There was an increase of 42.85 per cent in the ham weight from 5 to 7 months and 17.7 per cent from 7 to 9 months of age. An overall increase of 68.13 per cent in the ham weight was observed from 5 to 9 months of age.

The animals in group 3 showed an increase in the weight of ham from 6.44 kg at 5 months to 10.14 kg at 7 months and to 13.26 kg at 9 months of age. An increase of 57.45 per cent from 5 to 7 months and 30.76 per cent from 7 to 9 months was recorded. An overall increase of 105.9 per cent was observed from 5 to 9 months of age.

The weight of ham showed an increase from 5 to 9 months of age in all the groups of animals. The percentage of growth was higher between 5 and 7 months than between 7 and 9 months of age.

The weight of ham also followed the same trend as the gain in live weight showing an increase in the rate of gain upto 7 months followed by a decreasing rate thereafter.

The chitin fed groups showed higher weights of ham than the controlls at each slaughter age. However, the weight of ham as percentage of carcass weight without head did not show much difference between the groups at 5 months (25.25 to 26.0 per cent), 7 months (24.43 to 25.0 per cent) or 9 months (21.38 to 21.59 per cent) of age.

The percentages of ham weight to carcass weight as observed in the present study, are in agreement with the observation of Mishra et al. (1989) who reported that ham percentages varied from 18.73 to 25.3 among various weight groups of pigs from 51 to over 91 kg in Large White Yorkshire pigs.

The decrease in percentage of ham weight to body weight with increasing age and body weight indicate that the ham attains its maximum rate of gain at an earlier age than

the body as a whole, and hence the ham weight as percentage of body weight decreases as body weight increases.

The finding of the present study is in agreement with the reports of Anjaneyulu et al. (1982), Matousek et al. (1988) and Mishra et al. (1989) who observed a decrease in ham percentage with increase in weight of animals.

5.3.4 Backfat thickness

The backfat thickness for the animals in group 1 showed an increase from 0.9 cm at 5 months to 2.4 cm at 7 months and to 2.56 cm at 9 months of age. The increase in backfat thickness was higher between 5 and 7 months (1.53 cm) as compared to that between 7 and 9 months of age (0.13 cm).

In the case of the pigs in group 2, the backfat thickness increased from 1.10 cm at 5 months to 2.23 cm at 7 months and to 2.9 cm at 9 months of age. The increase in backfat thickness was higher between 5 and 7 months (1.13 cm) than between 7 and 9 months (0.67 cm) of age.

The backfat thickness for the pigs in group 3 increased from 1.13 cm at 5 months to 2.46 cm at 7 months and to 3.16 cm at 9 months of age. The increase was more between 5 and 7 month (1.33 cm) than between 7 and 9 months (0.70 cm) of age.

The deposition of backfat was maximum between 5 and 7 months of age in all groups of animals. The maximum deposition of backfat between 5 and 7 months followed the pattern of rate of gain in body weight noted in all groups of pigs.

The comparatively lower backfat thickness of pigs in the chitin-fed groups could be attributed to their higher growth rate associated with higher lean deposition. The hypolipidemic action of chitin might have also played a role in the lower deposition of backfat in the chitin-fed groups.

Increase in backfat thickness with increase in age and weight has been reported by several workers (Davey et al., 1969; Quijandria and Robison, 1971; Standal, 1973; Anjaneyulu et al., 1982; Otto et al., 1983; Shields et al., 1983; Kolesen and Kurilo, 1988; Mishra et al., 1989; Matousek et al., 1990). Davey et al. (1969) reported that the relation between separable fat or lean and age was nearly linear, at least until about 40 weeks of age (130 to 150 kg live weight). Similarly Quijandria and Robison (1971) and Standal (1973) have suggested that backfat deposition is linearly associated with age or weight.

Literature regarding the hypolipidemic action of chitin in pigs is scanty.

5.3.5 Eye-muscle area

The eye-muscle area showed an increase from 24.56 cm^2 at 5 months to 34.43 cm^2 at 7 months and to 37.75 cm^2 at 9 months of age, for the pigs in group 1. The increase was 40.18 per cent between 5 and 7 months and 9.64 per cent between 7 and 9 months of age.

In the case of the pigs in group 2, it increased from 23.22 cm^2 at 5 months to 34.73 cm^2 at 7 months and to 40.88 cm^2 at 9 months of age. An increase of 49.56 per cent was recorded between 5 and 7 months and 17.70 per cent between 7 and 9 months of age.

The eye-muscle area for the pigs in group 3 increased from 18.43 cm^2 at 5 months to 31.18 cm^2 at 7 months and to 33.30 cm^2 at 9 months of age. The increase observed between 5 and 7 months of age was 69.18 per cent and between 7 and 9 months 6.79 per cent.

For all groups of pigs, the eye-muscle area showed an increase from 5 to 9 months or age. However, the percentage of growth was much higher between 5 and 7 months than between 7 and 9 months of age. The higher percentage of gain in eye-muscle area between 5 and 7 months of age may be attributed to the higher rate of growth of animals during this period.

The increase in eye-muscle area with increase in age and weight of animals as observed in the present study is in agreement with the reports of Babatunde et al. (1966), Meeker (1973), Vaclavovsky et al. (1988) and Matousek et al. (1990).

The pigs in group 1 and group 2 showed greater eye-muscle areas than the pigs in group 3. The greater eye-muscle areas observed in the chitin-fed groups, as compared with the controls, at each stage of slaughter, may be attributed to their higher growth rate and feed efficiency. The pigs in group 2 showed the highest eye-muscle area and the pigs in group 3 the lowest at the later stages of slaughter.

5.3.6 Weight of leaf fat

At the time of slaughter at 5 months practically no quantity of leaf fat could be recovered.

In the case of the pigs in group 1, 0.55 kg of leaf fat was recorded at 7 months and 1.6 kg at 9 months of age.

In the case of the pigs in group 2, 0.50 kg of leaf fat was recorded at 7 months and 1.75 kg at 9 months of age.

The quantity of leaf fat recorded for the animals in group 3 was 0.525 kg at 7 months and 1.6 kg at 9 months of age.

There was practically no difference in the amount of leaf fat between the groups at 7 or 9 months of age though the amount of leaf fat increased about three times from 7 to 9 months of age.

But when the amount of leaf fat was expressed as percentage of live weight, it was found higher for the animals in group 3 as compared with those in group 1 and group 2 at 7 months (0.734 vs. 0.625 and 0.606 per cent) and at 9 months (1.72 vs. 1.67 and 1.69 per cent). The percentages of leaf fat to live weight were found to be lower for the chitin-fed groups indicating a clear hypolipidemic action of chitin in these groups of animals. The finding of the present study agrees well with the report of Zikakis et al. (1982) who observed that chicken, when fed chitin in the diet, had significantly lower weight of abdominal fat pads as compared with those fed a diet without chitin.

The weight of leaf fat and percentage of leaf fat increased with increase in age and weight of animals in the three groups. This finding is in agreement with the reports of Babatunde et al. (1966); Doornenbal (1971); McKay et al. (1984) and Christon (1988). Doornenbal (1971) reported that beyond 50 kg live weight, there was rapid increase in fat deposition. McKay et al. (1984) observed that the majority of leaf fat deposition occurred when the animals approached 90 kg

live weight. In the present study also, maximum deposition of leaf fat was observed when the animals were slaughtered at 9 months of age (93.0 to 101.5 kg live weight).

5.3.7 Dressing percentage

The dressing percentage (with head), in the case of the pigs in group 1, increased from 68.62 at 5 months to 70.11 at 7 months and to 79.47 at 9 months of age. An increase of 1.89 per cent was recorded between 5 and 7 months and 9.36 per cent between 7 and 9 months of age, for this group of animals.

In the case of the pigs in group 2, the dressing percentages observed were 68.77, 70.33 and 77.09 at 5, 7 and 9 months of age respectively. The increase in dressing percentage was lower between 5 and 7 months (1.6 per cent) than between 7 and 9 months (6.72 per cent) of age.

The dressing percentage for the pigs in group 3 increased from 63.57 at 5 months to 66.44 at 7 months and to 74.08 at 9 months of age. The increase in dressing percentage was higher between 7 and 9 months (7.64 per cent) than between 5 and 7 months (2.87 per cent).

The dressing percentage (with head) increased with increase in age and weight of animals in all the groups.

Considerable difference in dressing percentage (with head) was noticed between the control and chitin-fed groups. As compared with the chitin-fed groups, the control group of animals showed much lower dressing percentages at all slaughter ages. There was practically no difference in dressing percentage between the two chitin-fed groups (68.62 to 68.77, 70.11 to 70.37, and 77.09 to 79.47 at 5, 7 and 9 months, respectively).

The increase in dressing percentage (with head) was noted to be much lower between 5 and 7 months than between 7 and 9 months of age, for all the groups of animals.

In the case of dressing percentage (without head), a similar trend was observed.

The dressing percentage (without head), for the pigs in group 1, increased from 62.5 at 5 months to 63.06 at 7 months and to 72.25 at 9 months of age. The increase in dressing percentage without head was much less between 5 and 7 months (0.56 per cent) than between 7 and 9 months (9.19 per cent).

For the pigs in group 2, the dressing percentages recorded were 62.27, 63.03 and 70.34 at 5, 7 and 9 months of age respectively. An increase of only 0.76 per cent was

recorded between 5 and 7 months as compared with 7.31 per cent between 7 and 9 months of age.

In the case of the control group of pigs, dressing percentages of 57.04, 58.04 and 66.66 were recorded at 5, 7 and 9 months of age respectively. The increase in dressing percentage noted between 5 and 9 months (1.0 per cent) was much lower than that between 7 and 9 months (8.62 per cent) of age.

The dressing percentage (without head) tended to increase with increase in age and weight of animals in all the groups.

The dressing percentage (without head) was found to vary noticeably between the control and the chitin-fed groups of pigs at each stage of slaughter. The animals in the control group showed much lower dressing percentages as compared with the chitin-fed groups. There was practically no difference in dressing percentage between the two chitin-fed groups (62.27 to 62.5, 63.03 to 63.06, and 70.34 to 72.25 at 5, 7 and 9 months, respectively.

The increase in dressing percentage (without head) was found to be higher between 7 and 9 months than between 5 and 7 months of age, for all the groups of animals.

The higher dressing percentage (with or without head) recorded for the chitin-fed groups may be attributed to the effect of feeding chitin and the consequent higher growth rate.

A higher increase in dressing percentage observed between 7 and 9 months of age over that between 5 and 7 months of age may be due to the deposition of fat as observed in the case of leaf fat. A lower proportion of visceral organs and intestine to body weight at higher ages might have also contributed to the higher increase in dressing percentage at the later age between 7 and 9 months.

The increase in dressing percentage with increase in weight of animal as observed in the present study is in agreement with many reports (Babatunde et al., 1966; Anjaneyulu et al., 1982; Schmitten et al., 1986; Albar et al., 1990; Matousek et al., 1990).

5.4 Weight of internal organs

The total weight of internal organs (heart, liver, kidney, lungs and spleen), in the case of the pigs in group 1, showed an increase from 2.245 kg at 5 months to 3.44 kg at 7 months and then to 3.48 kg at 9 months of age. The increase noted was 53.22 per cent from 5 to 7 months and 1.16 per cent

from 7 to 9 months of age. An overall increase of 55.0 per cent was recorded from 5 to 9 months of age.

In the case of the animals in group 2, the total weight of internal organs increased from 2.215 kg at 5 months to 3.21 kg at 7 months and then to 3.745 kg at 9 months of age. An increase of 44.9 per cent was recorded from 5 to 7 months, and 16.66 per cent from 7 to 9 months. An overall increase of 69.07 per cent was recorded from 5 to 9 months of age.

The pigs in group 3 showed an increase in the total organ weight from 2.065 kg at 5 months to 2.82 kg at 7 months and then to 3.465 kg at 9 months of age. The weight of organs for this group of pigs increased by 36.56 per cent from 5 to 7 months and by 22.87 per cent from 7 to 9 months, with an overall increase of 67.8 per cent from 5 to 9 months of age.

Even as the total weight of internal organs showed an increase from 5 to 9 months, the maximum percentage of gain was observed during the period of 5 to 7 months and a considerably lower percentage rate of gain during the subsequent period of 7 to 9 months of age, indicating that the organs also attained a maximal growth rate during the period of rapid growth in body weight.

For the pigs in group 1, the total organ weight as percentage of live weight showed a decrease from 3.95 at 5 months to 3.90 at 7 months and then to 3.49 at 9 months of age.

For the pigs in group 2, the percentage of organ weight showed a decrease from 3.94 at 5 months to 3.90 at 7 months and then to 3.68 at 9 months of age.

In the case of the pigs in group 3, the percentage of organ weight decreased from 4.61 at 5 months to 3.94 at 7 months and then to 3.72 at 9 months of age.

It was observed that, while the weight of internal organs increased, the weight of internal organs as percentage of live weight decreased as the animals advanced in age and body weight. Such observations are in agreement with Brody (1945) who reported that the visceral organ weights in mature animals increased with a fractional power of body weight so that the weights of internal organs did not increase as rapidly as the body as a whole. The finding of the present study is also in agreement with McKay et al. (1984) who observed that the internal organs grew relatively slower as the live weight increased.

The individual organs (heart, liver, kidney, lungs and spleen), for the animals in all groups, also followed a

similar pattern of growth with respect to their absolute weights and weights as percentage of live weight.

Taking all the groups into consideration, the percentage of heart weight to live weight decreased from 0.38-0.48 at 5 months to 0.33-0.38 at 7 months and then to 0.30-0.32 at 9 months of age.

The percentage of liver weight was found to be 2.15-2.60 , 2.35-2.44 and 2.16-2.25 per cent at 5, 7 and 9 months of age respectively.

The percentage of kidney weight showed a decrease from 0.33-0.40 at 5 months to 0.30 at 7 months, and then to 0.28-0.30 at 9 months of age.

The percentage of the weight of lungs decreased from 0.79-0.93 at 5 months to 0.66-0.75 at 7 months, and then to 0.55-0.69 at 9 months of age.

The percentages of spleen weight recorded were 0.15-0.19 at 5 months, 0.15-0.17 at 7 months, and 0.12-0.14 per cent at 9 months of age.

The percentages of individual organ weights to live weight as observed in the present study are in close agreement with the observations of Libby (1975) who recorded 0.30 to 0.35 per cent for heart, 0.5 per cent for lung, 1.7 per cent

for liver, and 0.12 per cent for spleen. The observations made in the present study are also in close agreement with those reported by Saseendran (1979) for Large White Yorkshire female pigs of 7 months of age. He reported values of 1.69 to 1.72 per cent for liver, 0.27 to 0.35 per cent for heart, 1.22 to 1.46 per cent for lungs, and 0.28 to 0.33 per cent for kidney.

