EFFECT OF DIETARY POTASSIUM DIFORMATE ON GROWTH PERFORMANCE IN LARGE WHITE YORKSHIRE PIGS

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DECLARATION

I hereby declare that this thesis entitled **"EFFECT OF DIETARY POTASSIUM DIFORMATE ON GROWTH PERFORMANCE IN LARGE WHITE YORKSHIRE 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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CERTIFICATE

Certified that this thesis entitled **"EFFECT OF DIETARY POTASSIUM DIFORMATE ON GROWTH PERFORMANCE IN LARGE WHITE YORKSHIRE PIGS"** is a record of research work done independently by **Shri. M. Suresh,** under my guidance and supervision and that it has not previously formed the basis for the award of any degree, fellowship or associateship to him.

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Suresh, M.

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Introduction

1. INTRODUCTION

In developing countries, per capita protein consumption is about half of that of developed countries, the major portion of the total protein intake is of vegetable origin. According to Food and Agricultural Organisation of the United Nations (1971), one-third of the total protein requirements must be met from animal protein sources to correct the amino acid deficiencies of vegetable/cereal proteins.

Among the farm animals, pigs are the most prolific animals with higher litter size, shorter gestation period, higher growth rate and better feed efficiency. They attain market weight as early from six months of age. Hence increasing pork production will help to meet out the protein demand.

Feed accounts for about 70 to 75 per cent of the total cost of production (Ranjhan, 2001). So, ration formulation has become an important task to obtain maximum production of quality pork per unit of feed consumed, at a least cost and to exploit the maximum production potential of pigs. These can be achieved by the use of feed additives.

Antibiotics and antimicrobials have been largely used as additives in the ration of swine. In recent years, the use of sub-therapeutic levels of antibiotics as growth promoters has been reduced. Devèlopment of cross-resistance to antibiotic growth promoters and cross resistance of animal and human pathogens demonstrates the need for safer, alternative growth enhancers for rearing pigs.

Several naturally occurring compounds such as organic acids, fermented feed, probiotics and prebiotics have shown to affect the composition and activity of the microflora in the gastrointestinal tract of pigs. Organic acids have received much attention as alternatives. Formic acid has shown to be effective against pathogenic bacteria (Gedek *et al.*, 1992; Kirchgessner *et al.*, 1992b), but its use has been limited by problems of handling, strong odour and corrosion during feed processing and during its use on the farm. This disadvantage has been overcome by organic salts which started gaining importance.

Potassium diformate (Formi^{TM} LHS) is one of the most commonly used organic salts to decrease and alter microbial fermentation in monogastric animals. It is a dry crystalline powder, odourless, less corrosive and easy to handle. It provides a safer work environment, minimizes damage to feed mill equipment compared to liquid forms of organic acid such as formic acid. Its effectiveness as growth promoter in diets of both weanling pigs and growing-finishing pigs had already been proved (Paulicks *et al.,* 1996; Roth *et al.,* 1996; Kirchgessner *et al.,* 1997). European Union has issued approval for potassium diformate (Formi^{TM} LHS) as a non-antibiotic growth promoter for use in pig feeds (Anon, 2001). Similar study has not been undertaken in India. Hence this study was conducted to evaluate the effect of potassium diformate on growth performance, feed efficiency, carcass characteristics and to assess the economics in feeding of Large White Yorkshire pigs.

Review of Literature

2. REVIEW OF LITERATURE

2.1 MECHANISM OF ACTION OF POTASSIUM DIFORMATE

Broek (2000) opined that the organic acids can be divided into two groups based on the mode of action viz., 1. Acids with indirect effect on decreasing bacterial population by lowering the pH (fumaric acid, malic acid, citric acid and lactic acid) in the stomach. In the intestine, these acids do not have any effect since the pH is brought back to 6.5 by high bicarbonate secretion. 2. Acids that act directly (formic acid, acetic acid, propionic acid and sorbic acid) on the bacterial population by interfering with enzyme complexes in the bacterial cell, thereby destroying cell membrane and DNA-duplicating mechanism in addition to the indirect effect by lowering the pH of the stomach contents.

Overland *et al.* (2000) found that a large proportion (79 to 93 per cent) of formic acid and formate from potassium diformate were present in small intestine of piglets up to 245 minutes after feeding. They also found that a combination of high concentration of formic acid and low pH in the duodenum causes a strong antimicrobial effect.

Canibe *et al.* (2001a) reported that the action of potassium diformate is due to the antimicrobial properties of their anions and cations, when they dissociate after passing through bacterial cell wall and exert a disruptive effect on bacterial protein synthesis. Undissociated organic acid can diffuse freely through the semi-permeable membrane of micro organisms into their cell cytoplasm. Once inside the cell, where the pH is maintained near seven, the acid will dissociate and suppress the cell enzymes and nutrient transport systems.

Canibe *et al.* (2001c) explained that the action of organic acid is due to a reduction of pH, as well as due to their ability to dissociate which is determined by the pK_a-value of the respective acids. Organic acids are lipid soluble in the undissociated form, in which they enter microbial cell through a carrier-mediated transport. Once inside the microbial cell they dissociate and release protons decreasing the intracellular pH. This affects microbial metabolism and force them to use energy to release protons and leading to accumulation of acid anions which is responsible for the antibacterial effect. Similar mode of action for organic acids was reported by Puyalto and Mesia (2002).

Overland and Granli (2001) reported that the antimicrobial effect of potassium diformate is restricted to the stomach and first part of jejunum where it reduces the pH and a high concentration of formate was found. They added that the effects can be expressed in three ways. 1. A general reduction of microbial activity, leaving more nutrients for the animal and less harmful bacterial metabolites. 2. A special effect against opportunistic pathogens such as *Escherichia coli.* 3. An improved bacterial composition of lactic acid bacteria Vs enterobacteria and lactic acid producers Vs lactic acid consumers. The similar mode of action of potassium diformate on the microbial population was also reported by Overland (2001) and Granli *et al.* (2002).

2.2 GROWTH PERFORMANCE AND FEED EFFICIENCY

Cole *et al.* (1968) supplemented either 0.8 per cent lactic acid, or 0.8 per cent propionic acid or calcium propionate (equivalent to 0.8 per cent propionate) or calcium acrylate (equivalent to 0.8 per cent acrylate) in drinking water of weaned pigs and found that lactic acid improved growth rate. In contrast, Li *et al.* (1999) reported that supplementation of organic blend (mixture of lactic acid, fumaric acid, propionic acid, formic acid and ortho-phosphoric acid) to the diet of weaned piglets at 0.5 per cent level produced no significant improvement in daily gain or feed conversion efficiency. Similarly, Starkey *et al.* (2000) supplemented the diet of sows with or without Kemgest™ 0.5 per cent (a cocktail of phosphoric, lactic and citric acids) and Acid Lac™ 0.5 per cent (a cocktail of fumaric, lactic, citric, propionic and formic acids) and opined that Acid Lac™ supplementation resulted in weight loss. However no difference was seen in rebreeding, average daily feed intake, number of piglets born alive, still births, mummies, piglet survivability and litter weight gain among sows in the various dietary treatments.

Falkowski and Aherne (1984) supplemented crossbred piglet diets with zero, one or two per cent fumaric acid or citric acid and reported that average daily gain was four to seven per cent greater and feed conversion efficiency was improved by five to ten per cent for pigs fed diets containing fumaric or citric acid. A similar increase in feed utilization was reported by Edmonds *et al.* (1985) when pigs were supplemented with 1.5 per cent citric or fumaric acid, both in the presence or absence of copper, Aureo-Sulfa-Pencillin (ASP) or in the combination of copper and ASP. Burnell *et al.* (1988) conducted a study in weanling pigs by supplementing the diet with organic acid (citric acid and sodium citrate, 2:1) at 0, 0.5 or 1 per cent level. It was found that addition of organic acid to corn soybean meal diet at one per cent level improved growth rate. The feed conversion efficiency of pigs was similar for both levels of supplementation which was better than the unsupplemented group.

Radecki *et al.* (1988) supplemented 0, 1.5, or 3.0 per cent of fumaric or citric acid with or without antibiotic supplementation to the diet of weanling pigs and found that fumaric acid improved average daily gain and gain:feed during the second week. Risley *et al.* (1993) measured the efficacy of organic acid by supplementing weaned piglets with either 1.5 per cent fumaric acid or 1.5 per cent citric acid and challenged with 10^{10} *E. coli* and reported that organic acid addition had no measurable effect on growth performance or scouring and did not modify the effects of the post weaning *E. coli* challenge. Increase in daily gain and feed efficiency were reported by Schoenherr (1994), when fumaric acid was added to a complex diet. Vankol (2000) opined that addition of organic acids (lactic acid, fumaric acid or both) to diet of finishing pigs increased the daily gain significantly. The feed intake and conversion ratios were also improved by acid treatment. These effects were similar to antibiotic (Tylosine) treatment.

Eckel *et al.* (1992a) opined that supplementation of formic acid at 0.6, 1.2 and 1.8 per cent in the diet of crossbred piglets increased the daily weight gain by 21.8, 22.1 and 4.6 per cent, respectively. Similarly, *ad libitum* feed intake improved by 14.2, 12.7 and 3.5 per cent and feed conversion efficiency by 5.6, 7.5 and 1.0 per cent, respectively. It was opined that the most effective inclusion level of formic acid in the feed was 1.2 per cent. Similarly, Eidelsburger *et al.* (1992a) reported that addition of 1.25 per cent formic acid to the diet of piglets improved daily weight gain by 7.4 per cent. Feed conversion efficiency was significantly improved. Supplementation of 1.8 per cent calcium formate increased (2.7 per cent) the daily weight gain and feed conversion rate (1.7 per cent) in the prestarter period. Baustad (1993) reported that addition of 0.6 per cent formic acid to the diet of pigs in the period from 28 to 100 kg live weight improved growth rate and feed conversion efficiency (eight per cent). In another experiment, it was found that there was no positive effect of 0.6 per cent formic acid supplementation from weaning to 20 kg live weight, but in the growth period from 20 to 100 kg, there was improvement in daily gain and feed conversion.

Ludke and Schone (1994) reported an increased weight gain and feed conversion efficiency when formic and phosphoric acid adsorbates were supplemented to the diet of weaner pigs. The incidence of diarrhoea was also decreased. Similarly, Tossenberger *et al.* (1998) supplemented three levels (0, 10 and 15g/kg) of Formic-Stabil 65^{TM} (preparation containing 6.5 per cent formic acid) to diet of piglets and found that at a dose level of 10g/kg, there was an improvement of 12.5 per cent in daily gain and 7.6 per cent in feed conversion than the control animals.

Roth *et al.* (1996) compared two diformate based products (LHS-N and LHS-S, Norsk Hydro a.s., Oslo) with different dosages (0.65, 1.3 and 1.95 per cent) and found that the weight gain and feed conversion efficiency of piglets weighing between 6.5 and 16 kg live weight was significantly higher than that of control and there were no differences between the type of products and the levels of supplementation. They also reported that fattening pigs fed with similar dosages improved feed conversion efficiency significantly from 2.68 to 2.57 and there was no significant difference in the effects of potassium diformate between the initial and final fattening period. Paulicks *et al.* (1996) supplemented the diet of growing piglets with 0, 0.4, 0.8, 1.2, 1.6, 2.0, 2.4 and 2.8 per cent of potassium diformate (Formi^{TM} LHS) and found to have 22 per cent increase in daily weight gain and 15 per cent higher daily feed intake in two per cent supplemented group. The feed conversion efficiency was also improved significantly. They opined that the optimal level of Formi^{TM} LHS supplementation in the feeds of piglets weighing between 7 and 30 kg was 2.0 to 2.2 per cent.

Kirchgessner *et al.* (1997) stated that there was an improvement over control animals in weight gain, feed intake and feed conversion by seven per cent, three per cent and five per cent, respectively in piglets during the piglet period (1-42 days) when supplemented with 1.6 per cent Formi^{TM} LHS. In another study, with the same animals during the fattening period (43-134 days) with supplementation of 0.8 per cent potassium diformate, improved daily weight gain, daily feed intake and feed efficiency. Roth *et al.* (1998b) reported that there was an increase in nitrogen retention by seven per cent and reduction in mean faecal and urinary nitrogen excretion by ten per cent when pigs were fed with 1.8 per cent potassium diformate (Formi^{TM} LHS Norsk Hydro a.s., Oslo) at varying dietary lysine levels. Nitrogen retention and nitrogen utilization were increased with increase in dietary lysine level. Overland *et al.* (1999) conducted an experiment in growing-finishing pigs with three levels of potassium diformate (0, 0.6 or 1.2 per cent). It was found that increasing levels of Formi^{TM} LHS increased average daily gain and average daily feed intake and tended to increase gain:feed ratio.