For the pigs in group 1, group 2 and group 3 respectively, the total weights of internal organs were recorded at 2.245, 2.215 and 2.065 kg at 5 months; 3.44, 3.21 and 2.82 kg at 7 months; and 3.48, 3.745 and 3.465 kg at 9 months of age.

For the pigs in group 1, group 2 and group 3 respectively, the total weights of internal organs as percentage of live weight were recorded at 3.95, 3.94 and 4.61 at 5 months; 3.90, 3.90 and 3.94 at 7 months; and 3.49, 3.68 and 3.72 at 9 months of age.

It was observed that the total weights of internal organs were lower for the control group of pigs as compared with the chitin-fed groups at each stage, whereas the percentages of total organ weight to live weight tended to be slightly higher for the control group of pigs. This indicates that chitin did not have any adverse effect on the internal

organs. Watkins and Knorr (1983) demonstrated that addition of upto 8.5 per cent chitin in feed resulted in normal vigour and organ weight in gerbils. It was further demonstrated that when azo dye was added to the diet of gerbils without chitin, it resulted in lower animal weight and higher kidney weight due to stress condition which was counterbalanced when chitin was added to the diet.

The comparatively lower percentages of organ weight to live weight observed for the chitin-fed groups may be attributed to their relatively higher body weights attained because of chitin feeding.

The slightly higher percentage of organ weight to live weight for the pigs in the control group might have contributed to their lower dressing percentage. Sather et al. (1991) stated that heavier kidneys, liver and full gut in Landrace pigs contributed to their lower dressing percentage as compared to Large White pigs.

5.5 Haematological studies

5.5.1 Hamaglobin concentration and total erythrocyte count

One of the hazards facing pig farmers is the prevalence of anaemia, particularly in the young stock. Anaemia is a condition in which there is a reduction in the

number of circulating erythrocytes or in the concentration of haemoglobin in the peripheral blood causing a decrease in the oxygen-carrying capacity of the blood.

The haemoglobin concentration for the pigs in group 1 increased from 8.16 ± 0.39 g per dl at the pre-treatment stage to 13.53 ± 0.48 g per dl at 7 months of age. The haemoglobin concentrations recorded at the subsequent ages of 7 and 9 months were 13.00 ± 0.30 and 12.93 ± 0.39 g per dl respectively.

In the case of the pigs in group 2, the haemoglobin concentration increased from 8.38 ± 0.45 g per dl at the pre-treatment stage to 13.0 ± 0.31 g per dl at 5 months of age. Thereafter, the haemoglobin concentrations recorded were 13.20 ± 0.37 and 13.30 ± 0.29 g per dl at 7 and 9 months of age respectively.

The pigs in group 3 showed an increase in haemoglobin concentration from 8.26 ± 0.53 g per dl at the pre-treatment stage to 12.73 ± 0.41 g per dl at 5 months of age. The haemoglobin concentrations recorded at 7 and 9 months of age were 12.53 ± 0.35 and 13.06 ± 0.34 g per dl respectively.

The haemoglobin concentration was observed to be at a much lower level (8.16 ± 0.39 to 3.38 ± 0.39 g per dl) at the pre-treatment stage, increasing to a much higher level (12.73

± 0.41 to 13.53 ± 0.48 g per dl) at 5 months, after which it was maintained at a constant level at 7 months (12.53 ± 0.35 to 13.20 ± 0.37 g per dl) and 9 months (12.93 ± 0.39 to 13.30 ± 0.29 g per dl) of age.

The total erythrocyte count (TEC) for the pigs in the three groups followed the same trend as haemoglobin.

The TEC for the pigs in group 1 increased from 5.56 ± 0.20 x 10^6 per cu mm at the pre-treatment stage to 6.91 ± 0.11 x 10^6 per cu mm at 5 months of age. The TEC recorded at 7 and 9 months of age were 6.94 ± 0.12 x 10^6 and 7.03 ± 0.07 x 10^6 per cu mm respectively.

The pigs in group 2 showed a TEC of 5.73 ± 0.17 x 10^6 per cu mm at the pre-treatment stage, which increased to 6.88 ± 0.13 x 10^6 per cu mm at 5 months of age. The TEC values recorded at 7 and 9 months of age were 7.00 ± 0.08 x 10^6 and 7.10 ± 0.11 x 10^6 per cu mm respectively.

In the case of the pigs in group 3, the TEC was 5.60 ± 0.13 x 10^6 per cu mm at the pre-treatment stage, increasing to 6.85 ± 0.10 x 10^6 per cu mm at 5 months of age. The TEC observed at 7 and 9 months were 6.79 ± 0.14 x 10^6 and 6.83 ± 0.13 x 10^6 per cu mm respectively.

The TEC was noticed to be at a lower level (5.56 ±

0.20×10^6 to $5.73 \pm 0.17 \times 10^6$ per cu mm at the pre-treatment stage. It increased to a considerably higher level ($6.85 \pm 0.10 \times 10^6$ to $6.91 \pm 0.11 \times 10^6$ per cu mm at 5 months, after which it maintained a constant level at ages of 7 months (6.79 ± 0.14 to $7.00 \pm 0.08 \times 10^6$ per cu mm) and 9 months ($6.83 \pm 0.13 \times 10^6$ to $7.10 \pm 0.11 \times 10^6$ per cu mm).

The differences noticed in haemoglobin concentration between the groups were found to be non-significant at all ages.

Also, the differences in total erythrocyte count noticed between the groups were not found to be significant at any age.

The increase in total erythrocyte count and haemoglobin concentration from the pre-treatment stage to 5 months of age without much variation thereafter, as observed in the present study, is in agreement with the report of Miller *et al*. (1961) who observed that, after weaning, the haemoglobin and RBC values increased to adult values at 5 months of age. The observed values for haemoglobin in the present experiment are in close agreement with those reported by Miller *et al*. (1961) (9.0 ± 0.2 g per dl at 7 weeks, 13.1 ± 0.2 g per dl at 5 months, 14.2 ± 0.3 g per dl at 7 months, and 13.7 ± 0.3 g per dl at 9 months of age). The observed TEC

values in the present study also follow closely to those reported by the same authors ($5.13 \pm 0.34 \times 10^6$ per cu mm at 7 weeks, $6.65 \pm 0.21 \times 10^6$ per cu mm at 5 months, $7.52 \pm 0.18 \times 10^6$ per cu mm at 7 months, and $6.95 \pm 0.27 \times 10^6$ per cu mm at 9 months of age).

The haemoglobin concentration and TEC appeared to be similar between the groups as no significant difference could be observed between them indicating that chitin feeding had no effect on TEC or haemoglobin concentration. This is in agreement with Gordon and Williford (1983) who reported that giving only increased levels of chitin at 20 per cent or chitosan at 10 per cent in the feed, iron absorption was depressed. In the present study chitin might not have affected iron absorption being fed at such lower levels of 0.5 and 1 per cent in the ration.

5.5.2 Total leukocyte count (TLC) and differential leukocyte count (DLC)

For the pigs in group 1, the TLC was $15.78 \pm 0.59 \times 10^3$ per cu mm at the pre-treatment stage. The TLC values at 5, 7 and 9 months of age were $13.98 \pm 0.67 \times 10^3$, $11.15 \pm 0.39 \times 10^3$ and $12.88 \pm 0.90 \times 10^3$ per cu mm respectively

In the case of the pigs in group 2, the TLC was $16.20 \pm 0.64 \times 10^3$ per cu mm at the pre-treatment stage. The TLC

values were found to be and 14.5 ± 0.69 x 10^3, 11.90 ± 0.39 x 10^3 and 12.50 ± 0.16 x 10^3 per cu mm at 5, 7 and 9 months of age respectively.

For the pigs in group 3, the TLC was 16.39 ± 0.40 x 10^3 per cu mm at the pre-treatment stage followed by 14.01 ± 0.95 x 10^3, 10.95 ± 0.58 x 10^3 and 11.90 ± 0.16 x 10^3 per cu mm at 5, 7 and 9 months of age respectively.

The pigs in group 1 showed a neutrophil count of 34.5 ± 1.31 per cent at the pre-treatment stage followed by 27.33 ± 1.938, 38.5 ± 1.258 and 28.33 ± 1.81 per cent at 5, 7 and 9 months of age respectively.

The pigs in group 2 showed a neutrophil count of 34.0 ± 1.19 per cent at the pre-treatment stage; and 27.16 ± 1.979, 37.33 ± 1.134 and 27.5 ± 1.607 per cent at 5, 7 and 9 months of age respectively.

In the case of the pigs in group 3, the neutrophil count observed was 36.0 ± 1.144 per cent at the pre-treatment stage. The neutrophil count was found to be 28.83 ± 1.855 per cent at 5 months, 38.33 ± 1.183 per cent at 7 months and 28.16 ± 1.346 per cent at 9 months of age.

The pigs in group 1 showed an eosinophil count of 3.66 ± 0.333 per cent at the pre-treatment stage. The eosinophil

counts were 2.50 ± 0.393, 2.50 ± 0.412 and 2.33 ± 0.415 per cent at 5, 7 and 9 months of age respectively.

In the case of the pigs in group 2, the eosinophil count observed was 3.50 ± 0.367 per cent at the pre-treatment stage. The eosinophil count was 2.66 ± 0.40 per cent at 5 months, 3.0 ± 0.425 per cent at 7 months and 2.16 ± 0.42 per cent at 9 months of age.

The pigs in group 3 showed an eosinophil count of 3.0 ± 0.274 per cent at the pre-treatment stage, 2.50 ± 0.408 per cent at 5 months, 2.66 ± 0.422 per cent at 7 months and 2.33 ± 0.413 per cent at 9 months of age.

The lymphocyte count observed for the pigs in group 1 was 58.0 ± 1.39 per cent at the pre-treatment stage. The same was found to be 67.0 ± 2.258 per cent at 5 months, 55.83 ± 1.851 per cent at 7 months and 65.33 ± 2.531 per cent at 9 months of age.

In the case of the pigs in group 2, the lymphocyte count recorded was 58.5 ± 0.565 per cent at the pre-treatment stage, 66.83 ± 2.304 per cent at 5 months, 56.33 ± 2.333 per cent at 7 months and 66.5 ± 1.176 per cent at 9 months of age.

The pigs in group 3 showed a lymhocyte count of 56.66 ± 1.283 per cent at the pre-treatment stage, 65.66 ± 2.184 per cent at 5 months, 55.0 ± 2.278 per cent at 7 months and 66.0 ± 0.966 per cent at 9 months of age.

The pigs in group 1 showed a monocyte count of 3.83 ± 0.435 per cent at the pre-treatment stage. The monocyte counts at 5, 7 and 9 months of age were 3.16 ± 0.456, 3.16 ± 0.513 and 4.0 ± 0.480 per cent respectively.

In the case of the pigs in group 2, the monocyte count recorded at the pre-treatment stage was 4.0 ± 0.446 per cent. The monocyte counts at 5, 7 and 9 months of age were 3.33 ± 0.464, 3.33 ± 0.513 and 3.83 ± 0.488 per cent at 5, 7 and 9 months of age respectively.

The pigs in group 3 showed a monocyte count of 4.33 ± 0.457 per cent at the pre-treatment stage, and 3.0 ± 0.468, 4.0 ± 0.519 and 3.5 ± 0.504 per cent at 5, 7, and 9 months of age respectively.

The percentages of neutrophil, eosinophil, lymphocyte and monocyte did not follow any definite trend over the ages.

For all the groups, the TLC at the pre-treatment stage was found to be high. This was found to have decreased at later ages at fluctuating levels. Weide and Twiehaus (1959)

reported that the total leukocyte count rose from 10 days to 7 weeks of age, after which a fluctuating level was maintained.

The total leukocyte counts observed in the present study across different ages agrees well with the report of Giltner (1907) who observed 9.5 x 10^3 to 25.0 x 10^3 per cu mm of TLC for pigs of 2.5 to 6 months of age. Swenson (1982) also reported a range of 15 x 10^3 to 22 x 10^3 per cu mm of TLC for pigs of 6 weeks and older age.

The differential leukocyte count as observed in the present study also agrees well with the findings of Swenson (1982) who reported that for pigs of 6 weeks and older, the percentages of neutrophil, eosinophil, lymphocyte and monocyte were 30-35, 2-5, 55-60 and 5-6 respectively.

There was no significant difference between the groups of pigs in TLC and DLC at any stage. This indicates that feeding of chitin did not affect the TLC and DLC in pigs.

5.6 Serum cholesterol and triglyceride concentrations

The mean serum cholesterol concentrations did not differ significantly between the groups at the pre-treatment stage (95.73 $\pm$ 2.35, 97.33 $\pm$ 2.77 and 94.14 $\pm$ 2.66 mg per 100 ml for pigs in group 1, group 2 and group 3 respectively).

The animals in group 1 showed an increase in serum

cholesterol concentration from 84.25 ± 2.47 mg per 100 ml at 5 months to 108.79 ± 2.75 mg per 100 ml at 7 months and to 118.18 ± 2.26 mg per 100 ml at 9 months of age.

For the animals in group 2, the serum cholesterol concentration increased from 77.65 ± 2.82 mg per 100 ml at 5 months to 99.50 ± 3.03 mg per 100 ml at 7 months and to 107.77 ± 2.33 mg per 100 ml at 9 months of age.

In the case of the pigs in group 3, the serum cholesterol concentration increased from 85.28 ± 2.80 mg per 100 ml at 5 months to 110.70 ± 2.79 mg per 100 ml at 7 months and to 122.38 ± 2.50 mg per 100 ml at 9 months of age.

The cholesterol concentration, for pigs in all groups, showed a decreasing trend from the pre-treatment stage to 5 months of age. Thereafter, the concentration increased as age advanced to 7 and 9 months.

When compared between groups, the serum cholesterol concentrations were found to be the lowest for the pigs in group 2 and the highest for the pigs in group 3 at 5, 7 and 9 months of age.

The pigs in group 2 had significantly ($P < 0.05$) lower concentration than those in group 1 and group 3 at 7 months.

These differences were found to be highly significant ($P<0.01$) at 9 months.

Eventhough the differences between the pigs in group 1 and group 3 were not found to be significant, the pigs in group 1 showed lower concentrations at each age.

The observation made in the present experiment is in agreement with that of Christon (1988) who observed in Large White pigs reared in tropical climate that the cholesterol concentration was high (118.9 mg per 100 ml) in young growing pigs (8-25 kg body weight), followed by a drop (98.5 mg per 100 ml) in the growing stage (29-50 kg body weight) and again a rise (113.0 mg per 100 ml) in the finishing stage (54-79 kg body weight). A similar trend was noticed in the present study. The serum cholesterol concentration showed a decrease from the pre-treatment stage to 5 months of age, and thereafter increased again at successive ages of 7 and 9 months.

The chitin-fed groups exhibited a lower serum cholesterol concentrations than the control group at 5, 7 and 9 months of age. The pigs in group 2 showed the lowest concentration at every stage, which indicates a specific effect of chitin on the serum cholesterol concentration in pigs.

The mean serum triglyceride concentration did not show any significant difference between the groups at the pre-treatment stage (75.50 ± 3.07, 76.03 ± 3.12 and 74.57 ± 2.50 mg per 100 ml for pigs in group 1, group 2 and group 3 respectively).

The triglyceride concentration for animals in group 1 showed an increase from 45.50 ± 2.32 mg per 100 ml at 5 months to 53.95 ± 2.67 mg per 100 ml at 7 months and to 61.75 ± 2.88 mg per 100 ml at 9 months of age.

The pigs in group 2 showed an increase in triglyceride concentration from 43.50 ± 2.56 mg per 100 ml at 5 months to 51.15 ± 2.30 mg per 100 ml at 7 months and to 58.50 ± 2.92 mg per 100 ml at 9 months of age.

In the case of the pigs in group 3, the serum triglyceride concentration increased from 45.82 ± 2.13 mg per 100 ml at 5 months to 54.50 ± 2.37 mg per 100 ml at 7 months and to 62.80 ± 2.88 mg per 100 ml at 9 months of age.

The serum triglyceride concentration, for pigs in all the groups, showed a decreasing trend from the pre-treatment stage to 5 months of age, and thereafter increased at successive ages of 7 and 9 months of age.

Eventhough, the differences in serum triglyceride concentration between the groups were not found to be significant, the pigs in group 2 showed the lowest concentrations and the pigs in group 3 the highest at 5, 7 and 9 months of age.

The observation made in the present study is in agreement with that of Christon (1988) who observed in Large White pigs reared in tropical climate that the serum triglyceride level was high (93.6 mg per 100 ml) in young growing pigs (8-25 kg body weight) followed by a decrease (53.7 mg per 100 ml) in the growing stage (29-50 kg body weight) and again a rise (63.0 mg per 100 ml) in the finishing stage (54-79 kg). Mersmann and MacNeil (1985) also observed highest values at 2 months followed by a drop at 4 months and again a rise at 6 months of age in both lean and obese pigs whether fed or fasted. In the present study, a similar trend was noticed. The serum triglyceride concentration showed a decrease from the pre-treatment stage to 5 months of age followed by successive increases at 7 and 9 months.

The serum triglyceride concentrations observed were lower for the pigs in the chitin-fed groups. The concentrations were found to be the lowest for the pigs in group 2 indicating that chitin had a specific effect on triglyceride concentration. This is also supported by the

lower deposition of backfat and leaf fat in the chitin-fed groups as compared with the control group.

The lower concentrations of serum cholesterol and triglyceride observed for the chitin-fed groups indicate that chitin has hypolipidemic and hypocholesterolemic effect when fed to pigs. Chitin and chitosan, have high fat-binding ability which is attributed to their hypolipidemic and hypocholesterolemic action (Knorr, 1982; Furda, 1983; Nauss et al., 1983). Knorr (1982) reported that the fat-binding capacity of chitin, chitosan and microcrystalline chitin ranged from 170 to 215 per cent with chitosan having the lowest and chitin the highest. Chitosan has been reported as a powerful sequestrant of bile salts and whole micelles consisting of cholesterol, fatty acids and monoglycerides which thus escape absorption in the intestine (Nagyvary et al., 1980; Furda, 1983; Nauss et al., 1983). Chitosan has been reported as having a greater potency than many hypocholesterolemic agents in preventing hyper cholesterolemia induced by cholesterol feeding in rats (Sugano et al., 1978; Kobayashi et al., 1979; Nagyvary et al., 1979; Vahouny et al., 1983). Sugano et al. (1980) reported that rats fed a cholesterol-free diet containing 0.5 per cent chitosan had relatively more high-density lipoprotein-cholesterol and less low-density lipoprotein-cholesterol. The same authors also

observed significant reduction (25 to 30 per cent) of plasma cholesterol, liver cholesterol and liver triglyceride concentrations in rats fed chitosan along with a high cholesterol diet. Hirano et al. (1990) reported that an increased level of cholesterol and triglyceride in serum and liver of hens, broilers and rabbits was suppressed by addition of chitosan in the cholesterol-additive diets.

5.7 Fatty acid composition of muscle and backfat

Three predominant fatty acids, namely palmitic, stearic and oleic acid were found both in muscle and backfat. Traces of myristic acid were also found in some samples of muscle and backfat from animals at 7 and 9 months of age.

The percentage of unsaturated fatty acid of muscle appeared to be similar for all the groups of pigs at 5 months of age. The percentage of unsaturated fatty acid for the pigs in group 1 remained almost constant at 5 months (22.2), 7 months (23.2) and 9 months (22.72) of age.

For the pigs in group 2, the unsaturated fatty acid percentage of muscle showed an increasing tendency from 5 months (21.3) to 7 months (26.7) followed by a reduction at 9 months (24.5). As compared with 5 months, an increase of 3 to 6 per cent was noticed in the subsequent months.

In the case of the pigs in group 3, the percentage of unsaturated fatty acid showed a drastic reduction from 5 months (22.0) to 7 months (12.45) and 9 months (14.2).

The saturated fatty acid percentage of muscle for the pigs in group 1 remained almost constant at 5, 7 and 9 months of age (77.42, 76.8 and 76.81 respectively).

The percentage of saturated fatty acid of muscle for pigs in group 2 showed a decreasing tendency from 5 months (78.66) to 7 months (72.85) and 9 months (75.49). A reduction in the percentage of saturated fatty acid of muscle to the extent of 3 to 6 per cent was noticed in this group of pigs.

In the case of the pigs in group 3, the percentage of saturated fatty acid showed an increasing trend from 5 months (77.97) to 7 months (87.25) and 9 months (85.7). An overall increase of 8 to 10 per cent was noticed from 5 to 9 months of age.

The 8 to 10 per cent increase in the saturated fatty acid percentage of muscle, for the pigs in group 3, appeared to be at the expense of a corresponding reduction in unsaturated fatty acid of muscle as the animals advanced in age.

In the case of backfat, the percentage of unsaturated

fatty acid showed a decreasing tendency from 5 months (29.87) to 7 months (20.47) and then increased at 9 months (28.31), for the pigs in group 1. The overall trend appeared to be a reduction in the percentage of unsaturated fatty acid of backfat as age advanced.

For the pigs in group 2, the percentage of unsaturated fatty acid of backfat showed a decreasing tendency from 5 months (28.51) to 7 months (24.33) and 9 months (24.69). An overall reduction of 4 per cent in unsaturated fatty acid of backfat was recorded for the pigs in this group from 5 to 9 months of age.

In the case of the pigs in group 3, the percentage of unsaturated fatty acid showed a drastic reduction from 5 months (29.4) to 7 months (14.1) and 9 months (13.1). An appreciable reduction of 15 to 16 per cent in unsaturated fatty acid of backfat was recorded for this group of animals.

The saturated fatty acid percentage of backfat for the pigs in group 1 showed an increasing trend from 5 months (70.12) to 7 months (78.96) and 9 months (71.21).

Similarly, for the pigs in group 2, the percentage of saturated fatty acid showed an increasing trend from 5 months (70.61) to 7 months (75.43) and 9 months (75.29). An overall

increase of 5 per cent in saturated fatty acid was recorded for this group of pigs.

In the case of the pigs in group 3, the percentage of saturated fatty acid showed significant increase from 5 months (70.43) to 7 months (84.95) and 9 months (86.85). An overall increase of 15 to 16 per cent in the percentage of saturated fatty acid of backfat was recorded for this group of animals.

The increase of 15 to 16 per cent in saturated fatty acid of backfat appeared to be at the expense of a corresponding reduction in unsaturated fatty acid of backfat as the animals advanced in age.

It was observed that the percentage of unsaturated fatty acids of muscle decreased with age, for the pigs in group 3, whereas it tended to increase for the pigs in group 2, and remained almost constant for the pigs in group 1. In the case of backfat, there was marked decrease in unsaturated fatty acid for the pigs in group 3 as age advanced, whereas the decrease in unsaturated fatty acid percentage for the chitin-fed groups was much less as compared with the pigs in group 3. The higher percentage of unsaturated fatty acids and lower percentage of saturated fatty acid observed for the chitin-fed groups may be attributed to the effect of feeding chitin.

It was observed that, eventhough the groups did not differ in the percentage of unsaturated fatty acid (oleic acid) at 5 months of age, the pigs in both the chitin-fed groups showed considerably higher percentages of oleic acid in both muscle and backfat, as compared with the controls, at 7 and 9 months of age.

The consumption of saturated fat has been reported to increase plasma low-density lipoprotein(LDL)-cholesterol which increases the risk of coronary heart disease in human (Mattson and Grundy, 1985). Recent reports indicate that dietary mono-unsaturated fat decreases LDL-cholesterol (Mattson and Grundy, 1985; Grundy, 1986). Grundy (1986) reported that diets high in oleic acid lowered levels of plasma cholesterol in human, and therefore, replacing saturated fat with mono-unsaturated fat in the diet could lower plasma cholesterol in human. Mattson and Grundy (1985) suggested that pork with an increased proportion of unsaturated fatty acid and less palmitic acid would be more healthful.

It was found from the present study that, compared with the controls, the pigs fed chitin showed higher oleic acid and lower palmitic acid contents in their muscle and backfat. This indicates that the pork obtained from chitin-fed pigs is more healthful than that from pigs fed a diet without chitin.

Summary

SUMMARY

An investigation was carried out to assess the influence of feeding chitin to pigs on their growth, carcass characteristics, haematological parameters, serum cholesterol and triglyceride concentrations and fatty acid profile of muscle and backfat.

Twenty-four weaned female piglings were divided into three groups of eight each. For two groups of pigs, chitin was added in the ration at levels of 0.5 per cent (Group 1) and 1 per cent (Group 2), while the remaining group, which served as the control, was given the same ration but without addition of chitin (Group 3).

All animals were housed and fed individually in separate pens. The animals in each group were fed the ration based an consumption in one hour period twice daily.

Observations were made during the course of the experiment which was continued until 40 weeks of age of the animals.

Digestibility of chitin was determined at different stages of growth of the animals.

Daily feed intake of individual animals was recorded. Body weight as well as body measurements (length, height, front girth and hind girth) were recorded at fortnightly intervals from weaning to 40th week of age. Data were utilised to find out feed intake, feed conversion ratio, rate of growth and patterns of growth in pigs.

Blood was collected from pigs at the pre-treatment stage and at 5.7 and 9 months of age for haematological studies and for determination of serum cholesterol and triglyceride levels.

Animals from each group were slaughtered at 5, 7 and 9 months of age to assess the carcass characteristics and weight of internal organs.

Samples of muscle and backfat were collected at the time of slaughter to find out the fatty acid profile.

Digestibility of chitin was found to be 79.37 $\pm$ 1.85 to 80.49 $\pm$ 1.55 per cent at 3 months, thereafter increasing to 95.36 $\pm$ 1.13 to 96.54 $\pm$ 1.05 per cent at 5 months, and 95.35 $\pm$ 1.33 to 95.77 $\pm$ 1.57 per cent at 7 months of age. Digestibility increased with advance in age, indicating gradual adaptability of the pigs to chitinous materials.

Both the chitin-fed groups of pigs showed higher average body weights than the control group. The differences in body weight were found significant ($P<0.05$ or 0.01) from 18th to 40th week of age, while no significant difference was noticed between the two chitin-fed groups. Compared with the controls, the chitin-fed groups showed higher total body weight gains by 11 to 12 kg, which indicates the growth-promoting effect of chitin in pigs.

The average daily gain in body weight for the pigs in all the groups increased with age from weaning and reached a peak at 32nd week, and thereafter declined gradually.

Both the chitin-fed groups showed higher daily gains in weight than the control group. The differences were found to be significant ($P<0.05$ or 0.01) from 18th to 40th week, while no significant difference was noticed between the two chitin-fed groups.

Pigs in both the chitin-fed groups averaged higher body lengths than the controls, and compared with the controls, they showed higher total gains in length by 3 to 5 cm.

The daily gain in length increased with age reaching a peak at 26th week for the pigs in group 1 and group 2, and at

24th week for the pigs in group 3. Both the chitin-fed groups showed higher average daily gains in length than the controls.

Pigs in the chitin-fed groups averaged higher heights than the controls, and compared with the controls, they showed higher total gains in height by 0.8 to 1.4 cm.

The daily gain in height increased with age reaching a peak at 20th week. The chitin-fed groups showed higher average daily gains than the controls.

The chitin-fed groups of pigs averaged higher body girths (front), and compared with the controls, they showed total gains in girth (front) higher by 2.5 to 3.0 cm.

The daily gain in girth (front) increased with age reaching a peak at 20th week for the chitin-fed groups and at 24th week for the control group. The chitin-fed groups showed higher average daily gains than the controls.

The chitin-fed groups showed higher body girths (hind), and showed higher total gains in girth (hind) by 4 to 5 cm than the controls.

The daily gain in girth (hind) increased with age reaching a peak at 24th week for the pigs in group 1 and group 3, and at 26th week for the pigs in group 2. The

chitin-fed groups showed higher average daily gains than the controls.

The daily feed intake of pigs increased progressively with advance in age from 10th week (0.821 ± 0.015, 0.827 ± 0.025 and 0.807 ± 0.016 kg for group 1, group 2 and group 3, respectively) to 40th week (1.988 ± 0.098, 2.062 ± 0.071 and 1.985 ± 0.056 kg for group 1, group 2 and group 3, respectively). There was no significant difference in feed intake between the groups.

The feed conversion efficiency was poor upto 14th week (4.33 ± 0.58 to 6.66 ± 1.07 for group 1, 4.36 ± 0.31 to 7.02 ± 1.02 for group 2, and 4.88 ± 0.39 to 6.92 ± 0.97 for group 3). It improved thereafter and kept stabilised from 16th to 30th week (3.33 ± 0.14 to 3.83 ± 0.07 for group 1, 3.39 ± 0.08 to 3.98 ± 0.25 for group 2, and 3.62 ± 0.10 to 4.43 ± 0.32 for group 3), and again showed a decrease thereafter from 32nd to 40th week (3.97 ± 0.06 to 4.52 ± 0.21 for group 1, 4.01 ± 0.08 to 4.70 ± 0.04 for group 2, and 4.21 ± 0.12 to 5.19 ± 0.09 for group 3).