Han *et al.* (1998) reported that average daily gain of pigs fed with diets containing 300 U/kg microbial phytase and 1.5 per cent citric acid with no inorganic phosphorus and control diets containing added inorganic phosphorus (0.2 per cent) were similar. The feed:gain ratio of supplemented group was significantly higher. In a similar study, Radcliffe *et al.* (1998) fed crossbred weanling pigs with corn-soybean meal diet which was low in calcium and phosphorus and supplemented with three levels of citric acid (0, 1.5 or 3.0 per cent) and four levels of phytase (0, 250, 500 or 750 U/kg) and they reported that, addition of citric acid resulted in improved feed efficiency but, no synergetic effect was observed on supplementation of citric acid along with phytase. Jongbloed *et al.* (2000) fed growing pigs with basal diet containing 0.6 per cent calcium and 0.1 per cent digestible phosphorus with or without supplemental phytase (410 U/kg) and lactic acid (0, 1.6 and 3.2 per cent) or formic acid (0, 0.8 and 1.6 per cent). Both organic acids and microbial phytase had positive response on growth rate and feed conversion ratio but there was no synergistic effect. The effect of supplementation of microbial phytase and organic acids in the diets for early weaned pigs was also investigated by Omogbenigun *et al.* (2003). They found that there was no difference in average daily feed intake, average daily gain and gain:feed ratio among treatment groups viz., pigs fed with control diet, supplemented with microbial phytase alone and supplemented with microbial phytase and organic acids. However the average daily gain was higher by 6.5 per cent in piglets supplemented with microbial phytase and organic acids compared with that of the control group.

Wolter *et al.* (2000) reported that using a particular combination of acid, enzyme blend and flavor prevents a reduction in pig performance when replacing more digestible animal protein feedstuffs with soybean meal in a nursery diet. According to Broek (2000) organic acids are more profitable by virtue of its antimicrobial activity resulting in a decreased mortality and lower medicine costs than obtaining benefits from improved feed conversion efficiency and weight gain.

Paulicks *et al.* (2000) conducted three experiments in weaned piglets fed with or without 1.8 per cent potassium diformate. In experiment I (singly reared) and experiment II (group reared) two levels of feed energy (13MJ ME/kg or 14MJ

ME/kg feed) were used for both and it was found that the final weights were improved by five and twelve per cent, respectively in supplemented groups. The daily weight gains were improved by eight per cent in experiment I and eighteen per cent in experiment II and feed conversion by six per cent in both. In low energy diet, the feed intake was higher by one per cent in experiment I and eight per cent in experiment II. Compared to unsupplemented low energy diet, the final weights, daily weight gain and feed conversion efficiency of high energy diet were higher by up to 10, 14, and 11 per cent, respectively. In experiment III, different grains with or without 1.8 per cent potassium diformate were used. Feed consumption increased significantly in supplemented wheat based diet. Feed efficiency was increased by six, four and seven per cent, respectively in barley, wheat and barley-wheat-corn diet.

Overland *et al.* (2000) reported that supplementation of potassium diformate at different levels (0.6, 0.8 and 1.2 per cent) in the diet of growing-finishing pigs improved the overall average daily gain and feed conversion efficiency. Anon (2001) conducted studies in piglets and pigs for fattening using different doses of potassium diformate and found that feed intake, daily gain and feed:gain increased significantly at dose range of 1.8 to 2.0 per cent for the piglets up to two months of age. There was only numerical increase in daily weight gain during the fattening period.

Overland (2001) reported that there was an improvement in growth rate by 8.6 per cent and feed efficiency by 7.3 per cent with addition of 1.2 per cent potassium diformate in the diet of piglets. They also reported that there was no significant difference between Avilamycin and potassium diformate in these parameters. Similar results were reported by Overland and Granli (2001). Windisch *et al.* (2001) studied the effect of potassium diformate in two experiments, one with varying levels of copper (25, 75, 125, 175 ppm) with either zero or 1.8 per cent potassium diformate, another with varying levels of potassium diformate (0, 0.6, 1.2 and 1.8 per cent) and copper at either 25 or 175 ppm. They found that, rising dietary addition of potassium diformate and copper improved weight gain, feed intake and feed conversion rate of piglets. It failed to act additively at highest dose levels of the two supplements. However, Canibe *et al.* (2001a) reported that there was no significant difference in average daily gain and gain:feed ratio between control and treatment groups supplemented with 1.8 per cent potassium diformate in the diet of piglets. Mroz *et al.* (2002) opined that supplementation of potassium diformate and potassium formate at varying levels improved body nitrogen by 3.7 per cent.

Min *et al.* (2001) reported that there were no significant differences in daily feed intake and feed conversion ratio between the growing-finishing pigs supplemented with acidified diet or control diet. The average daily gain was significantly higher than the mineral feed additive supplemented group. There was 3.2 per cent increase in weight gain by organic acid supplementation. Roura *et al.* (2002) stated that flavour, acid and enzyme supplementation of a simple diet resulted in growth performance and feed efficiency which was not significantly different from those of weaned pigs fed a complex diet. Stein *et al.* (2002) stated that supplementation of Aciprol^{TM} (a blend of organic and inorganic acids) to the diet of weanling pigs had no effect on daily gain and average daily feed intake. The gain:feed ratio was greater than the control group and it was similar to carbadox (Mecadox, Pfizer, Germany) supplemented group.

2.3 APPARENT DIGESTIBILITY OF NUTRIENTS

Radecki *et al.* (1988) supplemented the feed of weanling pigs with 1.5 per cent fumaric acid or antibiotic supplement (premix containing chlortetracycline, sulfamethazine and penicillin). It was found that the apparent nitrogen digestibility, percentage nitrogen retained and nitrogen balance were not affected by the diet. Gabert and Sauer (1995) studied the effect of supplementation of fumaric acid at 1.5 per cent or 3 per cent level or sodium fumarate at 1.5 per cent level in the diet of weanling pigs. They found that the supplemented fumaric acid or sodium fumarate did not increase the apparent ileal or total tract digestibility co-efficients of amino acids. Blank *et al.* (1999) opined that supplementation of fumaric acid to the starter diet of piglets during the first three to four week after weaning increased ileal digestibilities of gross energy, crude protein and amino acids. Piva *et al.* (2002) reported that addition of organic acid blend (mixture of phosphoric, citric, fumaric and malic acids) to diets of pigs reduced ammonia, isoacids and acetic acid concentrations in fermentation fluid regardless of type of diet.

Eckel *et al.* (1992a) observed that supplementation of formic acid at 1.8 and 2.4 per cent levels to the diet of piglets increased the protein and energy digestibility significantly in the prestarter period whereas, only protein digestibility was increased significantly in 2.4 per cent supplemented group during the grower period. In another study Eckel *et al.* (1992b) supplemented 0, 0.6, 1.2, 1.8 or 2.4 per cent formic acid in the diet of piglets and found that ammonia content in the stomach was significantly reduced by formic acid. Also, the concentration of cadaverine, putrescine and spermidine in the caecum were reduced. Similarly, Eidelsburger *et al.* (1992a) stated that supplementation of formic acid at 1.25 per cent level or calcium formate at 1.8 per cent level significantly increased the protein digestibility in the prestarter period. In the rearing period, addition of formic acid with buffer sodium bicarbonate (2.0 per cent) significantly increased protein, energy and dry matter digestibilities when compared with the controls. Roth *et al.* (1992) supplemented 0, 0.6, 1.2, 1.8 or 2.4 per cent formic acid to the diet of piglets. They found that the dry matter content was unaltered in the stomach but, there was a slight increase of the same in small intestine and caecum. In colon the dry matter content was significantly higher.

Gabert *et al.* (1995) reported that supplementation of one per cent formic acid to corn starch based fish meal diets with low and high buffering capacity for weanling pigs (7.8 to 13.8 kg) did not affect the digestibility of nutrients in small intestine and apparent amino acid digestibility in ileum. Tossenberger *et al.*

(1998) conducted a study in weaned piglets by supplementing the diet with two levels of Formic-Stabil 65™ (0 and 15 g/kg). They observed that the apparent ileal digestibility of crude protein was improved from 76.5 to 79.3 per cent, lysine from 77.6 to 82.2 per cent and that of methionine from 86.2 to 88.0 per cent. A similar improvement in digestibility was also found for other amino acids.

Jongbloed *et al.* (1996) reported significantly increased apparent digestibility of dry matter and organic matter when growing pigs were supplemented with microbial phytase and organic acids such as lactic acid, formic acid and propionic acid. Similar results were also reported by Jongbloed *et al.* (2000) in growing pigs. Overland *et al.* (2002) reported that there was a synergistic effect between potassium diformate and phytase on digestibility of protein. Omogbenigun *et al.* (2003) found that the addition of microbial phytase and organic acids (citric, malic, phosphoric, sorbic, tartaric and lactic acids) increased the apparent ileal digestibility of isoleucine, histidine and aspartic acid whereas those of dry matter and crude protein were unaffected.

Mroz *et al.* (1997) reported that addition of calcium benzoate (2.4 per cent) to the diet of pigs enhanced the ileal digestibility of dry matter, organic matter, arginine, isoleucine, leucine, phenyl alanine, alanine, aspartic acid and tyrosine. The total tract digestibility of dry matter, ash and gross energy was greater. It was also reported that addition of organic acids (formic, fumaric or n-butyric acid) at the amount of 300 mEq acid/kg feed of growing-finishing pigs exerted a positive effect on the ileal digestibility of amino acids (except for arginine, methionine and cysteine). The total tract digestibility of dry matter, organic matter and crude protein and nitrogen retention were found to be higher. A similar report was also given by Mroz *et al.* (2000).

Roth *et al.* (1998b) reported that there was an increase in digestibility of dry matter (85 per cent), crude protein (82.6 per cent), nitrogen free extract (91.9 per cent) and energy (84.7 per cent) when supplemented the diets of piglets with 1.8 per cent Formi™ LHS at different dietary lysine levels. Similarly, Fevrier *et al.* (2001) reported that addition of potassium diformate at 0.9 per cent and 1.8 per cent to the diet of weaned piglets improved dry matter digestibility significantly. Nitrogen digestibility was also improved at 0.9 per cent level than the control. An investigation was carried out by Mroz *et al.* (2002) by supplementing the diet of growing-finishing pigs with one per cent potassium diformate or 0.65 per cent potassium formate or 0.35 per cent formic acid or 1.3 per cent potassium formate. The results revealed that there was no significant difference in the ileal digestibility of dry matter, organic matter, crude protein or essential amino acids except phenyl alanine between the supplemented and unsupplemented groups.

Lesniewska *et al.* (2001) reported that there was no effect on basal pancreatic secretion in weanling pigs when given feed supplemented with lactic or formic acid. There was an increased outflow of pancreatic juice and bicarbonate ions on intra duodenal infusion and this effect was greater with lactic acid than formic acid. It was also found that the antral myoelectrical activity has been inhibited by intra duodenal infusion and was changed independent of dietary change. Partanen *et al.* (2001) reported that addition of formic acid (0.8 per cent level) to the diet of growing-finishing pigs improved significantly the faecal nutrient digestibility of organic matter in high fibre diet and ileal digestibility of several essential and non-essential amino acids. The apparent ileal and faecal nutrient digestibilities of crude protein and ether extract were improved significantly in high fibre diets. Formic acid also decreased the ileal flow of purines and that of bacterial nitrogen.

2.4 EFFECT ON GUT MICROFLORA

Cole *et al.* (1968) conducted an experiment in weaned pigs by supplementing with either 0.8 per cent lactic acid or 0.8 per cent propionic acid or calcium propionate (equivalent to 0.8 per cent propionate) or calcium acrylate (equivalent to 0.8 per cent acrylate) in drinking water and samples from proximal intestine were assessed for microflora. It was found that control pigs had a mixture of hemolytic and non hemolytic *E. coli* whereas, treatment group animals had only non hemolytic *E. coli*. The total bacterial count was lower in the treatment group. Significantly reduced levels of salmonella in carcass and in caeca were reported by Izat *et al.* (1990) when broiler ration was supplemented with 0.36 per cent calcium formate.

According to Gedek *et al.* (1992), dietary supplementation of formic acid to piglets significantly reduced the counts of Lactobacillus/Bifidobacterium and *E. coli* in both caecum and colon and Eubacterium in caecum. A similar decrease in counts of Bacteroidaceae and *E. coli* in small intestine was observed by Kirchgessner *et al.* (1992b) when diet was supplemented with formic acid (1.25 per cent) or calcium formate (1.8 per cent). Ludke and Schone (1994) compared the efficacy of formic acid and phosphoric acid adsorbates and found that formic acid was more effective in reducing the number of haemolytic bacteria in the ileum and colon whereas, Gabert *et al.* (1995) reported that supplementation of one per cent formic acid to diet of low or high buffering capacity for weanling pigs did not affect bacterial populations in the small intestine. Canibe and Jensen (2001) reported that addition of 1.8 per cent formic acid to diets of growing-finishing pigs lowers the lactic acid bacteria, enterobacteria and yeast counts in gastro intestinal tract of pigs.

Risley *et al.* (1992) reported that addition of 1.5 per cent citric or fumaric acid to the diet of weanling pigs had no effect on microflora populations in various sections of gastro intestinal tract. A numerical reduction of *E. coli* in stomach and small intestine was observed by Li *et al.* (1999) in weanling pigs supplemented with 0.5 per cent organic acid (mixture of lactic acid, fumaric acid, propionic acid, formic acid and ortho-phosphoric acid). A numerical increase of lactobacillus counts was observed in all the sections of gastro intestinal tract.

Hebeler *et al.* (2000) reported that dietary inclusion of Formi™ LHS at 1.8 per cent level reduced the total number of bacteria, including potential pathogens such as *E. coli* and led to a shift in the composition of microbes to a more favourable bacterial flora in the gut of piglets. A similar reduction was observed by Overland *et al.* (2000) and Anon (2001) in growing-finishing pigs when supplemented the diet with 1.2 per cent Formi™ LHS. It was also found that adding Formi™ LHS did not increase bacterial tolerance. No pathogenic *E. coli* was excreted by piglets supplemented with 1.8 per cent potassium diformate for seven days when challenged with 10^9 *E. coli* (Anon, 2001).