Both the chitin-fed groups showed higher feed conversion efficiency than the control group. The differences between the control and chitin-fed groups were found to be significant ($P<0.05$) at the end of the experiment, whereas no

significant difference could be noticed between the chitin-fed groups, indicating that chitin feeding resulted in greater efficiency of feed utilisation and higher rate of growth in pigs.

The pigs in group 1 and group 2 averaged higher live weights at slaughter than the pigs in group 3 at the slaughter ages of 5 months (56.8 and 56.2 vs. 44.7 kg), 7 months (88.0 and 82.5 vs. 71.5 kg), and 9 months (99.5 and 101.5 vs. 93.0 kg). The highest overall increase from weaning to 9 months of age was observed for animals in group 2 (91.8 kg), followed by group 1 (89.5 kg) and group 3 (84.0 kg).

For all the groups, higher percentages of gain were recorded between 5 and 7 months than between 7 and 9 months of age (54.9 vs. 13.06 per cent for group 1, 46.8 vs. 23.03 per cent for group 2, and 59.95 vs. 30.06 per cent for group 3).

The carcass length increased with increase in age and weight of animals. The pigs in group 1 and group 2 showed greater carcass lengths than the controls at the slaughter ages of 5 months (64 and 65 vs. 62 cm), 7 months (79 and 77 vs. 74 cm), and 9 months (80 and 89 vs. 77 cm). For all the groups, higher percentages of gain in length were recorded between 5 and 7 months than between 7 and 9 months of age

(23.43 vs. 1.26 per cent for group 1, 18.46 vs. 15.6 per cent for group 2, and 19.35 vs. 4.0 per cent for group 3).

The weight of ham increased with increase in age and weight of animals. The pigs in group 1 and group 2 showed greater ham weights than the controls at 5 months (9.0 and 9.1 vs. 6.44 kg), 7 months (13.44 and 13.0 vs. 10.14 kg), and 9 months (14.9 and 15.3 vs. 13.26 kg). For all the groups, higher percentages of gain in ham weight were recorded between 5 and 7 months than between 7 and 9 months of age (49.33 vs. 10.9 per cent for group 1, 42.85 vs. 17.7 per cent for group 2, and 57.45 vs. 30.76 per cent for group 3).

The ham weight as percentage of dressed weight without head showed a decreasing trend as age and weight of animals increased. The ham percentages did not show any appreciable difference between the groups at 5 months (25.35, 25.14 and 25.25 per cent for group 1, group 2 and group 3, respectively), 7 months (24.66, 25.0 and 24.43 per cent), or 9 months (21.59, 21.42 and 21.38 per cent).

The thickness of backfat increased with age of animals. The pigs in group 1 and group 2 had lower backfat thickness than the controls at 5 months (0.9 and 1.10 vs. 1.13 cm), 7 months (2.43 and 2.23 vs. 2.46 cm), and 9 months (2.56 and 2.9 vs. 3.16 cm). For all the groups, higher gains in

backfat thickness, were observed between 5 and 7 months than between 7 and 9 months of age (1.53 vs. 0.13 cm for group 1, 1.13 vs. 0.67 cm for group 2, and 1.13 vs. 0.70 cm for group 3).

The eye-muscle area increased with increase in age of animals. The pigs in group 1 and group 2 had greater eye-muscle areas than the controls at 5 months (24.56 and 23.22 vs. 18.43 cm^2), 7 months (34.43 and 34.73 vs. 31.18 cm^2), and 9 months (37.75 and 40.88 vs. 33.3 cm^2). For all the groups, higher percentages of gain in eye-muscle area were observed between 5 and 7 months than between 7 and 9 months of age (40.18 vs. 9.64 per cent for group 1, 49.56 vs. 17.7 per cent for group 2, and 69.18 vs. 6.79 per cent for group 3).

The amount at leaf fat and weight of leaf fat as percentage of live weight increased with increase in age, but the majority of leaf fat deposition occurred between 7 and 9 months of age. The amount of leaf fat deposited did not show any noticeable difference between groups either at 7 months (0.55, 0.50 and 0.525 kg for group 1, group 2 and group 3, respectively) or at 9 months (1.6, 1.76 and 1.6 kg). But the pigs in group 3, as compared with the pigs in group 1 and group 2, had higher percentages of leaf fat at 7 months (0.734 vs. 0.625 and 0.606 per cent), and 9 months (1.72 vs. 1.67 and 1.69 per cent).

The dressing percentage (with head) increased as slaughter weight increased. The pigs in group 1 and group 2, as compared to the pigs in group 3, yielded higher dressing percentages at 5 months (68.22 and 68.77 vs. 63.57 per cent), 7 months (70.11 and 70.37 vs. 66.44 per cent), and 9 months (79.47 and 77.09 vs. 74.08 per cent). The chitin-fed groups did not show any appreciable difference in dressing percentage. The increases in dressing percentage were found to be higher between 7 and 9 months than between 5 and 7 months of age (9.36 vs. 1.89 per cent for group 1, 6.72 vs. 1.6 per cent for group 2, and 7.64 vs. 2.87 for group 3).

The dressing percentage (without head) followed the same trend as dressing percentage (with head).

The total weight of internal organs increased with increase in age of animals. The pigs in group 1 and group 2 showed higher weights of internal organs than the pigs in group 3 at 5 months (2.245 and 2.215 vs. 2.065 kg), 7 months (3.44 and 3.21 vs. 2.82 kg), and 9 months (3.48 and 3.745 vs. 3.465 kg). The organ weight showed higher percentage rates of gain between 5 and 7 months than between 7 and 9 months of age (53.22 vs. 1.16 per cent for group 1, 44.9 vs. 16.66 per cent for group 2, and 36.56 vs. 22.87 per cent for group 3.

The weight of internal organs as percentage of live

weight decreased with increase in age and weight of animals. The pigs in group 3 showed higher percentages of internal organs than the pigs in group 1 and group 2 at 5 months (4.61 vs. 3.95 and 3.94 per cent), 7 months (3.94 vs. 3.9 and 3.9 per cent) and 9 months 3.72 vs. 3.49 and 3.68 per cent).

The haemoglobin concentration, total erythrocyte count, total leukocyte count and differential leukocyte count did not differ between groups at any stage.

The cholesterol concentrations were similar between the groups at the pre-treatment stage (95.73 $\pm$ 2.35, 97.33 $\pm$ 2.77 and 94.14 $\pm$ 2.66 mg per 100 ml for group 1, group 2 and group 3, respectively). The concentrations were found to be the lowest for group 2 followed by group 1 and group 3, in that order, at the subsequent ages of 5 months (77.65 $\pm$ 2.82, 84.25 $\pm$ 2.47 and 85.28 $\pm$ 2.80 mg per 100 ml), 7 months (99.50 $\pm$ 3.03, 108.79 $\pm$ 2.75 and 110.70 $\pm$ 2.79 mg per 100 ml), and 9 months (107.77 $\pm$ 2.33, 118.18 $\pm$ 2.26 and 122.38 $\pm$ 2.50 mg per 100 ml). The differences were found to be significant ($P<0.05$) at 7 months, and highly significant ($P<0.01$) at 9 months between the pigs in group 2 and the pigs in group 1 or group 3, indicating hypocholesterolemic effect of chitin in pigs.

The serum triglyceride concentration showed a similar

pattern as serum cholesterol concentration. The serum triglyceride concentrations were similar for the three groups at the pre-treatment stage (75.5 ± 3.07, 76.03 ± 3.12 and 74.57 ± 2.50 mg per 100 ml for group 1, group 2 and group 3, respectively). The concentrations were found to be the lowest for group 2 followed by group 1 and group 3, in that order, at the subsequent ages of 5 months (43.5 ± 2.56, 45.5 ± 2.32 and 45.82 ± 2.13 mg per 100 ml), 7 months (51.15 ± 2.30, 53.95 ± 2.67 and 54.50 ± 2.37 mg per 100 ml) and 9 months (58.50 ± 2.92, 61.75 ± 2.88 and 62.8 ± 2.88 mg per 100 ml). The differences between the groups were not found to be statistically significant. The lower concentrations of triglyceride for chitin-fed groups indicate hypolipidemic action of chitin in pigs.

The pigs in group 1 did not exhibit any appreciable variation in the percentage of saturated and unsaturated fatty acid of muscle as the animals advanced in age. The pigs in group 2 showed an increase in unsaturated fatty acid and a decrease in saturated fatty acid of muscle, while the pigs in group 3 showed a drastic reduction in unsaturated fatty acid and increase in saturated fatty acid as the animals advanced in age from 5 to 9 months.

In the case of backfat, eventhough the pigs in all groups showed a decrease in unsaturated fatty acid and an

increase in saturated fatty acid with advance in age from 5 to 9 months, the pigs in group 3 showed a more drastic change.

It could be observed that the chitin-fed groups, as compared with the controls, showed markedly higher percentages of oleic acid and lower percentages of palmitic acid in the muscle and backfat at 7 and 9 months of age.

The results of the study revealed that chitin promoted growth in pigs, lowered serum cholesterol and triglyceride levels, decreased body depot fat and increased degree of unsaturation of fat in the meat.

References

REFERENCES

Abarca, V. and Tapia, J. (1963). Growth curve and correlations between weights at different ages in Duroc Jersey. Anim. Breed Abstr. 34: 455. (Cited by Robison, 1976).

Agarwala, O.P. (1961). Efficiency of feed utilisation of Desi versus Yorkshire graded pigs from three months to six months of age. Ind. Vet. J. 38 (8): 412-415.

Agarwal, O.P. and Arora, R.B. (1973). Blood lipid levels in pigs and their possible role in the development of aortic atherosclerosis. Indian J. Exp. Biol. 11 (4): 343-344.

Alaku, O., Steinbach, J. and Avery, P.J. (1984). Effect of season of birth and sex on heart weight and body weight, and their interrelationship in pigs reared in tropics. Anim. Prod. 38 (3): 495-502.

*Albar, J., Latimier, P. and Granier, R. (1990). Slaughter weight: Variation in fattening performance and carcass composition in pigs slaughtered at over 100 kg. 22es Journees de la Recherche Porcine en France : 119-132.

Ambler, A.S. and Wood, J.D. (1990). Changes in consumer perception of meat quality. In Recent Advances in Animal Nutrition. Eds. W. Haresign and D.J.A. Cole. Butterworths, London. pp. 7-17.

Anderson, J.A. and Fausch, H.D. (1964). Effect of restricted access to feed on the serum and liver lipids of swine. Proc. Soc. Exp. Biol. Med. 115: 402-405.

Anjaneyulu, A.S.R., Lakshmanan, V., Sharma, N. and Rao, V.K. (1982). Carcass traits of crossbred Middle White Yorkshire barrows. Indian J. Anim. Res. 16 (2): 103-106.

AOAC (1980). Official Methods of Analysis. Association of Official Analytical Chemists, Washington, D.C. 13th ed.

Arai, K., Kinumari, T. and Fujita, T. (1968). Toxicity of Chitosan. Bull. Tokai Reg. Fish. Res. Lab. No.56: 89-94.

*Arganoza, V.G., Siagian, P.M., Aquino, A.G., Lopez, C.C., Guzman, A.L. and Mateo, D.V. (1986). Productive performance of Yorkshire, Landrace and Duroe boars. Phillipine Agriculturist 69 (2): 119-129.

Ashford, N.A., Hattis, D. and Murray, A.E. (1977). Industrial prospects for chitin and protein from shellfish wastes. MIT Seagrant Report No. MITSG 77-3, MIT Sea Grant Programme, Cambridge, Massachusetts. pp. 69.

Austin, P.R., Zikakis, J.P. and Brine, C.J. (1979). U.S. Patent Application, Serial Number 051,850. (Cited by Austin et al., 1981).

Austin, P.R., Brine, C.J., Castle, J.E. and Zikakis, J.P. (1981). Chitin : new facets of research. Science 212: 749-753.

Babatunde, G.M., Pond, W.G., VanVleck, L.d., Kroening, G.H., Reid, J.T., Stouffer, J.R. and Wellington, G.H. (1966). Relationships among some physical and chemical parameters of full - versus limited - fed Yorkshire pigs slaughtered at different live weights. J. Anim. Sci. 25: 526-531.

*Bakke, H. (1975). Serum levels of cholesterol in lines of pigs selected for rate of gain and thickness of backfat. Acta Agricultural Scandinavica 25 (1): 14-16.

*Barbosa, A.S., Viana, L. de S., Santos, E.C. dos. and Barbosa, R.B. (1986). The effect of Cassava and byproducts on the fatty acid composition of lard from growing-finishing pigs. Arquivo Brasileiro de Medicina Veterinaria e Zootecnia 38 (6): 943-953.

Barton-Gade, P.A. (1984). Some experience on measuring the quality of pork fat. In Meat Research Institute Special Report No.2. Ed. J.D. Wood. A workshop in CEC Programme of Coordination of Research on Animal Husbandry, Brussels. pp. 47-52. (Cited by Barton-Gade, 1987).

Barton-Gade, P.A. (1987). Meat and fat quality in boars, castrates and gilts. Livestock Prod. Sci. 16: 187-196.

Battabayal, A.K. (1969). M.V.Sc. Thesis, J.N. Krishi Vishwavidyalaya, Jabalpur. (Cited by Gopalakrishnan, C.A. and Morley Mohan Lal, G., 1985. Livestock and Poultry Enterprises for Rural Development. Vikas Publishing Housing Pvt. Ltd., Delhi).

Batterham, E.S., Anderson, L.M., Baigent, D. and Green, A.G. (1991). Evaluation of meals from Linola^{R} low-linolenic acid linseed and conventional linseed as protein sources for growing pigs. Animal Feed Science and Technology 35 (3-4): 181-190.

Bell, J.M., Keith, M.O., Darroch, C.S. and McGregor, D.I. (1987). Effects of ammoniation of canola seed contaminated with wild mustard seed on growth, feed utilization and carcass characteristics of pigs. Can. J. Anim. Sci. 67 (1): 113-125.

Bender, A.E. (1974). Rpt. Adv. Panel Med. Aspects Food Policy. H.M.S.O. (London). (Cited by Rhodes, 1976).

*Berschauer, F., Ehrensvard, U., Gaush, G. and Menke, K.H. (1983a). Nutritional effects of dietary fat in rations for growing pigs. 1. Effect of an isoenergetic exchange of carbohydrate energy and fat energy on protein deposition, fat synthesis from glucose in vitro and some blood values in piglets. Archiv fur Tierernahrung 33 (9): 683-711.

*Berschauer, F., Ehrensvard, U. and Gaus, G. (1983b). Nutritional effects of feed fats in diets for growing pigs. 2. Effect of an isoenergetic exchange of carbohydrate energy for fat energy for piglets on growth and some metabolic indices during subsequent fattening. Archiv fur Tierernahruny 33 (10/11): 761-780.

*Berschauer, F., Ehrensvard, U. and Menke, K.H. (1983c). Nutritional effect of dietary fats in rations for growing pigs. 3. Effect of sunflower and coconut kernels on the deposition of protein and fat, the fatty acid pattern of backfat and some blood values in piglets. Archiv fur Tierernahrung 33 (12): 842-862.

*Berschauer, F., Rupp, J. and Ehrensvard, U. (1984). Effects of dietary fats on the nutritional physiology of growing pigs. 4. Effect of sunflower oil and coconut fat on deposition of protein and fat, fatty acid pattern of backfat and some blood values in piglets. Archiv fur Tierernahrung 34 (1): 19-23.

*Berschauer, F. and Ehrensvard, U. (1984). Effects of dietary fats on the nutritional physiology of growing pigs. 6. Effect of soya oil and lard on fatterning and carcass characteristics and on some blood values in fattening pigs. Archiv fur Tierernahrung 34 (3): 191-204.

*Beynen, A.C., Huisman, J. and West, C.E. (1991). Comparison between ileal and fecal excretion of bile acids and neutral steroids in pigs. In Digestive Physiology. Proc. 5th Int. Symp. on digestive physiology in pigs. Netherlands.

Bezkorovainy, A. and Topouzian, N. (1981). Int. J. Biochem. 13: 585. (Cited by Zikakis et al., 1982).

Bhagwat, S.V. and Sahastrabuddhe, M.G. (1971). A study on the growth potential of exotic pigs in India. Indian Vet. J. 48 (10): 1026-1034.

BiaLkowski, Z. (1983). The influence of microclimate, supplement of copper, managanese and zinc and vitamin A + cholecalciferol on some blood values and results of rearing piglets. Polskie Archiwum Weterynaryjne 23 (4): 23-35.

Biswas, D.K., Hart, P.V., Chapman, A.B., First, N.L. and Self, H.C. (1966). Feed efficiency and carcase desirability in swine. J. Anim. Sci. 25: 342-347.

*Bittante, G., Sorato, O. and Montobbio, P. (1989a). Crossing of Large White Sows with Belgian Landrace, Duroc and Spotted Poland boars: Effect on rearing performance. Zootecnica e Nutritionale Animale 15 (4): 307-320.

*Bittante, G., Sorato, O. and Montobbio, P. (1989b). Crossing of Large White Sows with Belgian Landrace, Buroc and Spotted Poland boars : Effect on performance. Rivista di Suinicolture 30 (12): 65-71.

Blair, H.S., Blair, S.E.M., Allen, M. and McGarel, D. (1982). Reduction of the algicidal properties of copper and mercury ions by chitin and chitosan. J. Biol. Education 73: 73. (Cited by Knorr, 1984).

Bligh, E.G. and Dyer, W.J. (1959). A rapid method of total lipid extraction and purification. Can. J. Biochem. Physiol 37 (8): 911-917.

Bogart, R. (1988). Scientific Farm Animal Production. Surjeet Publications, Delhi. pp.9-19.

Bough, W.A. and Landes, D.R. (1976). Recovery and nutritional evaluation of proteinaceous solids separated from whey by coagulation with chitin. J. Dairy Sci. 59 (11): 1874-1880.

Bough, W.A. and Landes, D.R. (1978). Treatment of food processing wastes with chitosan and nutritional evaluation of coagulated by-products. Proc. First Int. Conf. Chitin and Chitosan. MIT, Cambridge. pp.218-230.

*Bout, J., Girard, J.P., Sellier, P. and Runavot, J.P. (1990). A comparison of Duroc and Large White pigs for composition traits of backfat and longissimus dorsi muscle. 22es Journees de la Recherche Porcine en France: 22-23.

Bowland, J.P., Braude, R. and Rowell, J.G. (1965). A note on relations between carcase characteristics of bacon pigs and weaning weight, rate of gain and length. Anim. Prod. 7: 389-392.

*Brenner, K.V. and Tholking, L. (1991). Fat quality of slaughter pigs. Kraftfutter No.9: 403-405.

Brody, S. (1945). Bioenergetics and Growth. Hafner Publishing Company, Inc. New York.

Brooks, C.C., Davis, J.W., Thomas, H.R. and Vipperman, P.E.Jr. (1964). Effect of dietary lysine level on certain blood patterns in growing swine. J. Anim. Sci. 23: 385-391.

*Brooks, C.C., Thomas, H.R., Kelly, R.F., Graham, P.P. and Allen, L.B. (1964). Body composition and feed efficiency changes in swine. Virginia Agric. Exp. Stat. Tech. Bull. No. 176: 15.

Buck, S.F. (1963). A comparison of pigs slaughtered at three different weights. J. Agr. Sci. 60: 19.

Bunch, R.J., Speer, V.C., Hays, V.W. and McCall, J.T. (1963). Effect of high level of copper and chlortetracycline on performance of pigs. J. Anim. Sci. 22: 56-60.

Busboom, J.R., Rule, D.C., Colin, D., Heald, T. and Mazhar, A. (1991). Growth, carcass characteristics, and lipid composition of adipose tissue and muscle of pigs fed canola. J. Anim. Sci. 69: 1101-1108.

Bywaters, J.H. and Willham, O.S. (1935). A method of comparing growthiness in pigs weighed at different ages and subjected to different treatments. Proc. Amer. Soc. Anim. Prod. 116. (Cited by Robison, 1976).

Calvert, G.D. and Scott, P.J. (1974). Serum lipoproteins in pigs on high - cholesterol - high - triglyceride diets. Atherosclerosis 19 (3): 485-492.

Cameron, N.D. (1990). Comparison of Duroc and British Landrace pigs for meat and eating quality. Meat Science 27 (3): 227-247.

*Casa, G.D., Fabbri, R., Bergonzini, E., Gigli, S. and Rosi, M.A. (1991). Whole flaked soyabean in the feeding of heavy pigs. 3. Characteristics of subcutaneous fat and matured ham. Rivista di Suinicultura 32 (3): 87-92.

*Chichlowska, J., Perz, K. and Maruniewicz, W. (1986). Changes in some blood values of pigs given ammoniated or ensiled maize grain. Medycyna Weterynaryjna 46 (4): 236-238.

Christon, R. (1988). The effect of tropical ambient temperature on growth and metabolism in pigs. J. Anim. Sci. 66: 3112-3123.

CIFT (1992). Fisheries statistics-1992. Central Institute of Fisheries Technology, Cochin, India.

Coffin, D.L. (1953). Manual of Veterinary Clinical Pathology. Comstock Publishing Associates, Ithaca, New York. 3rd ed.

*Cole, D.J.A., Wood, J.D. and Kilpatrick, M.J. (1987). Effect of beta agonist GAH/034 on growth, carcass quality and meat quality in pigs. In Beta-agonists and their effect on animal growth and carcass quality. Elsevier Applied Science Publishers Ltd., U.K. pp.137-142.

Comstock, R.E. and Winters, L.M. (1944). The development of body form in swine. J. Anim. Sci. 3: 188-193.

Corino, C., Baldi, A. and Bontempo, V. (1991). Influence of low-glucosinolate rapeseed meal on performance and thyroid hormone status of heavy pigs. Animal Feed Science and Technology 35 (3-4): 321-331.

*Cortamira, O. and Garcia, P.T. (1984). Effect of a feed restriction by limiting access to feed on the performance and meat quality of growing-finishing pigs. Rivista Argentina de Produccion Animal 4 (3): 243-253.

*Cruz Bustillo, D., Dieguez, F.J. and Gonzalez, A.M. (1987). Carcass composition in commercial barrows and gilts slaughtered at 60-110 kg live weight. Ciencia y Technica en la Agricultura 10 (1): 71-87.

*Cuthbertson, A. and Pomeroy, R.W. (1962). Qualitative anatomical studies of the composition of pigs at 50, 68 and 92 kg carcass weight. 1. Experimental materials and methods. 2. Gross composition and skeletal composition. J. Agric. Sci. 59: 207-214; 215-223.

*Dalrymple, R.H., Baker, P.K. and Ricks, C.A. (1984). Repartitioning agents to improve performance and body composition. Proc. 1984. Georgia Nutr. Conf. for the Feed Industry, USA. pp.111-118.

Dalryple, R.H., Baker, P.K., Gingher, P.E., Ingle, D.L. and Ricks, C.A. (1984). Effect of the repartitioning agent CL 263, 780 on muscle and fat accretion in finishing swine. J. Anim. Sci. 59 (Suppl. 1): 212.

Davey, R.J., Morgan, D.P. and Kincaid, C.M. (1969). Response of swine selected for high and low fatness to a difference in dietary energy intake. J. Anim. Sci. 28 (2): 197-203.

Davey, R.J. and Bereskin, B. (1978). Genetic and nutritional effects on carcass chemical composition and organ weights of market swine. J. Anim. Sci. 46 (4): 992-1000.

*Delate, J.J. and Basu, R. (1990). Predicting live weight from body measurements in hardy pigs from a tropical area. 22es Journees de la Recherche Porcine en France : 35-42.

Denton, M. and Lacey, R.W. (1991). Intensive farming and food processing : implications for polyunsaturated fats. J. Nutr. Med. 2 (2): 179-189.

Diersen-Schade, D., Richard, M.J., Beitz, D.C. and Jacobson, N.L. (1985). Effects of beef, soy and conventional diets on body composition and plasma lipids of young pigs fed restricted or liberal amounts of diet. J. Nutr. 115 (8): 1016-1024.

*Dimov, V. and Banskalieva, V. (1990). Some aspects of energy metabolism in growing pigs. Zhivotnov "dni" Nauki 27 (1): 68-73.

*Doberschutz, K.D., Lusky, K., Stoyke, M. and Gobel, R. (1990). Influence of energy-rich and energy-depleted diets with n-alkaline yeast on the fatty acid composition of depot fat in pigs. Nahrung 34 (3): 345-355.

Donald, H.P. (1940). Growth rate and carcass quality of bacon pigs. A study of polynomial coefficients fitted to growth rate data. J. Agr. Sci. 30: 582. (Cited by Robison, 1976).

Doornenbal, H. and Martin, A.H. (1965). The evaluation of blood volume and total red cell mass as predictors of gross body composition in the pig. Can. J. Anim. Sci. 45: 203-210.

Doornenbal, H. (1971). Growth, development and chemical composition of the pig. 1. Lean tissue and protein. Growth 35: 281. (Cited by Robison, 1976).

Doornenbal, H. and Tong, A.K.W. (1981). Growth, development, and chemical composition of the pig. IV. Relative growth of visceral organs. Growth 45: 279. (Cited by Tess et al., 1986).

*Dubreuil, P., Petitclerc, D., Pellertier, G., Gaudreau, P., Farmer, C., mowles, T.F. and Brazeau, P. (1989). The relationship between body measurements and performance in young boars and gilts of dam breeds. Zivocisna Vyroba 34 (9): 857-862.

Elson, L.A. and Morgan, W.T.J. (1933). Biochem. J. 27: 1824. (Cited by Colowick, S.P. and Kaplan, N.O. 1957. Methods in enzymology. Vol.III. Eds. S.P. Colowick and N.O. Kaplan. Acad. Press, New York. pp.95-99).

*Fiego, D.P. (1988). Investigations on the characteristics of subcutaneous adipose tissue in the carcasses of heavy pigs. Rivista di Suinicoltura 29 (5): 129-135.

Fillar, L.T. and Wirick, M.G. (1978). Bulk solution properties of chitosan. Proc. First Int. Conf. Chitin and Chitosan. MIT, Cambridge. pp.169-181.

*Flanzy, J., Rerat, A. and Francois, A.C. (1965). Influence of structure of the glycerides and nature of the fatty acids in the feed on the composition of the depot fat of pigs. Ann. Biol. animale, Biochim. Biophys. 5: 237-247.

Fontin, A., Firend, D.W. and Sarkar, N.K. (1983). A note on the carcass composition of Yorkshire boars and barrows. Can. J. Anim. Sci. 63 (3): 711-714.

French, G.T. and Bussell, B.W. (1963). The effects of iron supplementation in piglets on haemoglobin levels and growth rates. Austral. Vet. J. 39: 41-45.

Fuller, M.F. (1965). The effect of environmental temperature on the nitrogen metabolism and growth of the young pig. Brit. J. Nutr. 19: 531-542.

Furda, I. (1983). Aminopolysccharides - their potential as dietary fiber. In Unconventional Sources of Dietary Fibers. Ed. I. Furda. ACS Symposium Series 214, American Chemical Society, Washington, D.C. pp. 105-122.

*Gadzier, G.K. (1962). Effect of activity on growth and development of pigs. Trudy Novecerkassk. Zootch - Vet. Inst. 14: 9-21.

*Gandemer, G., Bonnot, C., Vedrenne, P., Caritoz, J.C. and Legault, C. (1990). Lipid composition of the longissimus dorsi and trapezius muscles from four types of pigs with various proportions of Meishan genes. 22es Journees de la Recherché Porcine en France: 23-28.

*Garcia, P.T., Farias, G.E., Casal, J.J., Durselen, G. and Olsen, C. (1984a). Sorghum with high and low tanin contents and carcass quality of pigs. Rivista Argentina de Produccion Animal 4 (5): 609-620.

*Garcia, P.T., Casal, J.J., Farias, G.E., Dursclen, G. and Olsen, C. (1984b). Dietary protein and quantity and quality of intramuscular and depot fat in pigs. Rivista Argentina de Production Animal 4 (9): 957-964.

Garcia, P.T., Cassal, J.J., Olsen, C. and Berra, G. (1986). A comparison of distribution and composition of intramuscular fat in Duroc Jersey and Hampshire pigs at 100 kg live weight. Meat Science 16 (4): 283-295.

Giltner, W. (1907). The histology and physiology of normal pig's blood. J. Comp. Path. and Therap. 20: 18. (Cited by Wiede and Twiehaus, 1959).