Anon (2001) conducted a study in piglets using 1.2 per cent Formi™ LHS with or without copper (150 ppm). Microbial activity was measured by ATP concentration at different sections of intestinal tract of piglets. The values were significantly lower in stomach and small intestine of pigs treated with Formi™ LHS (with or without copper) than the control animals. There was a general tendency for lactobacilli to increase in the small intestine and coliforms to decrease throughout the intestinal tract as a result of Formi™ LHS addition with or without copper. Anon (2001) reported that a decrease in number of coliforms in ileum and rectum, lactobacilli in ileum and duodenum and a reduction in total number of anaerobes especially in ileum and rectum were observed when piglets were supplemented with 0.9, 1.8 and 2.7 per cent Formi™ LHS. The effects were more prominent at the highest dose. Anon (2001) reported that there were significantly lower numbers of lactic acid bacteria and lactobacilli in the faeces of piglets fed with feed containing copper (160 ppm), supplemented with 1.8 per cent potassium diformate and there was a tendency for the total anaerobes to decrease.

Canibe *et al.* (2001b) reported that addition of 1.8 per cent Formi™ LHS to a starter piglet diet decreased the counts of total anaerobic bacteria, lactic acid bacteria and yeast in the gastro-intestinal tract. The coliform bacterial count in faeces and digesta samples from the stomach, distal small intestine, caecum and middle segment of the colon of piglets were decreased to a lesser extent whereas, Fevrier *et al.* (2001) found that a minimal (0.9 per cent) supplementation of potassium diformate in the diet of piglets significantly lowered coliform and streptococci counts in stomach.

Knarreborg *et al.* (2001) conducted an *in vitro* study to find the effect of various organic acids (fumaric, lactic, butyric, formic and propionic acid), potassium diformate and pH on intestinal microflora. There was a significant reduction in density of coliforms and lactic acid bacteria in stomach in response to pH and potassium diformate addition. Growth depression of coliform in small intestine content was pH dependent and was not seen in lactic acid bacteria. They also reported that formic acid was the only acid killing coliforms without affecting lactic acid bacteria at pH 5.5. Puyalto and Mesia (2002) conducted an *in vitro* study and found that relative growth inhibition of salmonella and *E. coli* were found to be highest for organic acids (formic, propionic, butyric and lactic acid) followed by disalts (diformates and dipropionates) and saturated salts (calcium formate, calcium propionate and sodium butyrate).

Canibe *et al.* (2001c) reported that the effects of the different organic acids (formic, propionic, butyric, lactic and fumaric acid) on intestinal bacteria *in vivo* vary a lot and it depends on the dose of the organic acid in the feed. Majority of the organic acids inhibited the growth of coliform bacteria primarily in the proximal part of the digestive tract of pigs. Acidified diet reduced the number of *E. coli* by two log in the faeces of sow (Coupel, 2001). Mroz and Krasucki (2002) opined that acidifiers (propionic acid, formic acid and sodium benzoate) in sow diets may inhibit periparturient hypogalactia syndrome, bacteriuria and ammonia emission from manure.

2.5 EFFECTS ON pH AND BUFFERING CAPACITY

Burnell *et al.* (1988) conducted an experiment in weaned pigs by supplementing organic acid (citric acid and sodium citrate 2:1) to corn soybean meal diet containing 15 per cent dried whey. There was a numerical reduction in the pH of stomach, small intestine and large intestinal contents of pigs. It was also found that organic acid was effective in lowering the pH of the diet. Risley *et al.* (1992) observed that when fumaric acid and citric acid were supplemented to the diet of weanling pigs there was no appreciable effect on pH and Cl^- ion concentration of stomach, jejunum, caecum, or lower colon. Risley *et al.* (1993) conducted a study on weaned pigs by supplementing their diet either with 1.5 per cent fumaric acid or 1.5 per cent citric acid. They found that there were no effects on severity of scouring, intestinal digesta pH, Cl^- ion concentration, volatile fatty acid profiles except that fumaric acid and succinic acid concentration were greater in the stomach and jejunum of pigs fed fumaric acid. Radcliffe *et al.* (1997) opined that the diet pH and stomach digesta pH decreased significantly when citric acid was supplemented at two per cent level in the diet of weanling pigs.

Eidelsburger *et al.* (1992b) opined that supplementation of formic acid at 1.25 per cent level to the diets of piglets significantly reduced the pH of stomach contents and no effect was seen on pH of small intestine, caecum and colon. The ammonia content of stomach was decreased significantly by formic acid. Roth *et al.* (1992) supplemented formic acid at 0, 0.6, 1.2, 1.8 or 2.4 per cent levels to the diet of piglets and found that the stomach pH was unaltered whereas, the pH of small intestine, caecum and colon were increasing with increase in formic acid concentrations. Similar effects on pH were reported by Ludke and Schone (1994) when formic acid and phosphoric acids adsorbates were supplemented. Gabert *et al.* (1995) opined that addition of one per cent formic acid to the diet of pigs which had either low (pH 6.25) or high (pH 6.13) buffering capacity resulted in drop in pH to 4.46 and 4.59, respectively. The author also added that there was no difference in pH of ileal digesta for all the diets. In a similar study conducted by Canibe and Jensen (2001) in growing-finishing pigs by supplementing their diet with formic acid, they found that the concentration of formic acid was high in stomach and small intestine than the unsupplemented group.

Krause *et al.* (1994) reported that addition of organic acids (fumaric, malic or citric acids) and inorganic base (sodium bicarbonate) at varying levels to diets of pigs resulted in decrease in pH when acid was added alone and no change when it was added along with base. The blood pH remained the same for all treatments. Gabert and Sauer (1995) conducted a study in weanling pigs by supplementing its diet with 1.5 or 3.0 per cent fumaric acid or 1.5 per cent sodium fumarate. The pH of the diets were 6.3, 4.4, 3.9 and 6.3 for the control, 1.5 per cent fumaric acid, 3.0 per cent fumaric acid and 1.5 per cent sodium fumarate supplemented diets, respectively. It was found that the pH or the concentrations of acetate and propionate in ileal digesta were not affected.

Blank *et al.* (1999) reported that addition of fumaric acid to low buffering capacity diet decreased the pH of diet by 0.4 units for each per cent addition from 5.2 to 4.0. The buffering capacity decreased from 23.5 to 0 by supplementing three per cent fumaric acid. It was also reported that supplementation of three per cent sodium bicarbonate increased the pH from 5.2 to 7.4. There was a decrease in pH of about 0.9 units per each percentage of fumaric acid supplementation and buffering capacity decreased from 56.7 to 23.6 in the sodium bicarbonate supplemented diet. Li *et al.* (1999) supplemented 0.5 per cent organic acid mixture (mixture of lactic acid, fumaric acid, propionic acid, formic acid and ortho-phosphoric acid) in the diet of weanling pigs and they found to have a significant reduction in pH in the lower colon and a numerical reduction in pH in all other sections of the gastro intestinal tract.

Mroz *et al.* (2000) observed that partial replacement of alkalogenic limestone (632 mEq/kg feed) with 2.4 per cent acidogenic calcium benzoate lowered the dietary buffering capacity by 54 mEq/kg, dietary pH by 0.4 units and urinary pH by 1.6 units. It was also found that irrespective of buffering capacity, organic acid addition decreased pH of diets in the following order: fumaric acid > formic acid > n-butyric acid. Vankol (2000) reported that adding organic acids such as lactic and formic acid to feeds resulted in lower pH in the stomach and slow emptying of stomach. It was also reported that the buffering capacity of feed was reduced. Makkink (2001) opined that formulation of diets with calcium salts of organic acid can provide a lower B-value and thus helps to counteract digestive disorders in young animals or animals in stressful circumstances. It was also found that addition of formic acid, lactic acid, fumaric acid and citric acid lowered feed pH substantially.

Canibe *et al.* (2001a) reported that the pH along the gastrointestinal tract of piglets was not significantly affected by Formi™ LHS when supplemented at 1.8 per cent level in the diet whereas, Fevrier *et al.* (2001) found that addition of potassium diformate at 0.9 per cent level to the diet of piglets reduced the gastric pH significantly. The production of ammonia was decreased in the stomach when compared with control animals. Mroz *et al.* (2001) reported that potassium diformate supplemented to the diet of weaned piglets at graded doses (0, 0.9 and 1.8 per cent) acidified the duodenal digesta until 65 minutes after feeding by 0.3 to 0.5 pH units. Increase in concentration of potassium diformate in diet increased concentration of formic acid in duodenal digesta and it ranged between 79 and 93 per cent of formate dosed. There was also an increase in intra duodenal flow of potassium with respect to the dosage used.

2.6 EFFECTS ON THE AVAILABILITY OF MINERALS

Radecki *et al.* (1988) conducted a study in weaning pigs with supplementation of 1.5 per cent fumaric acid or with antibiotic (chlortetracycline, sulfamethazine and penicillin). They found that calcium balance and calcium retention were unaffected by the diet. Faecal phosphorus and zinc were higher and urinary phosphorus lower for pigs consuming fumaric acid. Partanen *et al.* (2001) reported that addition of 0.8 per cent formic acid to diets of growing-finishing pigs improves the apparent digestibility of calcium in high fibre (219 g/kg NDF) diets. Coupel (2001) opined that acidification of sow's diet with organic acids increased presence of volatile fatty acids, thus increasing calcium solubility and digestibility from 47 to 55 per cent.

Jongbloed *et al.* (1996) found that supplementation of organic acids (lactic acid, formic acid, propionic acid) to diets of growing pigs enhanced the apparent digestibility of ash, calcium, and total phosphorus. Radcliffe *et al.* (1997) reported that addition of citric acid to the diets of weanling pigs caused a reduction in phytase activity in stomach digesta and reported that no clear interactions between phytase and citric acid were observed. Han *et al.* (1998) opined that inorganic phosphorus can be substituted in the corn-soy diets of growing pigs with addition of moderate quantity of cereals and microbial phytases along with citric acid without producing any adverse effects. Jongbloed *et al.* (2000) studied the main and interactive effects of microbial phytase and organic acids such as lactic acid and formic acid and found to increase apparent digestibility of ash, calcium, and total phosphorus. Also they found that there was a positive synergetic effect between organic acid and microbial phytase on ash, phosphorus digestibility and magnesium digestibility. Overland *et al.* (2002) reported that there is a synergistic effect between potassium diformate and phytase on digestibility of calcium and phosphorus. Omogbenigun *et al.* (2003) found that addition of microbial phytase along with organic acid to pig starter diets improved phosphorus digestion and utilization and reduced phosphorus excretion.

Roth *et al.* (1998a) stated that supplementation of 1.8 per cent potassium diformate to diet of piglets increased the apparent digestibility coefficient and retention of phosphorus, calcium, magnesium, zinc, copper and manganese. Due to extra dietary intake of potassium there was an increased urinary excretion of potassium but no change was seen in fecal excretion. Fevrier *et al.* (2001) reported that there was an improvement in calcium and phosphorus digestibility at 0.9 per cent level of supplemented potassium diformate in the diet of weanling pigs. In a similar study, Mroz *et al.* (2002) did not observe any significant difference in body retention of calcium, total phosphorus and potassium among treatments when growing-finishing pigs were fed with either no acidifiers or one per cent potassium diformate or 0.65 per cent potassium formate or 0.35 per cent formic acid or 1.3 per cent potassium formate.

Mroz *et al.* (2000) reported that addition of calcium benzoate to diets of growing-finishing pigs at 2.4 per cent levels increased digestibility and retention of calcium. They also found that there was an increased digestibility of calcium and total phosphorus and increased retention of calcium when organic acids (formic, fumaric and n-butyric acid) were supplemented to growing-finishing pig diets at 300 mEq/kg levels.

2.7 EFFECTS ON CARCASS QUALITY

Kirchgessner *et al.* (1992a) reported that supplementation of formic acid to diets of piglets resulted in significantly higher carcass protein content. Protein retention was significantly higher in 0.6 to 1.8 per cent formic acid supplemented groups. It was also found that neither partial efficiency nor total efficiency of energy deposition was influenced by formic acid. Utilization of protein was increased from 0.68 in control to 0.73 in formic acid supplemented group. Min *et al.* (2001) reported that there were no significant differences in dressing percentage, carcass length, carcass grade, loin eye area and back fat thickness at 10^{th} rib between the control and acidified diet fed animals.

Roth *et al.* (1996) reported that there was no significant difference among animals in carcass characteristics such as carcass weight, side fat thickness, back fat thickness, fat area outside loin eye muscle, area of loin eye muscle, meat:fat ratio, ham per cent and lean meat per cent when fed with or without two types of diformates (Formi™ LHS-S and Formi™ LHS-N) in different doses (0.65, 1.3 and 1.95 per cent). Similar results were reported by Kirchgessner *et al.* (1997) when animals were supplemented with or without 0.8 and 1.6 per cent potassium diformate.