Gordon, D.T. and Williford, C.B. (1983). Influence of chitin and chitosan on element absorption in rats. In Unconventional Sources of Dietary Fibers, Their Physiological and In vitro Functional Properties. ACS Symposium Series, Amer. Chem. Soc., Washington, D.C. (Cited by Knorr, 1984).

Gordon, D.T. (1985). Nontraditional Fiber Sources. Paper presented at Second Annual Conference on Food Science, Univ. of Delaware, Newark, D.F. (Cited by Knorr, D., 1986. Nutritional quality, food processing, and biotechnology aspects of chitin and chitosan. A review. Process. Biochemistry 21 (3): 90-92.

Green, J.H. and Krammer, A. (1979). Food Processing Waste Management. AVI Publishing Co., Westport, Conn. (Cited by Knorr, 1984).

*Gregor, G., Triebler, G. and Drzewiecki, C. (1986). Optimal fattering weight of pigs and it's importance for the national economy. Tierzucht 40 (11): 489-491.

*Grela, E. (1983). Carcass depot fat and liver characteristics of fattening pigs as affected by protein and energy content of feeds. Annales Universitatis Mariae Curie Sklodowska, DD (Medicina Veterinaria) 38: 85-97.

*Grela, E.R., Raczkiewicz, J. and Wielbo, E. (1987). The influence of differences in genetic and housing conditions on carcass fatness and fatty acid composition in pigs of Polish breeds. Proc. Seminar 2nd Technical Section of the C.I.G.R., Illinois, USA pp. 22-26.

Grundy, S.M. (1986). Comparison of monounsaturated fatty acids and carbohydrates for lowering plasma cholesterol. N. Engl. J. Med. 314 (12): 745. (Cited by Miller et al., 1990).

Gu, Y., Schinckel, A.P. and Forrest, J.C. (1991). Effect of ractopamine, genotype, and growth phase on finishing performance and carcass value in swine. 1. Growth performance and carcass value. J. Anim. Sci. 69 (7): 2685-2693.

Gupta, R.N. (1983). Comparative growth rate in five strains from weaning to 18 weeks in Large White Yorkshire pigs. Livestock Adviser 8 (9): 47-49.

Gyorgy, P., Kuhn, R., Rose, C. and Zilliken, F. (1954). Arch. Biochem. Biophys. 48: 202. (Cited by Austin et al., 1981).

Gyorgy, P., Kuhn, R. and Zilliken, F. (1955). U.S. Patent 2710806. Chem. Abstr. 49: 18550. (Cited by Nair et al., 1987).

Hale, O.M., Newton, G.L. and Haydon, K.D. (1986). Effect of diet and exercise on performance, carcass traits and plasma components of growing-finishing barrows. J. Anim. Sci. 62 (3): 665-671.

Hartman, A.D., Costello, W.J., Libal, G.W. and Wahlstrom, R.C. (1985). Effect of sunflower seeds on performance, carcass quality, fatty acids and acceptibility of pork. J. Anim. Sci. 60 (1): 212-218.

Hawk, P.B., Oser, B.L. and Summerson, W.H. (1954). Practical Physiological Chemistry, McGraw-Hill Book Company, Inc., New York. 13th ed. pp.580-587.

Heath, M.E. (1983). The effects of rearing temperature on body composition in young pigs. Comparative Biochemistry and Physiology 76 (2): 363-366.

Heidenreich, C.J., Garwood, V.A. and Carter, M.W. (1962). Seasonal influence on serum cholesterol levels in swine. Amer. J. Vet. Res. 23: 457-459.

Heidenreich, C.J., Garwood, V.A. and Harrington, R.B. (1964). Swine growth and composition as associated with total serum cholesterol. J. Anim. Sci. 23: 496-498.

Hirano, S., Itakura, C., Seino, H., Akiyama, Y., Nonaka, I., Kanbara, N. and Kawakami, T.C. (1990). Chitosan as an ingredient for domestic animal feeds. J. Agric. Food Chem. 38 (5): 1214-1217.

*Hladky, V. and Fl' ak, P. (1989). Allometric growth of body measurements in Czech Improved White and Landrace pigs and their crossbreds and back crosses. Zivocisna Vyroba 34 (1): 55-62.

*Holme, D.W. (1963). The cost of pig ment production from pigs of different weights. Agriculture in N. Ireland. 38: 74-77.

Honeyfield, J.A.F. and Barke, R.J. (1985). Dietary sodium and chloride levels for growing-finishing pigs. J. Anim. Sci. 60 (3): 691-698.

*Honkavaara, M. (1989). Influence of porcine stress and breed on the fatty acid profiles of subcutaneous and intramuscular total lipids. Fleischwirtschaft 69 (9): 1429-1432.

*Hoppenbrock, K.H. (1985). Double-quality rapeseed for fattening pigs. Fette Seifen Anstrichmittel 87 (3): 276-278.

Horning, E.C., Ahrens, E.H., Lipsky, S.R., Mattson, F.H., Mead, J.F., Turner, D.A. and Goldwater, W.H. (1964). Quantitative analysis of fatty acids by gas-liquid chromatography. J. Lipid Research 5: 21-27.

Howard, A.N., Leat, W.M.F., Gresham, G.A., Bowyer, D.E. and Dalton, E.R. (1965). Studies on pigs reared on semi-synthetic diets containing no fat, beef tallow or maize oil : husbandry and serum bio-chemistry. Brit. J. Nutr. 19: 383-395.

Husby, F.M., Brundage, A.L. and White, R.L. (1981). Utilization of shellfish meals in domestic feeds. Proc. Conf. Seafood Waste Management in the 1980's. Orlando, Florida. pp.230-260.

*Hwang, Y.J., Po, C. and Chyr, S.C. (1984). Efficiency of gains and carcass characteristics of three-way cross hogs slaughtered at five diferent weights in Taiwan. Jornal of the Taiwan Livestock Research 17 (2): 255-265.

*Inoue, Y., Kanamaru, G. and Shigyo, F. (1980). Influence of kapok oil on fatty acid composition of porcine fat. Japanese Journal of Zootechnical Science 51 (12): 830-836.

*Irie, M. (1988). Influences of supplementing soyabean oil and kapok meal on characteristics of porcine fat. Japanese Journal of Swine Science 25: 125-132.

Ittner, V.R. and Hughes, E.H. (1938). A normal growth curve for swine. J. Hered. 29: 385. (Cited by Robison, 1976).

Jain, N.C. (1986). Schalm's Veterinary Haematology. Lea and Febiger, Philadelphia. 4th ed. pp.1-20.

*Jarkova, A.S. (1962). Comparative effectiveness of fattening young Large White pigs to different live weights. Izv. Timirjazev. Sciskohoz. Akad. No.3: 112-117.

Jones, R.W., Easter, R.A., McKeith, F.K., Dalrymple, R.H., Maddock, H.M. and Bechtel, P.J. (1985). Effect of the beta-adrenergic agonist cimaterol (CL 263, 780) on the growth and carcass characteristics of finishing swine. J. Anim. Sci. 61 (4): 905-913.

Jones, S.D.M., Murray, A.C., Sather, A.P. and Robertson, W.M. (1988). Body proportions and carcass composition of pigs with known genotypes for stress susceptibility fasted for different periods of time prior to slaughter. Can. J. Anim. Sci. 68 (1): 139-149.

Joubert, D.M. (1963). Puberty in female farm animals. Anim. Breed Abstr. 31: 295. (Cited by Robison, 1976).

*Jung, Y.C., Kim, S.H. and Chung, C.S. (1989). Analysis of growth patterns in pigs. 1. Growth patterns of specific pathogen free (SPF) swine. Korean J. Anim. Sci. 31 (11): 666-676.

*Kanis, E. and Koops, W.J. (1990). Daily gain, food intake and food efficiency in pigs during the growing period. Anim. Prod. 50 (2): 353-364.

*Kastarov, V. (1989). The correlation among some finishing and carcass traits in Large White and British Landrace pigs. Zhivotnov "dni" Nauki 26 (3): 16-20.

*Kavanov, V.D. and Koshel, P.P. (1985). Effectiveness of using pigs of a new White-Russian meat type in three breed cross - breeding. Vestnik Sel'skokhozyaistvennoi Nauki No.11: 98-103.

Kehagias, C., Jao, Y.C., Mikolajcik, E.M. and Hansen, P.M.T. (1977). Growth response of Bifidobacterium bifidus to a hydrolytic product isolated from bovine serum. J. Food Sci. 42 (1): 146-150.

Kent, A.W., Whitehouse, H.W. (1955). In Biochemistry of Amino Sugars. Academic Press Inc. New York, N.Y. (Cited Nair et al., 1987).

Knorr, D. (1982). Functional Properties of chitin and chitosan. J. Food Sci. 47: 593-595.

Knorr, D. (1984). Use of chitinous polymers in food. Food Technol. 38 (1): 85-97.

Knorr, D. (1991). Recovery and utilization of chitin and chitosan in food processing waste management. Food Technol. 45: 114-122.

Kobayashi, T., Otsuka, S. and Yugai, Y. (1979). Effect of chitosan on serum and liver cholesterol levels in cholesterol - fed rats. Nutr. Rep. Int. 19 (3): 327-334.

Kobelke, D.N. (1990). By-products from crustacean wastes - chitin production. Food Australia 42 (1): 17-19.

*Koinarski, V. (1983). Growth intensity of Duroc pigs from birth to 130 kg body weight. 1. The average daily gain. Zhivotnov "dni" Nauki 20 (2): 28-36.

*Kolacz, R., Grzegorzak, A. and Dobrzanski, Z. (1983). Effect of different environmental conditions in haematological and biochemical blood values of weaners reared in batteries. Acta Agraria et Silvestria Zootechnica 22: 61-71.

*Kolesen, V.P. and Kurilo, A.S. (1988). Carcass quality of pigs slaughtered at different body weights. Nauchnye Osnovy Razvitiya Zhivotnovodstva No.18: 127-131.

Kono, M., Matsui, T. and Shimizu, C. (1987a). Effect of chitin, chitosan and cellulose as diet supplements on the growth of cultured fish. Bull. Jap. Soc. Sci. Fisheries 53 (1): 125-129.

Kono, M., Matsui, T. and Shimizu, C. (1987b). Chitin-decomposing bacteria in the digestive tracts of cultured Red Sea Bream and Japanese Eel. Bull. Jap. Soc. Sci. Fisheries 53 (2): 305-310.

*KreLowska-Kulas, M., Kedzior, W., Jedryka, T. and Urbanczyk, J. (1982). Effect of feeding pigs on a mixture with yeast on the properties of fat. Roczniki Institutu PrzemysLu Miesnego i TLuszczowego 19: 31-41.

*Kresan, J. and Studena, K. (1988). Growth and carcass quality of Czech Improved White pigs from birth to 240 days of age. 4. Growth of bones. Acta Zootechnica Universitatis Agriculturae Nitra 44: 35-51.

Kumar, A. and Barsaul, C.S. (1987). Determination of best sex and economic slaughter weight with standard ration in Large White Yorkshire Pigs. Ind. Vet. J. 64 (11): 935-939.

Laflamme, L.F. (1988). Utilization of crab meal fed to young beef cattle. Can. J. Anim. Sci. 68 (4): 1237-1244.

Lamkey, J.W., Myer, R.O., Walker, W.R. and Brendemuhl, J.H. (1990). Modification of the unsaturated : saturated ratio of pork fat by feeding growing-finishing diets containing canola oil and supplemented with 250 ppm copper. 3. Effect on carcass fat fatty acid composition. Annual Swine Field Day 35: 84-90.

Landes, D.R. and Bough, W.A. (1976). Effects of chitosan - a coagulating agent for food processing wastes - in the diet of rats on growth and liver and blood consumption. Bull. Environment Contamin. and Toxicol. 15 (5): 555-563.

Leat, W.M.F. (1962). Studies on pig diets containing different amounts of linoleic acid. Brit. J. Nutr. 16: 559-569.

Leat, W.M.F. (1963). Fatty acid composition of the serum lipids of pigs given different amounts of linoleic acid. Biochem J. 89: 44-51.

Leena, K. (1992). Effect of stocking density on the performance of growing pigs. M.V.Sc. Thesis, Kerala Agricultural University, Kerala.

*Lefaucheur, L., Dividich, J. Le., Krauss, D., Ecolan, P., Mourot, J. and Monin, G. (1989). Influence of ambient temperature on growth performance, tissue metabolism and meat quality. In 21es Journees de la Recherche Porcine en France, Paris, France; Institut Technique du Proc.

Lefaucheur, L., Dividich, J. LE., Mourot, J., Monin, G., Ecolan, P. and Krauss, D. (1991). Influence of environmental temperature on growth, muscle and adipose tissue metabolism, and meat and adipose tissue metabolism, and meat quality in swine. J. Anim. Sci. 69 (7): 2844-2854.

Leseigneur-Meynier, A. and Gandemer, G. (1991). Lipid composition of pork muscle in relation to the metabolic type of the fibres. Meat Science 29 (3): 229-241.

Lewis, L.A. and Page, T.H. (1956). Hereditary Obesity: relation to serum lipoproteins and protein concentrations in swine. Circulation 14: 55-59.

Libby, J.A. (1975). Meat Hygiene. Lea and Febiger, Philadelphia. 4th ed. pp. 205-231.

*Luck, H., Kohn, R. and Saumweber, W. (1964). Changes in the composition of pig fat after feeding on concentrates with short-chain fatty acids or with conjugated saturated fatty acids. Stimulation of refining by feeding on fats containing conjugated unsaturated acids. Ztschr. Lebensmittel - Untersuch.- Forch. 125: 13-20.

Lunblad, G., Hederstedt, B. and Steby, M. (1974). Chitinase in goat serum: Preliminary characterisation and purification. Europ. J. Biochem. 46: 367-376.

Lush, J.L. and Kincaid, C.M. (1943). Adjusting weights of pigs to an age of 154 days. Regional Swine Breeding Laboratory Res. Item No.23, Iowa. (Cited by Robison, 1976).

Magee, W.T. (1962). Relationship between daily feed consumption and feed efficiency. J. Anim. Sci. 21 : 880-882.

*Maitre, C. and Kerist, R. (1990). The processing qualities of pig fat: influence of production conditions. Techni - Proc. 13 (1): 25-36.

Malmfors, B., Lundstrom, K. and Hansson, I. (1978). Fatty acid composition of porcine backfat and muscle lipids as affected by sex, weight and anatomical location. J. Agric. Res. 8 (1): 25-38.

*Mandel, L., Travnicek, J. and Simek, L. (1962). The red and white blood picture in pigs weaned early. Vet. Cas. 11: 292-296.