Overland *et al.* (1999) conducted an experiment in growing-finishing pigs by supplementing with 0, 0.6 or 1.2 per cent potassium diformate. It was found that potassium diformate supplementation decreased percentage carcass fat and increased percentage carcass lean. Overland *et al.* (2000) reported that there was no difference in carcass lean or fat content, sensory quality of pork or content of formate in liver, kidney or muscle tissue in growing-finishing pigs when they were fed with 0.8 per cent potassium diformate. In another experiment in growing-finishing animals fed with 1.2 per cent potassium diformate, there was reduction in percentage of carcass fat, fat area in the cutlet, increased percentage lean in the ham, flank, loin and neck and shoulder than those of animals fed with control diet. There was no significant difference in carcass weight, dressing percentage and back fat thickness between the control and potassium diformate supplemented animals.

Materials and Methods

3. MATERIALS AND METHODS

3.1 ANIMALS

Thirty Large White Yorkshire male pigs with an average body weight of 13.0 kg belonging to the Centre for Pig Production and Research (CPPR), Mannuthy were used as experimental animals.

The pigs were divided into three groups of ten pigs each, as uniformly as possible with regard to age and body weight. Ten pigs in each treatment were randomly distributed into five replicates of two pigs each.

The three groups of pigs were randomly allotted to three dietary treatments (T_1, T_2 and T_3). Each replicate was housed in separate pen and were maintained under identical management conditions. All the animals were dewormed before the commencement of the experiment.

3.2 EXPERIMENTAL DIETS

The pigs were fed with rations formulated to contain 18.0 and 15.5 per cent crude protein (NRC 1998), 3150 and 3100 kcal of metabolizable energy, during the growing and finishing period, respectively. They were fed with the grower ration until they attained an average body weight of 50 kg and thereafter changed to the finisher ration until the animals were slaughtered.

Animals in group I, II and III were allotted to the following three dietary treatments viz.,

I) T1 - Control standard ration.

II) T2 - Control ration with 0.75 per cent potassium diformate.

III) T3 - Control ration with 1.5 per cent potassium diformate.

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

The ingredient compositions of grower and finisher rations (experimental diets) are given in Tables 1 and 2, respectively.

3.3 CHEMICAL COMPOSITION

The percentage chemical composition of grower and finisher diets are presented in Tables 3 and 4, respectively.

3.4 GROWTH TRIAL

The pigs of each pen were group fed. *Ad libitum* feeding was followed throughout the experimental period. They were fed in the morning (8.00 AM) and evening (5.00 PM) and were allowed to consume as much feed as they could within a period of one hour. Clean drinking water was provided in all the pen throughout the experimental period.

The pigs were weighed once in a fortnight to record the gain in body weight.

3.5 DIGESTIBILITY TRIAL

Digestibility trial was conducted at the end of the experiment to determine the digestibility coefficient of nutrients of the experimental diets. Chromic oxide was added @ 0.05 per cent to each experimental diet as an external indicator for measuring the digestibility coefficient of nutrients. Chromic oxide was mixed first with small quantity of feed and then with the already mixed feed in a vertical feed mixer for 30 minutes to ensure proper mixing. The animals were fed chromic oxide mixed rations for a period of four days. Faeces were collected for three days from the second day onwards.

Table1. Ingredient composition of grower ration, %

Ingredients	Treatment		
	T_1	T_2	T_3
Yellow maize	46.55	48.50	50.00
Rice polish	12.00	12.00	11.80
Wheat bran	15.50	12.50	10.00
Soya bean meal	15.45	15.75	16.20
Fish meal	10.00	10.00	10.00
Potassium diformate[a]	-	0.75	1.50
Salt	0.50	0.50	0.50

[a] Potassium diformate (Norsk Hydro, Oslo, Norway) containing Potassium-30%, Formic acid-35.4% and Formates-34.6%

Indomix–A, B2, D3, K (Nicholas Piramal India Ltd., Mumbai) containing Vitamin A–40,000 IU, Vitamin B2–20 mg, Vitamin D3–5,000 IU per gram was mixed @ 25 g/100 kg feed

Rovi – BE (Roche Products Limited, Derbyshire, UK) containing Vitamin B1–4 mg, Vitamin B6–8 mg, Vitamin B12–40 mcg, Niacin–60 mg, Calcium panthothenate–40 mg, Vitamin E–40 mg per gram was mixed @ 25 g/100 kg feed

Table 2. Ingredient composition of finisher ration, %

Ingredients	Treatment		
	T_1	T_2	T_3
Yellow maize	54.80	56.50	58.50
Rice polish	10.00	10.00	10.00
Wheat bran	14.95	12.20	9.00
Soya bean meal	11.00	11.30	11.75
Fish meal	8.00	8.00	8.00
Potassium diformate[a]	-	0.75	1.50
Mineral Mixture[b]	0.75	0.75	0.75
Salt	0.50	0.50	0.50

[a] Potassium diformate (Norsk Hydro, Oslo, Norway) containing Potassium-30%, Formic acid-35.4% and Formates-34.6%

[b] Mineral Mixture (Pristine Nutrition Pvt. Ltd., Bangalore) containing Calcium–23%, Phosphorus–12%, Magnesium–6.5%, Sulphur–0.5%, Iron–0.5%, Zinc–0.38%, Manganese–0.12%, Copper–0.07%, Iodine–0.03%, Cobalt–0.01%, Fluorine (max)–0.07%, Acid insoluble ash (max)–2.5% and moisture (max)–5%

Indomix–A, B2, D3, K (Nicholas Piramal India Ltd., Mumbai) containing Vitamin A–40,000 IU, Vitamin B2–20 mg, Vitamin D3–5,000 IU, per gram was mixed @ 25 g/100 kg feed

Rovi–BE (Roche Products Limited, Derbyshire, UK) containing Vitamin B1–4 mg, Vitamin B6–8 mg, Vitamin B12–40 mcg, Niacin–60 mg, Calcium panthothenate–40 mg, Vitamin E–40 mg, per gram was mixed @ 25 g/100 kg feed

Table 3. Chemical composition of grower ration*, %

Item	Treatment		
	T_1	T_2	T_3
Dry matter	91.61	90.36	90.53
Crude protein	17.80	18.20	18.10
Ether extract	6.10	5.90	5.70
Crude fibre	5.25	4.80	4.50
Nitrogen free extract	60.94	61.73	62.18
Total ash	9.91	9.37	9.52
Acid insoluble ash	4.88	4.14	4.48
Ca	0.85	0.81	0.79
P	0.70	0.63	0.67

* On dry matter basis.

Table 4. Chemical composition of finisher ration*, %

Item	Treatment		
	T_1	T_2	T_3
Dry matter	88.81	88.16	87.99
Crude protein	15.41	15.45	15.96
Ether extract	2.25	2.42	2.85
Crude fibre	6.87	6.49	6.39
Nitrogen free extract	66.05	66.46	65.72
Total ash	9.42	9.18	9.08
Acid insoluble ash	3.27	3.41	3.17
Ca	0.85	0.82	0.79
P	0.68	0.70	0.71

* On dry matter basis.

Fāecal grab samples uncontaminated with urine and water were collected from different places of pen thrice daily during the collection period of three days. They were placed in double lined polythene bags, labelled and kept in the deep freezer until further analysis. The feed and faecal samples collected during the digestibility trial were analysed for proximate composition as per methods prescribed by AOAC (1990).

The chromium content was determined using Atomic Absorption Spectrophotometer (Perkin Elmer 3110). Phosphorus contents of the feed samples were analysed by colorimetry using Spectrophotometer (Spectronic 1001 Plus, MiltonRoy, USA). The digestibility coefficient of nutrients were calculated using appropriate formulae (Maynard *et al.*, 1971).

3.6 SLAUGHTER STUDIES

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

The animals were decapitated at the atlanto-occipital joint and the dressed weight of the carcass without head was recorded to determine dressing percentage of hot carcass.

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

3.7 STATISTICAL ANALYSIS

Data on body weight and carcass characters of pigs maintained on three dietary treatments were analysed by covariance analysis using MSTATC. For other parameters such as fortnightly cumulative average daily gain, fortnightly cumulative average feed conversion efficiency and digestibility coefficient of nutrients were analysed by Completely Randomised Design (CRD) method as described by Snedecor and Cochran (1985). Means were compared using Least Significant Difference (LSD) test.

Results

4. RESULTS

4.1 BODY WEIGHT AND BODY WEIGHT GAIN

The results of body weight of pigs under the three dietary treatments T_1, T_2 and T_3 recorded at fortnightly intervals are presented in Table 5 and graphically represented in Fig. 1. Average final body weight of pigs of the three treatments T_1, T_2 and T_3 were 80.4, 84.6 and 88.3 kg, respectively. Average values for body weight gain of animals belonging to the groups T_1, T_2 and T_3 were 67.4, 71.6 and 75.3 kg, respectively (Fig. 2).

4.2 AVERAGE DAILY GAIN AND FEED CONVERSION EFFICIENCY

The fortnightly cumulative average daily gain and average feed conversion efficiency of pigs under the three dietary treatments T_1, T_2 and T_3 are presented in Tables 6 and 7. For the three dietary treatments T_1, T_2 and T_3, the values for cumulative average daily gain were 465, 494 and 519 g, and for feed conversion efficiency were 3.97, 3.74 and 3.55, respectively (Table. 8, Fig. 3 and 4).

4.3 APPARENT DIGESTIBILITY COEFFICIENT OF NUTRIENTS

Chemical composition of faeces of pigs fed with different experimental diets is shown in Table 9. Data on apparent digestibility coefficient of nutrients of the three experimental diets T_1, T_2 and T_3 are presented in Table 10 and graphically represented in Fig. 5. The digestibility coefficient of dry matter for T_1, T_2 and T_3 were respectively, 64.1, 73.0 and 70.9; 65.6, 74.0 and 70.7 for crude protein; 55.4, 69.9 and 70.4 for ether extract; 27.5, 32.7 and 31.5 for crude fibre and 77.8, 84.4 and 83.4 for nitrogen free extract.

Table 5. Fortnightly average body weight of pigs maintained on three dietary treatments, kg (Mean ± SE)[1]

Fortnight	Treatment			P value
	T_1	T_2	T_3	
0	12.95 ± 0.56	12.95 ± 0.69	12.95 ± 0.93	-
1	18.55 ± 0.71	19.05 ± 1.00	18.85 ± 0.87	-
2	23.65 ± 0.93	24.50 ± 1.16	24.50 ± 0.87	-
3*	31.20 ± 1.13^{a}	32.55 ± 1.37^{ab}	34.05 ± 1.02^{b}	0.028
4*	38.66 ± 1.36^{a}	39.49 ± 1.61^{ab}	41.72 ± 1.22^{b}	0.038
5*	45.75 ± 1.54^{a}	48.15 ± 1.84^{ab}	50.70 ± 1.62^{b}	0.014
6*	55.05 ± 1.99^{a}	56.80 ± 2.03^{ab}	60.15 ± 1.44^{b}	0.022
7	62.60 ± 2.22	64.50 ± 2.12	67.20 ± 1.88	0.119
8	68.36 ± 2.40	70.92 ± 2.27	74.56 ± 2.18	0.064
9	76.00 ± 2.57	79.75 ± 2.67	82.90 ± 2.41	0.072
10*	80.35 ± 2.79^{a}	84.55 ± 2.57^{ab}	88.25 ± 2.48^{b}	0.05

1 Mean of ten values

a, b Means with different superscripts within the same row differ significantly

* Significant (P<0.05)

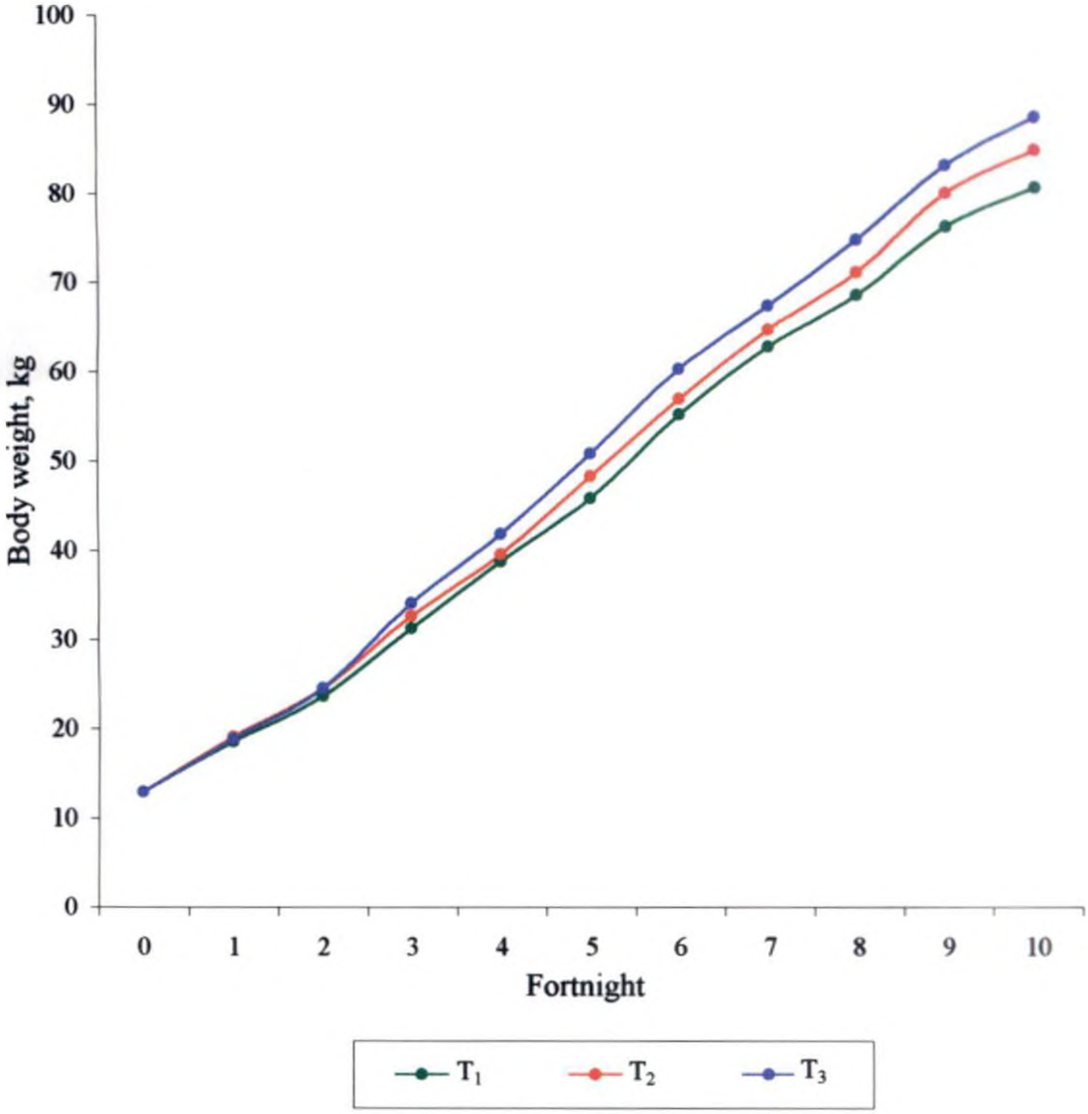

Fig.1. Fortnightly average body weight of pigs maintained on three dietary treatments

Table 6. Fortnightly cumulative average daily gain of pigs maintained on three dietary treatments, g (Mean ± SE)[1]

Fortnight	Treatment			P value
	T_1	T_2	T_3	
1	373.33 ± 19.11	406.67 ± 25.24	393.33 ± 39.69	0.72
2	356.67 ± 16.32	385.00 ± 17.82	385.00 ± 22.28	0.49
3*	405.56 ± 14.36^{a}	435.56 ± 15.78^{ab}	468.89 ± 17.98^{b}	0.03
4	428.50 ± 14.02	442.33 ± 16.16	479.50 ± 14.90	0.06
5*	437.33 ± 13.99^{a}	469.33 ± 16.08^{ab}	503.33 ± 17.96^{b}	0.03
6*	467.78 ± 16.62^{a}	487.22 ± 15.63^{ab}	524.44 ± 13.20^{b}	0.04
7	472.86 ± 16.69	490.95 ± 14.36	516.67 ± 16.02	0.16
8	461.80 ± 16.38	483.10 ± 14.09	513.41 ± 16.71	0.08
9	467.03 ± 15.85	494.81 ± 15.43	518.15 ± 16.80	0.09
10	464.82 ± 16.46	493.79 ± 13.65	519.31 ± 16.52	0.06

1 Mean of ten values

a, b Means with different superscripts within the same row differ significantly

* Significant ($P<0.05$)

Table 7. Fortnightly cumulative average feed conversion efficiency of pigs maintained on three dietary treatments (Mean ± SE)[1]

Fortnight	Treatment			P value
	T_1	T_2	T_3	
1	2.50 ± 0.08	2.31 ± 0.13	2.35 ± 0.08	0.3910
2*	2.71 ± 0.02^{a}	2.51 ± 0.08^{b}	2.50 ± 0.05^{b}	0.0401
3**	2.76 ± 0.02^{a}	2.58 ± 0.05^{b}	2.39 ± 0.04^{c}	0.00006
4**	2.92 ± 0.01^{a}	2.82 ± 0.05^{a}	2.60 ± 0.04^{b}	0.0001
5**	3.18 ± 0.03^{a}	2.96 ± 0.07^{b}	2.76 ± 0.04^{b}	0.0002
6**	3.23 ± 0.05^{a}	3.10 ± 0.06^{a}	2.87 ± 0.04^{b}	0.0007
7**	3.41 ± 0.01^{a}	3.28 ± 0.05^{ab}	3.12 ± 0.06^{b}	0.0023
8**	3.71 ± 0.03^{a}	3.54 ± 0.06^{ab}	3.33 ± 0.06^{b}	0.0013
9**	3.85 ± 0.03^{a}	3.64 ± 0.06^{ab}	3.47 ± 0.07^{b}	0.0016
10**	3.97 ± 0.02^{a}	3.74 ± 0.05^{b}	3.55 ± 0.07^{b}	0.0004

1 Mean of ten values

a, b, c Means with different superscripts within the same row differ significantly

* Significant (P<0.05)

** Significant (P<0.01)

Table 8. Average daily gain and feed conversion efficiency of pigs maintained on three dietary treatments (Mean ± SE)

Item	Treatment		
	T_1	T_2	T_3
Initial body weight (kg)	12.95 ± 0.56	12.95 ± 0.69	12.95 ± 0.93
Final body weight (kg)*	80.35 ± 2.79^{a}	84.55 ± 2.57^{ab}	88.25 ± 2.48^{b}
Body weight gain (kg)*	67.40 ± 2.39^{a}	71.60 ± 1.98^{ab}	75.30 ± 2.40^{b}
Total feed intake (kg)	267.64	267.41	267.26
Average daily gain (g)	464.82 ± 16.46	493.79 ± 13.65	519.31 ± 16.52
Feed conversion efficiency (kg feed/kg gain)**	3.97 ± 0.02^{a}	3.74 ± 0.05^{b}	3.55 ± 0.07^{b}

a, b Means with different superscripts within the same row differ significantly

* Significant (P<0.05)