Marchello, M.J., Cook, N.K., Slanger, W.D., Johnson, V.K., Fischer, A.G. and Dinusson, W.E. (1983). Fatty acid composition of lean and fat tissue of swine fed various dietary levels of sunflower seed. J. Food Sci. 48: 1331-1334.

*Martincic, T., Svetina, A. and Fulgosi, E. (1984). The levels of monoesterified fatty acids, total lipids and cholesterol in the serum of swine: the influence of age, diet, and body weight. Veterinarski Arhiv 54 (3): 133-142.

*Matenko, K.D. (1983). Use of boars for meat production. Roczniki Naukowe Zootechniki 10 (1): 297-305.

*Matousek, V., Vaclavovsky, J., Janakova, N. and Vejcik, A. (1988). The effect of slaughter weight on the performance traits of terminal hybrid pigs. Zivocisna Vyroba 33 (a): 839-844.

*Matousek, V., Vaclavovsky, J., Nydl, V. and Janakova, N. (1989). Growth curves in hybrid pigs. Zivocisna Vyroba 34 (a): 769-774.

*Matousek, V., Vaclavovsky, J., Kernerova, N. and Vejcik, A. (1990). Finishing ability and carcass quality of terminal hybrids finished to high slaughter weights. Nas Chov 50 (5): 221-223.

Mattson, F.H. and Grundy, S.M. (1985). Comparison of effects of dietary saturated, monounsaturated, and polyunsaturated fatty acids on plasma lipids and lipoproteins in man. J. Lipid. Res. 26 (2): 194-202.

Mazhar, A., Busboom, J.R., Field, R.A., Rule, D.C., Heald, T., Russell, W.C. and McCormick, R.J. (1990). Functional characteristics, fatty acid composition, and palatability of bacon from pigs fed canola. J. Food Sci. 55 (2): 575-576.

McKay, R.M., Rempel, W.E., Cornelius, S.G. and Allen, C.E. (1984). Visceral characteristics of three breeds of swine and their crosses. Can. J. Anim. Sci. 64 (1): 9-19.

*Meeker, D.L. (1973). The effects of market weight and skeletal size on performance and carcass characteristics of swine. Master of Science thesis, Iowa State University, Ames. (Cited by Robison, 1976).

Mersmann, H.J. and MacNeil, M.D. (1985). Relationship of plasma lipid concentrations to fat deposition in pigs. J. Anim. Sci. 61 (1): 122-128.

Mersmann, H.J., Hu, C.Y., Pond, W.G., Rule, D.C., Navakotski, J.E. and Smith, S.B. (1987). Growth and adipose tissue metabolism in young pigs fed cimaterol with adequate or low dietary protein. J. Anim. Sci 64 (5): 1384-1394.

Miller, E.R., Ullrey, D.E., Ackermann, I., Schmidt, D.T., Luecke, R.W. and Hoefer, J.A. (1961). Swine hematology from birth to maturity. II. Erythrocyte population, size and haemoglobin concentration. J. Anim. Sci. 20 (1): 890-896.

Miller, M.F., Shackelford, S.D., Hayden, K.D. and Reagan, J.O. (1990). Determination of the alteration in fatty acid profiles, sensory characteristics and carcass traits of swine fed elevated levels of monounsaturated fats in the diet. J. Anim. Sci 68: 1624-1631.

Mishra, R.R., Prasad, S. and Lal, K. (1989). Studies on carcass traits of Large White Yorkshire pigs. Indian J. Anim. Prod. Mgmt. 5 (3): 130-133.

Morrison, F.B. (1984). Feeds and Feeding. CBs Publishers and Distributors, Delhi. 22nd ed. pp. 179-180.

Morrow, R.E., Pearson, A.M., Reineke, E.P. and Hoeffer, J.A. (1963). Effects of feeding, fasting and environmental temperature upon blood plasma lipid levels of swine. J. Anim. Sci. 22: 466-470.

Moser, R.L., Dalrymple, R.H., Cornelius, S.G., Pettigrew, J.E. and Allen, C.E. (1986). Effect of cimaterol (CL 263, 780) as a partitioning agent in the diet for finishing pigs. J. Anim. Sci. 62 (1): 21-26.

*Moughan, P.J., Smith, W.C. and Stevens, E.V.J. (1990). Allometric growth of chemical body components and several organs in the pig (20-90 kg live weight). NewZealand J. Agric. Res. 33 (1): 77-84.

*Mugge, B. (1961). Development of pigs at different weight classes from 20 to 110 kg during fattening. Thesis, Univ. Bonn., German. pp. 74.

*Mugge, B. (1963). Comparative fattening trials on pigs in different test periods. Zuchtungskunde 35: 353-362.

Muzzarelli, R.A.A. (1977). Chitin. Pergamon Press, Oxford, U.K. 1st ed. pp. 155-181.

Muzzarelli, R.A.A. (1986). Chitin. In The Polysaccharides. Vol.3. Ed. G.O. Aspinall, Willey, New York. pp. 417-447.

Myer, R.O., West, R.L., Gorbet, D.W. and Brasher, C.L. (1985). Performance and carcass characteristics of swine as affected by the consumption of peanuts remaining in the field after harvest. J. Anim. Sci. 61 (6): 1378-1386.

Nagyvary, J.J., Falk, J.D., Hill, M.L., Schmidt, M.L., Williams, A.K. and Bradbury, E.L. (1979). The hypolipidemic activity of chitosan and other polysaccharides in rats. Nutr. Rep. Int. 20 (5): 677-684.

Nagyvary, J.J. and Falk, J.D., and Nauss, J.L. (1980). Presentation at the 64th Annual Meeting of FASEB. Fred. Proc. 39, 2733 (abstract) (Cited by Furda, 1983).

Nair, K.G.R., Madhavan, P. and Gopakumar, K. (1986). Novel use of chitinous waste from crustacean processing plants. Infofish Marketing Digest No.4186: 20.

Nair, K.G.R., Mathew, P.T., Madhavan, P. and Prabhu, P.V. (1987). Chitin as a feed additive for broiler chicken. Indian J. Poult. Sci. 22 (1): 40-44.

Nair, K.G.R., Mathew, P.T., Madhavan, P. and Prabhu, P.V. (1993). Effect of feeding chitin on poultry. Fish. Technol. 30: 24-27.

Nauss, J.L., Thompson, J.L. and Nagyvary, J. (1983). The binding of micellar lipids to chitosan. Lipids 18 (10): 714-719.

NRC (1988). Designing Foods. National Academy Press, Washington, DC.

*Nurnberg, K. and Ender, K. (1990). Fat quality in pigs of different sexes. Fleischwirtschaft 70 (9): 1099-1102.

*Nurnberg, K. and Wegner, K. (1991). Fatty acid composition and adipocyte size in the backfat of growing boars. Archiv fur Tierzucht 34 (1): 51-56.

*Nowicki, B., Kowalski, Z., Gryez, S. and Doroszewski, K. (1963). Slaughter value of Large White and Swedish Landrace fattened pis in relation to weight at slaughter. Rocz. Nauk rol. 83: 115-133.

O'Connor, J.J. (1980). Mechanisms of growth promoters in single-stomach animals. In Growth in Animals. Ed. T.L.J. Lawrence. Butterworths, London. pp.207-227.

Odink, J., Smeets, J.F.M., Visser, I.J.R., Sandman, H. and Snijders, J.M.A. (1990). Haematological and clinicochemical profiles of healthy swine and swine with inflammatory processes. J. Anim. Sci. 68: 163-17||.

*Ohtake, Y., Hoshino, Y., Aoki, T., Ohgane, T., Ohnuki, M. and Fukumori, Y. (1975). Changes in fatty acid and triglyceride composition of porcine tissue lipids associated with growth of pigs. Japanese Journal of Zootechnical Science 16 (8): 460-468.

*Orlov, K. and Pogodaev, V. (1983). Carcass quality of Russian Large White pigs from intra-breed crossing. Svinovodstvo No.12: 25-26.

*Oslage, H.J., Bohme, H. and Petersen, U. (1984). Studies on the use of different feeding fats for growing fattening pigs. Fette Seifen Anstrichmittel 86 (10): 397-404.

*Osorio Bueno, E., Bordes Pillar, F.J., Mora Seco De Herrara, M., Benito Hernandez, J., Ferrera Claramount, J.L., Vasco Perez, P. and Lopez De Torre, G. (1983). Effect of diet on the fatty acid content of adipose tissue of Iberian pigs. 1. Effects of protein supplementation with soyabean oil meal. Anales de Instituto Nacional de Investigaciones Agravias, Ganadera No.18: 49-62.

*Osterballe, R., Madsen, A., Mortensen, H.P., Bejerholm, C. and Barton, P. (1990). The influence of feeds on meat quality of growing pigs. 2. Linoleic acid/linoleic acid and sunflower seed. Beretning fra statens Husdyrbrugsforsog No.685: 58.

*Otto, E., Klatt, G. and Ender, K. (1983). Finishing of gilts and barrows with the sexes separated. Tieruicht 37 (4): 166-168.

Palmer, C.C. (1917). Morphology of normal pigs' blood. J. Agric. Res. 9: 131. (Cited by Weide and Twiehaus, 1959).

Palsson, H. (1955). Conformation and body composition. In Progress in the Physiology of Farm Animals. Vol.2. Ed. J. Hammond. Butterworths Scientific Publications, London. pp.430-542.

*Patton, R.S. (1972). Evaluation of chitinous materials as a feed for ruminants. Ph.D. thesis, Virginia Polytechnic and State University, Blacksburg. (Cited by Husby et al., 1981).

Patton, R.S. and Chandler, P.T. (1975). In vivo digestibility evaluation of chitinous materials. J. Dairy Sci. 58 (3): 397-403.

Patton, R.S., Chandler, P.T. and Gonzalez, O.G. (1975). Nutritive value of crab meal for young ruminant calves. J. Dairy Sci. 58 (3): 404-409.

*Pavlik, J., Pulkrabek, J. and Polivkova, V. (1988). Evaluation of Czechoslovakian Improved White pigs from 80 to 180 days of age. Scientia Agriculturae Bohemoslovaca 20 (1): 53-60.

Pavlik, J. and Pulkrabek, J. (1989). Analysis of pig growth during the gorwing period. Pig News Inofrmation 10 (4): 465-468.

*Pavlov, V.I., Betaeva, A.P. and Karishin, A.I. (1983). Chelated compounds of iron in feeding of early-weaned young pigs. Byulleten' Vsesoyuznogo Nauchno-issledovatel'skogo Instituta Fizilogii, Biokhimii i Pitaniya Sel'skokhozyaistvennykh Zhivotnykh No.4172: 45-48.

*Petersen, U. and Sether, A. (1979) Nutritional effects of rapeseed oil in pigs. I. Performance and carcass characteristics. Proc. 5th Int. rapeseed Conf. Vol.II, Sweden.

Pig Industry Development Authority (1962). A report on growth and carcases. Brit. Vet.J. 118 (6): 272-274.

Pomeroy, R.W. (1955). Live-weight growth. In Progress in the Physiology of Farm Animals. Vol.2. Ed. J. Hammond. Butterworths Scientific Publications, London. pp. 395-429.

Pomeroy, R.W. (1978). Historical and general review of growth and development. In Patterns of growth and development in cattle. Vol.2. Eds. M.D. Boer and J. Martin, Martinus Nijhoff, London. pp. 3-11.

Pond, W.G., Yen, J.T., Mersmann, M.J. and Haschek, W.M. (1986). Comparative effects of dietary protein and cholesterol - fat content on genetically lean and obese pigs. J. Nutr. 116 (6): 1116-1124.

Pond, W.G., Jung, H.G. and Varel, G.H. (1988). Effect of dietary fiber on young adult genetically lean, obese and contemporary pigs: Body weight, carcass measurements, organ weights and digesta content. J. Anim. Sci. 66: 699-706.

Pond, W.G. and Mersmann, H.J. (1991). Subsequent response to early diet cholesterol and feed restriction in swine. Nutrition Research 11 (5): 461-469.

Poupard, J.A., Husain, I. and Norris, R.F. (1973). Bacteriol. Rev. 37: 136 (Cited by Austin et al., 1981).

*Poznanski, W. (1964). Efficiency of some methods of preventing anaemia in pigs. Zeszyty Nauk. No.59, Zootech. 13: 129-141.

Prabhakar, K. (1984). Comparative studies on the economics of pork production and carcass characteristics of traditionally reared indigenous pigs and intensively reared exotic Large White Yorkshires. Cheiron 13 (4): 172-177.

*Pulkrabek, J., Siler, R., Fiedler, J., Pavlik, J. and Arent, E. (1987). Variability of the triats of carcass value in the dam breeds of pigs. Scientia Agriculturae Bohemoslovaca 19 (3): 191-197.

Pusztai, A., Grant, G., King, T.P. and Clarke, E.M.W. (1990). Chemical Probiosis. In Recent Advances in Animal Nutrition - 1990. Eds. W. Haresign and D.J.A. Cole. Butterworths, London. pp.47-60.

Quijandria, B., Jr. and Robison, O.W. (1971). Body weight and backfat deposition in swine: Curves and correction factors. J. Anim. Sci. 33: 911.

Rao, R.M., Khan, M.Y. and Ranjhan, S.K. (1978). Growth rate and feed efficiency of Large White Yorkshire pigs fed different levels of dietary energy. Indian J. Anim. Sci. 48 (2): 123-125.

Rhodes, D.N. (1976). What do we want from the carcass? In Meat Animals: Growth and productivity. Eds. D. Lister, D.N. Rhodes, V.R. Fowler and M.F. Fuller. Plenum Press, New York and London. pp.9-25.

Robison, O.W. (1976). Growth patterns in swine. J. Anim. Sci. 42 (4): 1024-1035.

*Ruda, M. and Majewski, T. (1985). Effect of maintenance conditions and a supplement of vitamins A and D_3 on growth and development of piglets. Medycyna Weterynaryina 41 (11): 672-674.

*Rybalko, V.P. and Saglo, A.F. (1983). Effect of genotype and feeding on internal characteristics of pigs. Vestnik Sel'skokhozyaistvennoi Nauki No.9: 82-86.

Saseendran, P.C. (1979). The growth, carcass characteristics and economics of rearing of indigenous and exotic pigs. M.V.Sc. Thesis, Kerala Agricultural University, Kerala.

Sather, A.P., Jones, S.D.M. and Joyal, S. (1991). Feedlot performance, carcass composition and pork quality from entire male and female Landrace and Large White market-weight pigs. Can. J. Anim. Sci. 71 (1): 29-42.