** Significant (P<0.01)

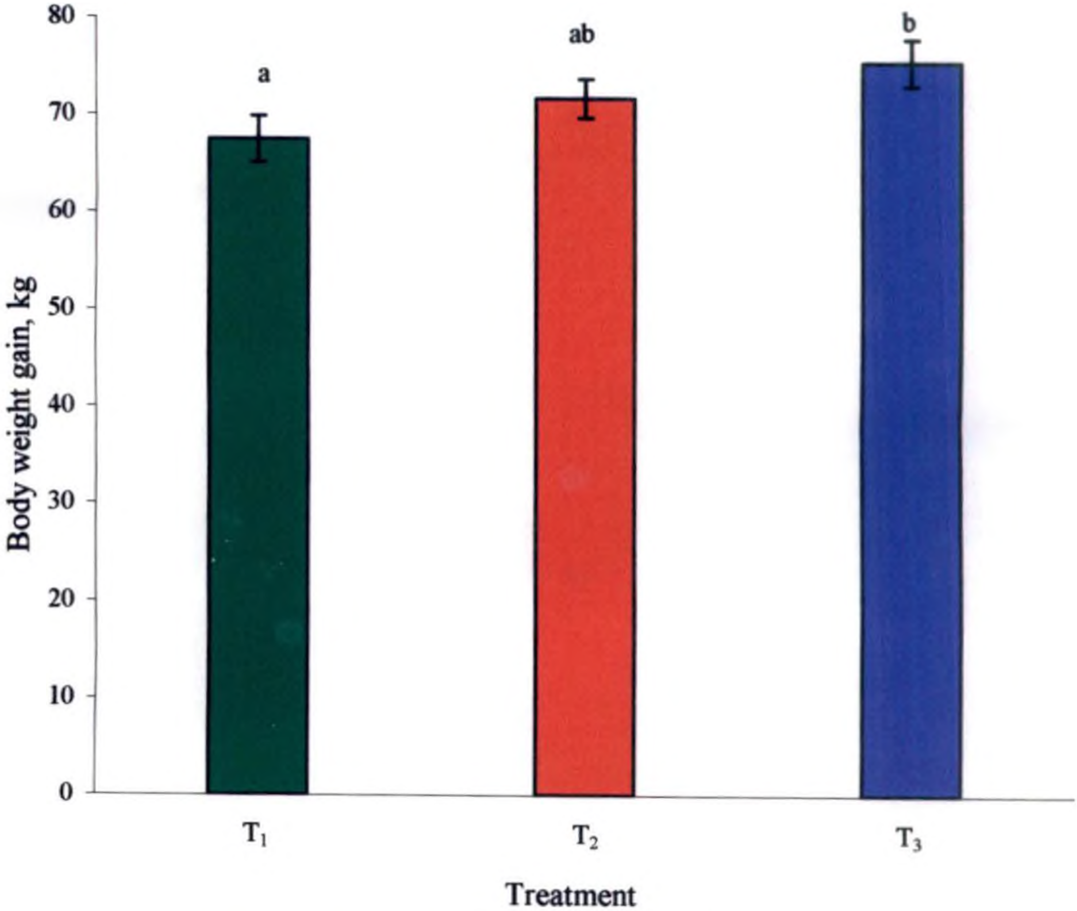

Fig.2. Average body weight gain of pigs maintained on three dietary treatments

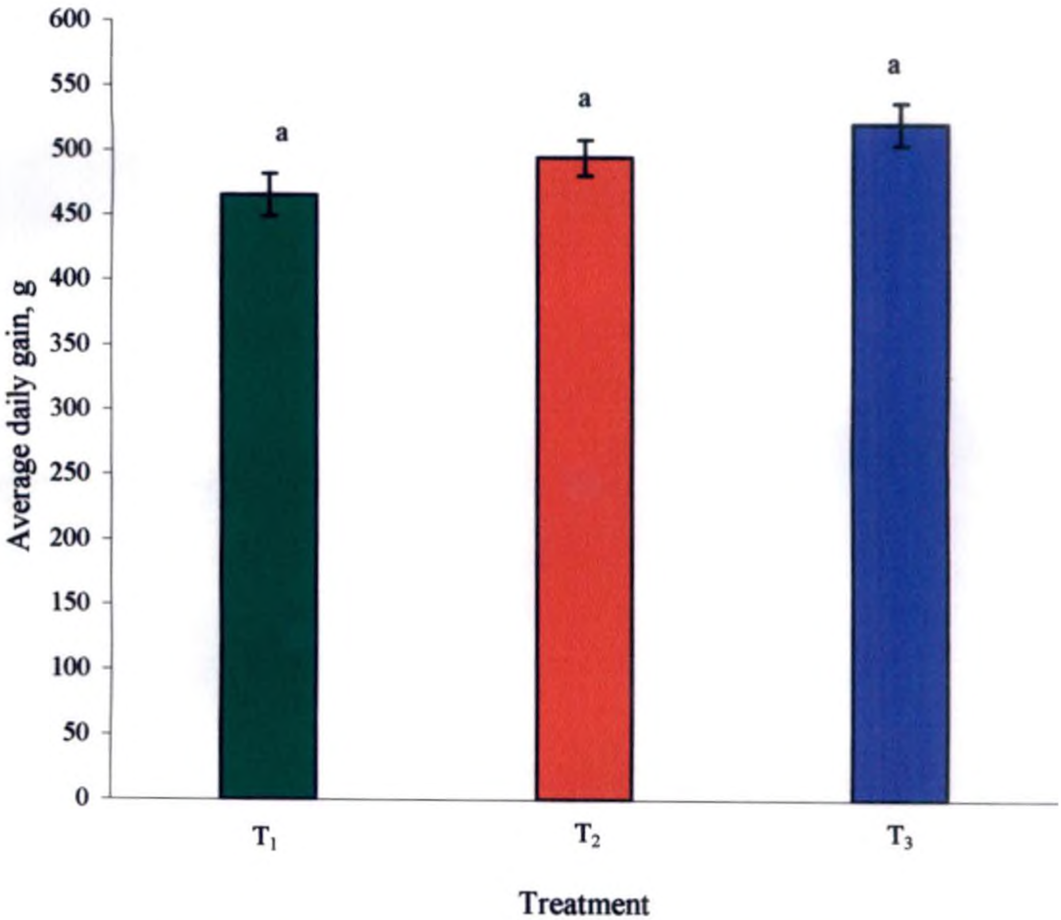

Fig.3. Average daily gain of pigs maintained on three dietary treatments

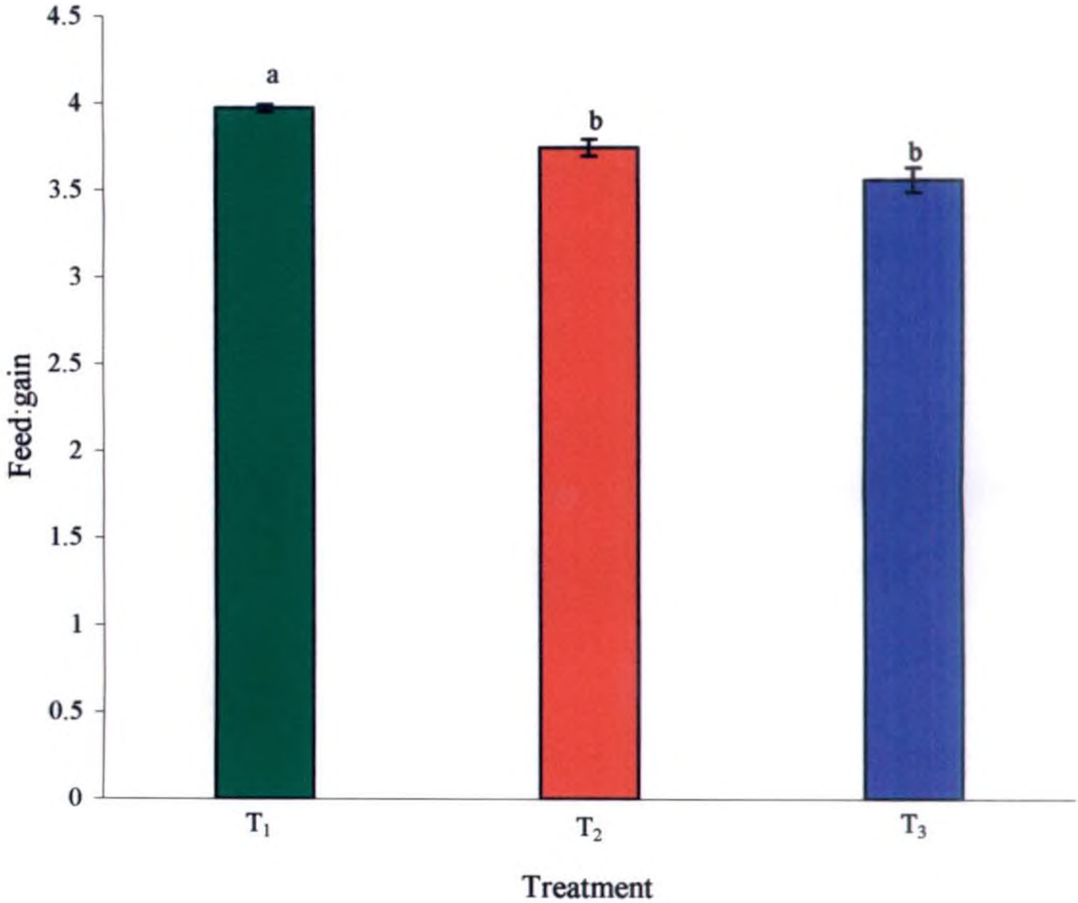

Fig.4. Average feed conversion efficiency of pigs maintained on three dietary treatments

Table 9. Chemical composition of faeces of pigs maintained on three dietary treatments[1], %

Item	Treatment		
	T_1	T_2	T_3
Dry matter	35.25	34.90	34.31
Crude protein (N x 6.25)	14.78	14.91	16.11
Ether extract	2.83	2.70	2.93
Crude fibre	14.04	16.14	15.08
Nitrogen free extract	41.37	39.03	38.42
Total ash	26.98	27.23	27.46
Acid insoluble ash	15.02	15.24	14.77

1 Average of ten values on dry matter basis

Table 10. Average digestibility coefficient of nutrients of three dietary treatments (Mean ± SE)[1]

Item	Treatment			P value
	T_1	T_2	T_3	
Dry matter**	64.10 ± 1.61^a	72.98 ± 0.58^b	70.94 ± 0.49^b	0.000004
Crude protein**	65.55 ± 1.65^a	73.95 ± 0.85^b	70.71 ± 0.49^b	0.00005
Ether extract**	55.39 ± 1.75^a	69.92 ± 1.71^b	70.35 ± 2.77^b	0.00003
Crude fibre	27.53 ± 1.14	32.66 ± 1.97	31.47 ± 1.28	0.05761
Nitrogen free** extract	77.83 ± 1.21^a	84.43 ± 0.59^b	83.40 ± 0.66^b	0.00002

1 Average of ten values on dry matter basis

a, b Means with different superscripts within the same row differ significantly

** Significant (P<0.01)

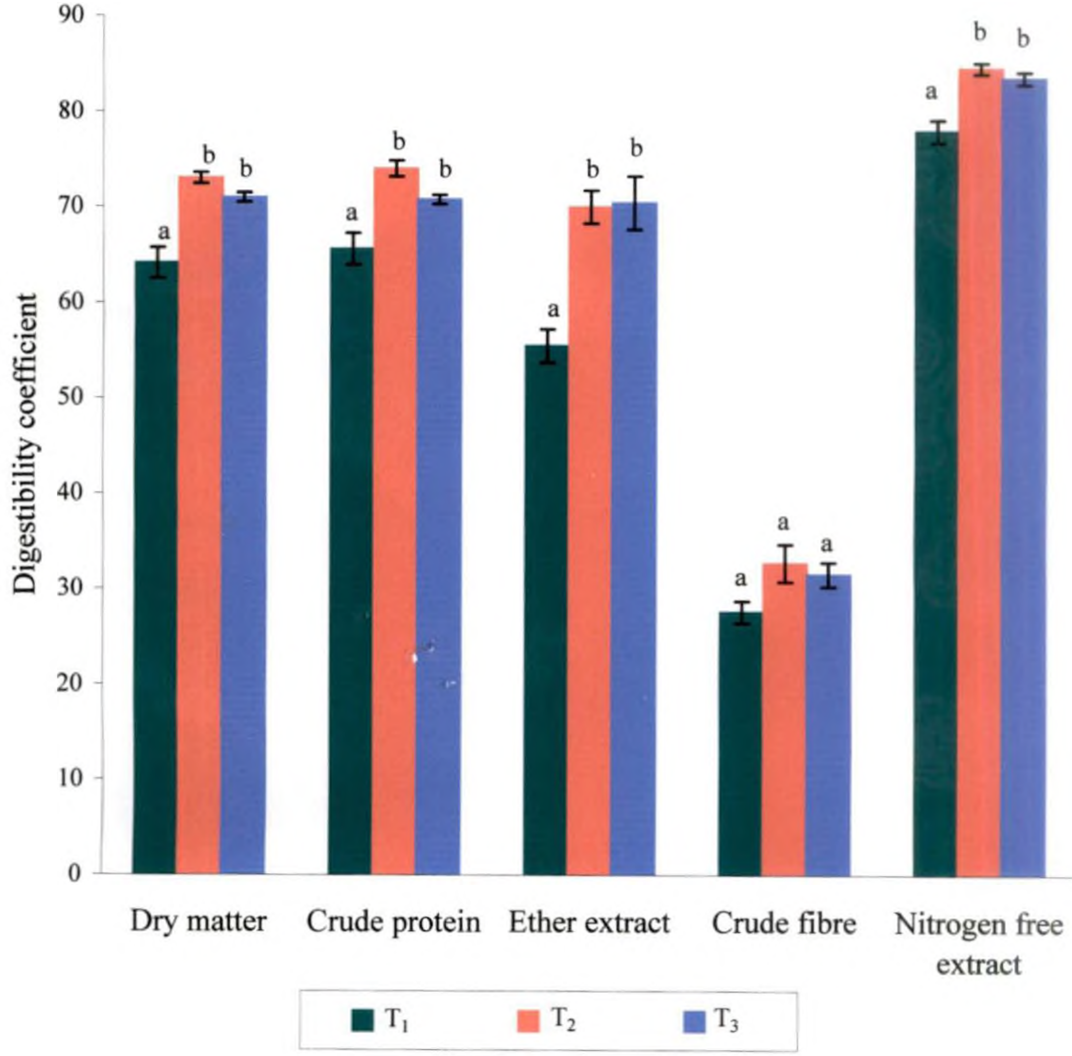

Fig. 5. Average digestibility coefficient of nutrients of the experimental diets

4.4 CARCASS CHARACTERISTICS

Data on carcass characteristics of pigs maintained on three experimental diets T_1, T_2 and T_3 are depicted in Table 11.

Body weight at slaughter was 74.5, 80.8 and 86.2 kg, respectively for the pigs of T_1, T_2 and T_3; 55.1, 59.9 and 63.3 kg for dressed weight without head; 74.0, 74.1 and 73.4 for dressing percentage; 62.4, 65.1 and 67.4 cm for carcass length; 3.4, 3.9 and 4.0 cm for back fat thickness and 28.5, 29.6 and 30.7 cm^2 for loin eye area.

4.5 ECONOMICS OF GAIN

Data on cost of feed per kg body weight gain of pigs maintained on the three dietary treatments are presented in Table 12 and Fig. 6. The values were Rs. 32.82, Rs. 32.05 and Rs. 31.50 for T_1, T_2 and T_3, respectively.

Table 11. Carcass characteristics of pigs maintained on three dietary treatments (Mean ± SE)[1]

Item	Treatment			P value
	T_1	T_2	T_3	
Live body weight (kg)	74.5 ± 4.02	80.83 ± 3.57	86.17 ± 0.60	-
Carcass weight (kg)	55.13 ± 3.07	59.85 ± 2.48	63.25 ± 0.78	NS
Dressing percentage	73.98 ± 0.37	74.10 ± 0.74	73.40 ± 0.65	NS
Back fat thickness (cm)	3.41 ± 0.16	3.86 ± 0.16	3.99 ± 0.14	0.23 (NS)
Loin eye area (cm^2)	28.45 ± 0.77	29.60 ± 2.10	30.68 ± 1.58	NS
Carcass length (cm)	62.38 ± 0.81	65.13 ± 0.97	67.38 ± 0.74	0.06 (NS)

1 Mean of six values

NS Non significant

Table 12. Cost of feed per kg body weight gain of pigs maintained on three dietary treatments

Item	Treatment		
	T_1	T_2	T_3
Cost/kg of grower ration[a] (Rs.)	8.39	8.69	8.99
Cost/kg of finisher ration[a] (Rs.)	8.14	8.44	8.75
Cost of feed per kg body weight gain (Rs.)	32.82	32.05	31.50

a Cost of feed ingredients is based on the rate contract fixed for the supply of various feed ingredients to the farm for the year 2002-03.

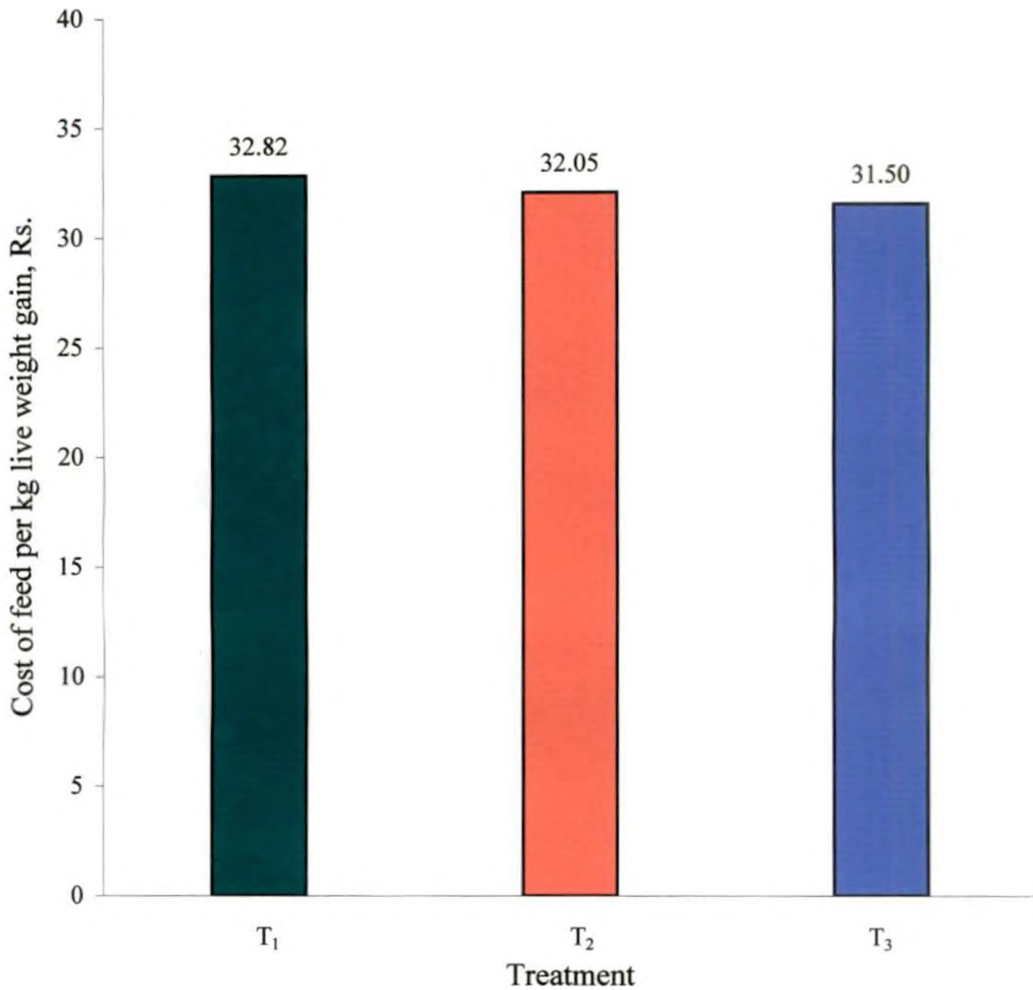

Fig.6. Cost of feed per kg body weight gain of pigs maintained on three dietary treatments

Discussion

5. DISCUSSION

5.1 BODY WEIGHT GAIN AND AVERAGE DAILY GAIN

The average final body weight (kg) of animals belonging to the three dietary treatments T_1, T_2 and T_3 were 80.4, 84.6 and 88.3 kg, respectively (Table 5) and the body weight gain recorded were 67.4, 71.6 and 75.3 kg, respectively (Table 8). The cumulative average daily gain (g) of animals fed diets supplemented with 0, 0.75 and 1.5 per cent potassium diformate were 465, 494 and 519 g, respectively (Table 6).