*Schmitten, F., Klingelholler, A., Schepers, K.M., Festerling, A. and Jungst, H. (1986). Effect of final fattening weight on carcass quality in pigs. Ziichtungskunde 58 (4): 282-292.

Scott Allen, R. (1982). Lipid metabolism. In Dukes Physiology of Domestic Animals. Ed. M.J. Swenson. Cornell University Press Ltd., London. 9th ed. pp.336-345.

Sebastian, K.S. (1992). Effect of season of birth and energy levels of feed on production performance of pigs. Ph.D. Thesis, Kerala Agricultural University, Kerala.

*Seher, A., Ellinghaus, L., Werner, G. and Petersen, U. (1984). Physiological effect of various mixtures of oleic, linoleic and linolenic acids on growing pigs. 4. Effect on liver lipids. Fette Seifen Anstrichmittel 56 (2): 47-51.

Sharma, B.D., Dubey, C.B. and Singh, S.K. (1990). A comparative study of growth in pure and crossbred pigs. Indian J. Anim. Sci. 60 (4): 492-495.

Shields, R.G. Jr., Mahan, D.C. and Graham, P.L. (1983). Changes in swine body composition from birth to 145 kg. J. Anim. Sci. 57 (1): 43-54.

Shurson, G.C., Ku, P.K., Waxler, G.L., Yokoyama, M.T. and Miller, E.R. (1990). Physiological relationships between microbiological status and dietary copper levels in the pig. J. Anim. Sci. 68: 1061-1071.

Siebert, B.D., Lewis, G. and Topping, D.L. (1987). Comparative effect of lean and high-fat meat or cereal diets on plasma lipids in the pig. Nutrition Research 7 (8): 877-881.

Singh, K.I., Singh, R.L., Singh, S.K., Sharma, B.D. and Dubey, C.B. (1990). Body weight and efficiency of feed utilisation in pigs. Indian J. Anim. Sci. 60 (5): 605-608.

Skelly, G.C., Borgman, R.F., Handlin, D.L., Action, J.C., McConnel, J.C., Wardlaw, F.B. and Evans, E.J. (1975). Influence of diet on quality, fatty acids and acceptibility of pork. J. Anim. Sci. 41 (5): 1298-1304.

Smithard, R.R., Smith, W.C. and Ellis, M.A. (1980). A note on fatty acid composition of backfat from boars in comparison with gilts and barrows. Anim. Prod. 31 (2): 217-219.

Snedecor, G.W. and Cochran, W.G. (1967). Statistical Methods. Oxford and IBH Publishing Co., New Delhi. 6th ed.

Spreen, K.A., Zikakis, J.P. and Austin, P.R. (1984). In Chitin, Chitosan and Related Enzymes. Ed. J.P. Zikakis. Academic Press. Inc, Orlando. pp.57-75.

Stahly, T.S. (1990). Impact of somatotropin and beta-adrenergic agonists on growth, carcass composition and nutrient requirements of pigs. In Recent Advances in Animal Nutrition-1990. Eds. W. Haresign and D.J.A. Cole. Butterworths, London. pp.103-112.

Standal, N. (1973). Studies on breeding and selection schemes in pigs. 11. Environmental factors affecting "on-the-farm" testing results. Acta. Agr. Scand. 23: 61. (Cited by Robison, 1976).

Stoll, P., Gutzwiller, A., Jost, M., Schneeberger, H., Sieber, R., Staehelin, H.B., Steffen, C. and Ritzel, G. (1991). Short-term effect of whole milk and milk fermented by Pseudomonas fluorescens on plasma lipids in adult boars. Brit. J. Nutr. **66** (1): 129-138.

Sugano, M., Fujikawa, T., Hiratsuji, Y. and Hasegawa, Y. (1978). Hypocholesterolemic effects of chitosan in cholesterol-fed rats. Nutr. Rep. Int. **18** (5): 531-537.

Sugano, M., Fujikawa, T., Hiratsuji, Y., Nakashima, K., Fukuda, N. and Hasegawa, Y. (1980). A novel use of chitosan as a hypocholesterolemic agent in rats. Amer. J. Clin. Nutr. 33: 787-793.

Sugano, M., Watanabe, S., Kishi, A., Izume, M. and Ohtakara, A. (1988). Hypocholesterolemic action of chitosans with different viscosity in rats. Lipids 23 (3): 187-191.

Swenson, M.J. (1982). Physiological properties and cellular and chemical constituents of blood. In Dukes' Physiology of Domestic Animals. Ed. M.J. swenson. Cornell University Press Ltd., London. 9th ed. pp. 14-35.

Taylor, J.M. and Hazel, L.N. (1955). The growth curve of pigs between 134 and 174 days of age. J. Anim. Sci. 14: 1133.

Tess, M.W., Dickerson, G.E., Nienaber, J.A. and Ferrell, C.L. (1986). Growth, development and body composition in three genetic stocks of swine. J. Anim. Sci. 62: 968-979.

Tewe, O.O. (1984). Cyanogenic glucoside, protein interaction in cassava peel based ration: effect on some haematological parameters in growing pigs. Nutr. Rep. Int. 30 (20): 425-431.

*Thompson, E.G. (1965). Growth rhythm of spotted Belorussian pigs. Vestn. Sel'skohoz. Nauki No.6: 89-90.

Tumbleson, M.E., Hicklin, K.W. and Burks, M.F. (1976). Serum cholesterol, triglyceride and total bilirubin concentrations, as functions of age and sex, in Sinclair (s-1) miniature swine. Growth 40 (3): 293-300.

*Vaclavovsky, J., Matousek, V. and Janakova, N. (1988). The effect of different slaughter weights on some carcass traits. Rada Zootechnicka 5 (1): 61-72.

Vahouny, G.V., Sachithanandam, S., Cassidy, M.M., Lightfoot. BS, F.B. and Furda, I. (1983). Comparative effects of chitosan and cholestyramine on lymphatic absorption of lipids in the rat. Am. J. Clin. Nutr. **38**: 278-284.

Varney, W.Y., Kemp, J.D., Phillips, C.D. and Barnhart, C.E. (1962). Relative cut-out percentages and values of light and heavy weight hugs. J. Anim. Sci. 21: 593-596.

*Wahlstrom, R. (1984). Feeding flowers. South Dakota Farm and Home Research 35 (2): 7-9.

Wallace, H.D., McCabe, G.E., Palmer, A.Z., Koger, M., Carpenter, J.W. and Combs, G.E. (1959). Influence of slaughter weight on economy of production and carcass value of swine. J. Anim. Sci. **18**: 1484.

Walsh, L.S., Wiggers, K.D., Richards, M.J. and Jacobson, N.L. (1983). Effect of soy versus beef diets on blood and tissue cholesterol and body composition of growing swine. Nutrition Research **3** (4): 557-569.

*Walstra, P. (1980). Growth and carcass composition from birth to maturity in relation to feeding level and sex in Dutch Landrace pigs. Mededelingen Landbouwhogeschool Wageningen **80** (4): 206.

Warriss, P.D., Brown, S.N., Franklin, J.G. and Kestiin, S.C. (1990). The thickness and quality of backfat in various pig breeds and their relationship to intramuscular fat and the setting of joints from the carcass. Meat Science 28 (1): 21-29.

Watkins, T.R. and Knorr, D. (1983). In vivo dye-binding of chitin and its effect on gerbil growth and gut function. Nutr. Rep. Int. 27: 189. (Cited by Knorr, 1984).

Weide, K.D. and Twiehaus, M.J. (1959). Haematological studies of normal, ascarid-infected, and hog cholera-vaccinated swine, Am. J. Vet. Res. 20: 562-567.

West, R.L. and Mayer, R.O. (1987). Carcass and meat quality characteristics and backfat fatty acid composition of swine as affected by the consumption of peanuts remaining in the field after harvest. J. Anim. Sci. 65 (2): 475-480.

White, R.L. (1981). Ruminant utilization of chitin and other components of tanner crab meal. M.S. thesis, Univ. of Alaska, Fairbanks, Alaska. (Cited by Yohoyama and Husby, 1990).

*Widenski, K. and Wojcik, S. (1984). Effect of protein in feeds on some anatomical and chemical characteristics of fattening pigs. 1. anatomical characteristics of digestive tract, heart and liver. Annales Universitatis Mariae Curie Sklodowska, DD (Medicina Veterinaria, Publ. 1984). 35/36: 45-48.

Wood, J.D. (1983). Factors affecting carcass composition. Span, 26 (1): 58-61.

Wood, J.D. (1984). Fat deposition and quality of fat tissue in meat animals. In Fats in Animal Nutrition. Ed. J. Wiseman. Butterworths, London. pp.407-435.

Wood, J.D., Jones, R.C.D., Bayntun, J.A. and Dransfield, E. (1985). Backfat quality in entire males and barrows at 90 kg live weight. Anim. Prod. 40: 481-487.

Wood, J.D., buxton, P.J., Whittington, F.M. and Enser, M. (1986). The chemical composition of fat tissue in the pig: Effects of castration and feeding treatment. Livestock Prod. Sci. 15 (1): 73-82.

*Yatsenko, L.I. (1986). Meat yield of pigs in relation to level of protein feeding. Majasnaya Industriya SSR No.8.: 6-8.

Yen, J.T., Mersmann, H.J., Hill, D.A. and Pond, W.G. (1990). Effect of ractopamine on genetically obese and lean pigs. J. Anim. Sci. 68 (11): 3705-3712.

Yokoyama, M.T. and Husby, F.M. (1990). Ruminal degradation of chitinous waste from the marine seafood industry. Project No.RIGLE-39, Michigan Sea Grant College Programme, Michigan State Univ., East Lansing.

Zikakis, J.P. and Austin, P.R. (1978). Presented at the 2nd World Congress in Science, Thessaloniki, Greece. (Cited by Zikakis et al., 1982).

Zikakis, J.P., Saylor, W.W. and Austin, P.R. (1982). Utilization of chitinous products and whey in animal nutrition. In Chitin and Chitosan. Eds. S. Hirano and S. Tokura. Japanese Soc. Chitin and Chitosan, Sapporo, Japan. pp.233-238.

zilliken, F.P., Rose, C. and Gyorgy, P. (1954). J. Biol. Chem. 208: 299. (Cited by Austin et al., 1981).

* Originals not consulted

INFLUENCE OF CHITIN ON GROWTH AND FATTY ACID COMPOSITION IN GROWING PIGS

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ABSTRACT

A study was carried out to find out the influence of feeding chitin to pigs on their growth, carcass characteristics, blood cell count and haemoglobin concentration, serum cholesterol and triglyceride levels, and fatty acid profile of muscle and backfat.

Twenty-four weaned female piglings of Large White Yorkshire breed were assigned to three groups of eight each. Two groups were fed chitin with a standard farm ration at levels of 0.5 per cent (Group 1) and 1 per cent (Group 2), and the remaining group, which served as the control, was fed only the ration without addition of chitin (Group 3). All animals were housed individually and were fed in two 1-hour feeding periods daily.

Digestibility of chitin did not differ between the two chitin-fed groups. The percentage of digestibility increased from age 3 months (79.37 $\pm$ 1.85 to 80.49 $\pm$ 1.85) to 5 months (95.36 $\pm$ 1.13 to 96.54 $\pm$ 1.05) and thereafter remained constant at 7 months (95.35 $\pm$ 1.33 to 95.77 $\pm$ 1.57).

The chitin-fed groups had significantly ($P<0.05$ or 0.01) higher body weights than the controls from 18th to 40th

week of age. Compared with the controls, the chitin-fed groups had higher total gains in weight by 11 to 12 kg.

Both the chitin-fed groups also had significantly ($P<0.05$ or 0.01) higher average daily gains than the controls from 18th to 40th week of age. The pigs in all groups showed a peak rate of gain at 32nd week of age.

The chitin-fed groups also averaged higher body lengths, heights and girths, and also higher daily gains in these measures as compared with the control group.

Daily feed intake increased with age of animals in all the groups. Daily feed intake did not differ significantly between the groups.

For all the groups, maximum feed efficiency was recorded between 16th and 30th week of age. As compared with the controls, the chitin-fed groups showed higher feed efficiency. The differences between the control and chitin-fed groups were found to be significant ($P<0.05$) at the end of the experiment.

The pigs in the chitin-fed groups averaged higher slaughter weights than the controls at 5, 7 and 9 months of age.

For the pigs in all groups, carcass length, ham weight and eye-muscle area showed higher percentages of gain between 5 and 7 months than between 7 and 9 months of age. The percentage of ham decreased with increase in age and weight of animals. The chitin-fed groups of pigs showed higher carcass lengths, ham weights and eye-muscle areas than the control group at each stage of slaughter.

The backfat deposition showed a higher deposition between 5 and 7 months than between 7 and 9 months of age, while the majority of leaf fat deposition took place between 7 and 9 months of age. The percentage of leaf fat increased with increase in age and weight of animals in all the groups. The chitin-fed groups showed lower backfat thickness and lower percentages of leaf fat than the controls at each stage of slaughter.

The increase in dressing percentage was found to be higher between 7 and 9 months than between 5 and 7 months of age, for all groups of pigs. The chitin-fed groups yielded higher dressing percentages than the control group at each stage of slaughter.

The weight of internal organs increased with age of animals, whereas weight of internal organs as percentage of live weight decreased. The control group of pigs had higher

percentages of internal organs than the chitin-fed groups at each slaughter age.

The haemoglobin concentration, total erythrocyte count, total leukocyte count, and differential leukocyte count did not differ significantly between the groups of pigs at 5, 7 or 9 months of age.

The pigs in group 2 averaged the lowest serum cholesterol and triglyceride levels followed by the pigs in group 1 and group 3, in that order, at 5, 7 and 9 months of age. The differences in serum cholesterol concentration between the pigs in group 2 and the pigs in either group 1 or group 3 were found to be significant ($P<0.05$) at 7 months and highly significant ($P<0.01$) at 9 months of age.

The serum triglyceride concentration followed the same trend as serum cholesterol concentration, between the groups of pigs. However, the differences were not found to be statistically significant.

The fatty acid composition of muscle and backfat did not differ noticeably between the groups at 5 months of age. At the subsequent ages of 7 and 9 months, the chitin-fed groups showed markedly higher degree of unsaturation and lower saturation than the control group. Higher percentages of oleic acid and lower percentages of palmitic acid were

recorded for the chitin-fed groups as compared with the control group.

The results revealed that chitin had growth-promoting, hypolipidemic and hypocholesterolemic effect in pigs. It also improved the degree of unsaturation in pig meat.