Pigs belonging to the dietary treatment T_3 fed with 1.5 per cent potassium diformate recorded higher ($P<0.05$) body weight (88.3 kg) and body weight gain (75.3 kg) than those fed unsupplemented feed (T_1). When compared with the values obtained for T_2, final body weight and body weight gain were not significantly higher ($P>0.05$) but, there was a trend for an increase by 4.3 and 5.2 per cent, respectively.

The final body weight (kg) and body weight gain (kg) for animals belonging to 0.75 per cent supplemented group (T_2) were not significantly higher than the unsupplemented group (T_1) but, there was a tendency to improve by 5.2 and 6.2 per cent, respectively. The cumulative average daily gain (g) of animals belonging to the three dietary treatments T_1, T_2 and T_3 did not differ significantly.

The observed increase in daily gain and final body weights of pigs fed 0.75 and 1.5 per cent potassium diformate might be caused by antimicrobial action of organic acid anion, especially against *E. coli*. The reduced impact of these bacteria resulting in improved health status and reduction in metabolic needs in the stomach and anterior intestinal tract and the effect of organic acids in decreasing the pH of the duodenal digesta might have helped for the improved weight gain.

It can be observed from the Table 5 that there was a significant ($P<0.05$) increase in the body weight in dietary treatment T_3 compared to that of T_1 during the third, fourth, fifth and sixth fortnights. Similarly from Table 6 it can be observed that there is a significant difference ($P<0.05$) in cumulative average daily gains between the dietary treatments T_3 and T_1 during third, fifth and sixth fortnights. The final body weight and average daily gain for the dietary treatment T_2 were not significantly higher than those fed control diets but, there was trend for an increase over those fed control diet (T_1). The results of the present study are in accordance with the results reported by Overland *et al.* (2000), who reported that the average daily gain was significantly high during the growing period and during the overall experimental period for pigs fed with 0.6 or 1.2 per cent potassium diformate than the unsupplemented group.

The final body weight of animals belonging to the dietary treatment T_3 were significantly higher ($P<0.05$) than that of dietary treatment T_1 and those of T_2 which had a numerical increase over treatment T_1. A similar increase in the final body weight and the daily weight gains were reported by Roth *et al.* (1996), Kirchgessner *et al.* (1997) and Overland *et al.* (1999) with various levels of supplementation of potassium diformate in the diet of growing-finishing pigs.

5.2 FEED CONVERSION EFFICIENCY

The cumulative feed conversion efficiency of pigs maintained on three dietary treatments T_1, T_2 and T_3 at fortnightly intervals were 3.97, 3.74 and 3.55, respectively (Table 7). Analysis of data revealed that the feed conversion efficiency of pigs maintained in dietary treatments T_2 and T_3 were significantly ($P<0.01$) higher than those of the dietary treatment T_1. There was no significant difference in feed conversion efficiency between the potassium diformate supplemented groups (T_2 and T_3). There was a trend for a higher feed conversion efficiency in those fed 1.5 per cent potassium diformate supplemented diet over the group supplemented with 0.75 per cent.

The antimicrobial activity of potassium diformate might have reduced the microbial population resulting in reduced metabolic needs and increased availability of dietary energy and nutrients to the host animal. This might have led to enhanced feed conversion efficiency. Similar results were reported by Roth *et al.* (1996), Kirchgessner *et al.* (1997), Overland *et al.* (1999) and Overland *et al.* (2000) in pigs fed diets containing potassium diformate at varying levels.

5.3 DIGESTIBILITY COEFFICIENT OF NUTRIENTS

5.3.1 Dry Matter

The digestibility coefficient of dry matter of the diets T_1, T_2 and T_3 were 64.1, 73.0 and 70.9, respectively (Table 10). The dry matter digestibility of diets T_2 and T_3 were significantly higher ($P<0.01$) than that of the diet T_1. There was no significant difference between the diets T_2 and T_3.

The mild decrease in pH of the duodenal digesta as reported by Mroz *et al.* (2002) might have led to some alterations in gastrointestinal conditions such as digestive, secretory, transepithelial transport of nutrients, gut morphology, colonization of residient and transient microflora. This change might have helped in improving the dry matter digestibility of the two diets T_2 and T_3. Similar increase in dry matter digestibility have been reported by Mroz *et al.* (1997), Roth *et al.* (1998b), Mroz *et al.* (2000) and Fevrier *et al.* (2001) when potassium diformate was supplemented to the diet of pigs at different levels. When formic acid was supplemented in the diet of pigs Jongbloed *et al.* (2000) and Partanen *et al.* (2001) obtained similar results.

In contrast to the results obtained in the present study Mroz *et al.* (2002) obtained a non significant difference in illeal dry matter digestibility when pigs were supplemented with one per cent potassium diformate.

5.3.2 Crude Protein

On perusal of the data in Table 10 further indicates that the digestibility coefficient of crude protein of the experimental diets T_2 (74.0) and T_3 (70.7) were significantly higher ($P<0.01$) than that of dietary treatment T_1 (65.6). There were no significant differences between the groups T_2 and T_3.

In growing-finishing period the improvement observed may be partly attributed by reduced bacterial protein synthesis. The depression of bacterial growth by potassium diformate might have resulted in availability of more endogenous nitrogen for reabsorbtion rather than being bound to bacterial protein. Decreasing gastric pH and a consequent slow movement of digesta might have led to increased action time for enzymes and improving the crude protein digestibility.

A similar increase in protein digestibility was reported by Roth *et al.* (1998b) and Fevrier *et al.* (2001) when diets of piglets were supplemented with 0.9 and 1.8 per cent potassium diformate. Digestibility studies by Eckel *et al.* (1992a), Eidelsburger *et al.* (1992a), Tossenberger *et al.* (1998) and Partanen *et al.* (2001) using formic acid as supplement to diets of pigs had shown a significant increase in crude protein digestibility which is in accordance with the results of the present study.

Mroz *et al.* (2002), on the other hand, found no significant difference in crude protein digestibility coefficient when potassium diformate was supplemented to diets of growing-finishing pigs.

5.3.3 Ether Extract

The average ether extract digestibility were 55.4, 69.9 and 70.4 per cent, respectively for the three treatments T_1, T_2 and T_3 (Table 10). There was statistically significant improvement ($P<0.01$) for T_2 and T_3 than T_1. There was no significant difference in ether extract digestibility between the treatments T_2 and T_3.

The antimicrobial activity of potassium diformate might have enhanced the digestibility of ether extract. Microbial deconjugation and dehydroxylation of bile impair lipid absorbtion of host animal (Partanen *et al.,* 2001) which might have been prevented by decreased microbial activity in the gut.

The result of the present study is in accordance with the results of Partanen *et al.* (2001) when formic acid was supplemented to diet of growing-finishing pigs. In contrast, Roth *et al.* (1998b) and Mroz *et al.* (2000) failed to observe any positive effects on ether extract digestibility when pigs were fed with diets containing 1.8 per cent potassium diformate and 2.4 per cent of calcium benzoate, respectively.

5.3.4 Crude Fibre

The digestibility coefficient of crude fibre for the three experimental diets T_1, T_2 and T_3 were 27.5, 32.7 and 31.5, respectively (Table 10). There was no significant difference in crude fibre digestibility among the pigs fed with the three experimental diets T_1, T_2 and T_3.

Formic acid and its salts are believed to inhibit microbial fermentation or may have changed the type of fermentation, which might have led to a non significant difference in crude fibre digestibility among the animals fed three dietary treatments T_1, T_2 and T_3. The observed results are in line with the results obtained by Roth *et al.* (1998b) and Mroz *et al.* (2002) when pigs were fed with diets containing 1.8 and 1.0 per cent potassium diformate, respectively.

5.3.5 Nitrogen Free Extract

The digestibility coefficient of nitrogen free extract were 77.8, 84.4 and 83.4 for the three experimental diets T_1, T_2 and T_3, respectively (Table 10).

Analysis of data revealed a statistically significant ($P<0.01$) increase in values for the dietary treatments T_2 and T_3 over that of treatment T_1. There was no significant difference between the treatment groups T_2 and T_3.

The antimicrobial activity of potassium diformate might have helped in preventing the easily digestible carbohydrates from microbial fermentation and increasing the availability of nutrients to the animal. The enzymatic digestion capacity also might have increased by a decrease in transit time leading to an increase in quality and quantity of nutrients absorbed from intestinal lumen of small intestine (Roth *et al.*, 1998b). This may be the reason for the increased nitrogen free extract digestibility obtained in the present study.

The result of the present study confirms the results of Roth *et al.* (1998b) and Eidelsburger *et al.* (1992a). Mroz *et al.* (2002) reported a non significant difference in nitrogen free extract digestibility between pigs supplemented with and without potassium diformate.

5.4 CARCASS CHARACTERISTICS

5.4.1 Dressing Percentage

The average dressing percentage of pigs slaughtered from the three dietary treatments T_1, T_2 and T_3 were 74.0, 74.1 and 73.4, respectively (Table 11). Analysis of data revealed no statistical significance among the treatments.

The results of the present study is in accordance with the results of Overland *et al.* (2000) who obtained a non significant difference in dressing percentage between animals fed with or without 1.2 per cent potassium diformate. Similar result was also obtained by Min *et al.* (2001) when acidified diets were fed to animals.

5.4.2 Back Fat Thickness, Carcass Length and Loin Eye Area

The values of carcass characteristics were 62.4, 65.1 and 67.4 cm for carcass length; 3.4, 3.9 and 4.0 cm for back fat thickness and 28.5, 29.6 and 30.7 cm^2 for loin eye area of pigs maintained on the three dietary treatments T_1, T_2 and T_3 (Table 11). There were no significant differences among the treatments in these carcass characteristics.

A difference in protein level of feed, quality of diets as well as the genotype of the pig may influence these carcass characteristics. The above said factors are similar for the three dietary treatments T_1, T_2 and T_3. This might have led to a non significant difference in carcass characteristics among the treatment groups in the present study. The effect of potassium diformate on carcass characteristics might have been greater when pigs are provided with a limited supply of protein and other nutrients (Roth *et al.,* 1998b). The diet used in the present study contains a protein percentage and composition of other nutrients at an adequate level and because of this the effect of potassium diformate on carcass characteristics might have been minimal.

The result of the present study is in agreement with the findings of Roth *et al.* (1996), Kirchgessner *et al.* (1997) and Overland *et al.* (2000) when pigs were fed with diets containing varying levels of potassium diformate. Similarly, when supplementing organic acid in the diet of growing-finishing pig, Min *et al.* (2001) obtained a non significant difference in these carcass characteristics between the supplemented and unsupplemented group.

5.5 ECONOMICS OF GAIN

The cost of feed per kg body weight gain of pigs maintained on the three dietary treatments T_1, T_2 and T_3 were Rs. 32.82, 32.05 and 31.50, respectively (Table 12). The cost of feed per kg of body weight gain was slightly lower for T_3 than those for T_1 and T_2. The increase in cost per kg of feed due to addition of potassium diformate at 0.75 per cent and 1.5 per cent levels were Rs. 0.38 and

0.76, respectively. Even though the cost per kg of feed was higher in T_2 and T_3 due to addition of potassium diformate, cost per kg of live weight gain was lesser in these groups compared to T_1. Improved average daily gain and feed conversion efficiency of pigs in T_2 and T_3 resulted in the reduced cost of production.

An overall critical evaluation of results obtained in the present study indicates that potassium diformate can be used economically at 1.5 per cent level as a feed supplement for better growth and feed efficiency in Large White Yorkshire pigs.

Summary

6. SUMMARY

A study was carried out to assess the nutritive value of potassium diformate as feed additive for growth in Large White Yorkshire pigs. Thirty male pigs with an average body weight of 13.0 kg were selected from the Centre for Pig Production and Research (CPPR), Mannuthy and were divided into three equal groups, viz., T_1, T_2 and T_3 as uniformly as possible with regard to age and body weight. The ten pigs in each treatment were randomly distributed into five replicates of two pigs each. The pigs in the three groups were fed with three different experimental diets viz., T_1 -control standard grower (18 per cent CP and 3150 kcal/kg ME) and finisher (15.5 per cent CP and 3100 kcal/kg ME) ration, T_2-control ration supplemented with 0.75 per cent potassium diformate and T_3–control ration supplemented with 1.5 per cent potassium diformate.

The experiment was conducted for five months. Each replicate was housed in separate pen and was maintained under identical conditions of management. The piglets were offered feed *ad libitum* twice a day. Records of daily feed intake and fortnightly body weight were maintained throughout the experimental period. Digestibility trial was carried out at the end of the experiment to determine the digestibility coefficient of nutrients of the experimental diets. When the animals attained 80 kg body weight, were slaughtered and carcass characteristics of six animals from each group were studied.

The average daily gain of 464, 493 and 519 g were recorded for the groups T_1, T_2 and T_3, respectively. There was no significant difference ($P>0.05$) between the supplemented group and the group fed control diet. However, there was a trend for a higher growth rate of 6.2 per cent and 11.7 per cent, reported for T_2 and T_3 over those fed control diet. The average feed conversion efficiency were 3.97, 3.74 and 3.55 for the groups T_1, T_2 and T_3, respectively. Addition of potassium diformate at 0.75 and 1.5 per cent level in the diet of growing-finishing

pigs had a higher (P<0.01) feed conversion efficiency over those fed control diet. There was no significant difference (P>0.05) between the supplemented groups. However, there was a trend for a higher feed efficiency for those fed 1.5 per cent potassium diformate supplemented diet.

The digestibility coefficients of nutrients were found to be higher for ration T_2 and T_3 than those of T_1. The digestibility coefficient of dry matter, crude protein, ether extract and nitrogen free extract in T_2 and T_3 were significantly higher (P<0.01) than those in T_1. The digestibility coefficient of crude fibre was almost similar for all the three rations. There was no significant difference between the supplemented groups.

Carcass characteristics such as dressing percentage, carcass length, back fat thickness and loin eye area were not significantly influenced (P>0.05) by the inclusion of potassium diformate at different levels.

The cost of production per kg weight gain of animals maintained on different dietary treatments were Rs. 32.82, 32.05 and 31.50 for T_1, T_2 and T_3, respectively.

From the present investigation it can be concluded that potassium diformate can be economically incorporated at 1.5 per cent level in the diet of Large White Yorkshire pigs.

References

REFERENCES

AOAC. 1990. *Official Methods of Analysis*. Fifteenth edition. Association of Official Analytical Chemists, Washington, D.C., p.587

Anon. 2001. *Report of the scientific committee on animal nutrition on the use of potassium diformate (Formi^{TM} LHS) as feed additive.* Health and Consumer Protection Directorate-General, European Commission, p.17

*Baustad, B. 1993. Effects of formic acid on performance in growing pigs. *Norwegian J. agric. Sci.* 7 (1): 61-69

Blank, R., Mosenthin, R., Sauer, W.C. and Huang, S. 1999. Effect of fumaric acid and dietary buffering capacity on ileal and fecal amino acid digestibilities in early-weaned pigs. *J. Anim. Sci.* 77: 2974-2984

Broek, V. 2000. Organic acid : Natural link between drug and growth promoter. *Feed Mix* 8 (2): 22-24

Burnell, T.W., Cromwell, G.L. and Stahly, T.S. 1988. Effects of dried whey and copper sulfate on the growth response to organic acid in diets for weanling pigs. *J. Anim. Sci.* 66: 1100-1108

Canibe, N. and Jensen, B.B. 2001. Effect of feed structure and processing and addition of formic acid to the feed on the microbial ecology of the gastrointestinal tract of pigs. *Proceedings of Workshop on Alternatives to Feed Antibiotics and Anticoccidials in the Pig and Poultry Meat Production, October 13-16, 2001* (ed. Bækbo, P.). Quality Savoy Universitetsgt. 11, N-0164 Oslo, pp. 20-24

Canibe, N., Steien, S.H., Overland, M. and Jensen, B.B. 2001a. Effect of K-diformate in starter diets on acidity, microbiota, and the amount of organic acids in the digestive tract of piglets, and on gastric alterations. *J. Anim. Sci.* 79: 2123-2133

Canibe, N., Steien, S.H., Overland, M. and Jenson, B.B. 2001b. Effect of Formi[TM] LHS on digesta and faecal microbiota, and on stomach alterations of piglets. *Digestive Physiology of Pigs*, (eds. Lindberg, J. E and Ogle, B.). CABI publishing, Swedish University of Agricultural Sciences, Uppsala, Sweden, pp. 288-290

Canibe, N., Engberg, M.R. and Jensen, B.B. 2001c. An overview of the effect of organic acids on gut flora and gut health. *Proceedings of Workshop on Alternatives to Feed Antibiotics and Anticoccidials in the Pig and Poultry Meat Production, October 13-16, 2001* (ed. Bækbo, P.). Quality Savoy Universitetsgt. 11, N-0164 Oslo, pp. 5-19

Cole, D.J.A., Beal, R.M. and Luscombe, J.R. 1968. The effect on performance and bacterial flora of lactic acid, propionic acid, calcium propionate and calcium acrylate in the drinking water of weaned pigs. *Vet. Rec.* 83: 459-464

Coupel, A. 2001. Acid feeds for sows has many advantages. *Feed Mix* 9 (6): 20-21

*Eckel, B., Kirchgessner, M. and Roth, F. X. 1992a. Influence of formic acid on daily weight gain, feed intake, feed conversion rate and digestibility. 1. Investigations about the nutritive efficacy of organic acids in the rearing of piglets. *J. Anim. Physiol. Anim. Nutr.* 67 (2): 93-100

*Eckel, B., Roth, F. X., Kirchgessner, M. Eidelsburger, U. 1992b. Influence of formic acid on concentrations of ammonia and biogenic amines in the gastrointestinal tract. 4. Investigations about the nutritive efficacy of organic acids in the rearing of piglets. *J. Anim. Physiol. Anim. Nutr.* 67 (4): 198-205

Edmonds, M.S., Izquierdo, O.A. and Baker, D.H. 1985. Feed additive studies with newly weaned pigs: Efficacy of supplemental copper, antibiotics and organic acids. *J. Anim. Sci.* 60: 462-469

*Eidelsburger, U., Roth, F. X. and Kirchgessner, M. 1992a. Influence of formic acid, calcium formate and sodium hydrogen carbonate on daily weight gain, feed intake, feed conversion rate and digestibility. 7. Investigations about the nutritive efficacy of organic acids in the rearing of piglets. *J. Anim. Physiol. Anim. Nutr.* 67 (5): 258-267

*Eidelsburger, U., Kirchgessner, M. and Roth, F. X. 1992b. Influence of formic acid, calcium formate and sodium hydrogen carbonate on dry matter content, pH value, concentration of carboxylic acids and ammonia in different segments of the gastrointestinal tract. 8. Investigations about the nutritive efficacy of organic acids in the rearing of piglets. *J. Anim. Physiol. Anim. Nutr.* 68 (1): 20-32

Falkowski, J.F. and Aherne, F.X. 1984. Fumaric and citric acid as feed additives in starter pig nutrition. *J. Anim. Sci.* 58: 935-938

Fevreir, C., Gotterbarm, G., Jaguelin-Peyraud, Y., Lebreton, Y., Legouevec, F. and Aumaitre, A. 2001. Effects of adding potassium diformate and phytase excess for weaned piglets. *Digestive physiology of pigs* (eds. Lindberg, J. E. and Ogle, B.). CABI publishing, Swedish University of Agricultural Sciences, Uppsala, Sweden, pp. 192-194

Food and Agricultural Organisation of the United Nations (1971). *Energy and protein requirements – Report of a joint FAO/WHO ad hoc Expert committee*, FAO Food and Nutrition Series, Rome. 7(1): p. 118.

Gabert, V.M. and Sauer, W.C. 1995. The effect of fumaric acid and sodium fumarate supplementation to diets for weanling pigs on amino acid digestibility and volatile fatty acid concentrations in ileal digesta. *Anim. Feed Sci. Technol.* 53: 243-254

Gabert, V.M., Sauer, W.C., Schmitz, M., Ahrens, F. and Mosenthin, R. 1995. The effect of formic acid and buffering capacity on the ileal digestibilities of amino acids and bacterial populations and metabolites in the small intestine of weanling pigs fed semipurified fish meal diets. *Can. J. Anim. Sci.* 75: 615-623

*Gedek, B., Kirchgessner, M., Eidelsburger, U., Wiehler, S., Bott, A. and Roth, F. X. 1992. Influence of formic acid on the microflora in different segments of the gastrointestinal tract. 5. Investigations about the nutritive efficacy of organic acids in the rearing of piglets. *J. Anim. Physiol. Anim. Nutr.* 67 (4): 206-214

Granli, T., Overland, M., Kjeldsen, K.C. and Mroz, Z. 2002. Antimicrobial properties of dietary potassium diformate in pigs. *Beyond Antimicrobials the Future of Gut Microbiology, June 12-15, 2002* (eds. Martin, C. and Karen, P. S.). Rowett Research Institute-INRA, Aberdeen, Scotland, pp. 41

Han, Y.M., Roneker, K.R., Pond, W.G. and Lei, X.G. 1998. Addition of citric acid enhances the efficacy of supplemental microbial and cereal phytases in corn-soy diets for growing pigs. *J. Anim. Sci.* 76 (Suppl. 1): 177

Hebeler, D., Kulla, S., Winkenwerder, F., Kamphues, J., Zentek, J. and Amtsberg, G. 2000. Effect of Formi® on the intestinal microflora of weaned piglets at different times post-weaning. *Hannover 54th Proc. Soc. Nutr. Physiol.* 9: 63

Izat, A.L., Adams, M.H., Cabel, M.C., Colberg, M., Reiber, M.A., Skinner, J.T. and Waldroup, P.W. 1990. Effects of formic acid or calcium formate in feed on performance and microbiological characteristics of broilers. *Poult. Sci.* 69: 1876-1882

Jongbloed, A.W., Jongbloed, R., Kies, A.K. and Lenis, N.P. 1996. The effect of organic acid in diets for growing pigs on enhancement of microbial phytase efficacy. *J. Anim. Sci.* 74 (Suppl. 1): 185

Jongbloed, A.W., Mroz, Z., Jongbloed, R. and Kemme, P.A. 2000. The effects of microbial phytase, organic acids and their interaction in diets for growing pigs. *Liv. Prod. Sci.* 67: 113-122

Kirchgessner, M., Paulicks, B.R. and Roth, F.X. 1997. Effect of supplementation of diformate complexes (Formi^{TM} LHS) on growth and carcass performance of piglets and fattening pigs in response to application time. *Agribiol. Res.* 50: 1-10

*Kirchgessner, M., Eckel, B., Roth, F. X. and Eidelsburger, U. 1992a. Influence of formic acid on carcass composition and retention of nutrients. 2. Investigations about the nutritive efficacy of organic acids in the rearing of piglets. *J. Anim. Physiol. Anim. Nutr.* 67 (2): 101-110

*Kirchgessner, M., Gedek, B., Wiehler, S., Bott, A., Eidelsburger, U. and Roth, F. X. 1992b. Influence of formic acid, calcium formate and sodium hydrogen carbonate on the microflora in different segments of the gastrointestinal tract. 10. Investigations about the nutritive efficacy of organic acids in the rearing of piglets. *J. Anim. Physiol. Anim. Nutr.* 68 (2): 73-81

Knarreborg, A., Miquel, N., Granli, T. and Jensen, B.B. 2001. *In vitro* methodology to evaluate the effect of various organic acids on the microflora in the gastrointestinal tract of pigs. *Digestive physiology of pigs* (eds. Lindberg, J. E. and Ogle, B.). CABI publishing, Swedish University of Agricultural Sciences, Uppsala, Sweden, pp. 302-304

Krause, O.D., Harrison, P.C. and Easter, R.A. 1994. Characterization of the nutritional interactions between organic acids and inorganic bases in the pig and chick. *J. Anim. Sci.* 72: 1257-1262

Lesniewska, V., Laerke, H.N., Hedemann, M.S. and Jensen, B.B. 2001. Effect of intraduodenal infusion of lactic and formic acid on pancreatic juice secretion and antroduodenal myoelectrical activity in piglets after weaning. *Digestive physiology of pigs* (eds. Lindberg, J. E. and Ogle, B.). CABI publishing, Swedish University of Agricultural Sciences, Uppsala, Sweden, pp. 215-217

Li, D., Liu, S.D., Qiao, S.Y., Yi, G.F., Liange, C. and Thacker, P. 1999. Effect of feeding organic acid with or without enzyme activity and performance of weaned piglets. *Asian-Aust. J. Anim. Sci.* 12 (3): 411-416

*Ludke, H. and Schone, F. 1994. Studies on the use of acids in compound feeds for weaner pigs. *Muhle Mischfuttertechnik* 131 (13): 163

Makkink, C. 2001. Acid binding capacity in feed stuffs – Lowering the 'B-Value', especially for young animals. *Feed Int.* 22 (10): 24-26

Maynard, L.A., Loosli, J.K., Hintz, H.F. and Warner, R.G. 1971. *Animal Nutrition.* Sixth edition. Tata McGraw Hill Publishing Company Ltd., New Delhi. p.613

Min, T.S., Kim, J.D., Hyun, Y., Sohn, K.S., Heo, K.N. and Han, I.K. 2001. Effects of environmentally friendly agents on growth performance, nutrient digestibility, nutrient excretion and carcass characteristics in growing-finishing pigs. *Asian-Aust. J. Anim. Sci.* 14 (4): 540-547

Mroz, Z. and Krasucki, W. 2002. Effects of in-feed acidifiers for multiparous sows. *J. Anim. Sci.* 80 (Suppl. 1): 392

Mroz, Z., Jongbloed, A. W., Jongbloed, V.W. and Overland, M. 2001. Post prandial flow rates of formic acid and potassium in duodenal digesta of weaned piglets fed graded doses of potassium diformate. *Digestive physiology of pigs* (eds. Lindberg, J. E. and Ogle, B.). CABI publishing, Swedish University of Agricultural Sciences, Uppsala, Sweden, pp. 305-307

Mroz, Z., Jongbloed, A.W., Partanen, K., Diepen, J.T.M.V., Kemme, P.A. and Kogut, J. 1997. Apparent digestibility of amino acids and balance of nitrogen and minerals as influenced by buffering capacity and organic acids in diets for growing swine. *J. Anim. Sci.* 75 (Suppl. 1): 186

Mroz, Z., Jongbloed, A.W., Partanen, K.H., Vreman, K., Kemme, P.A. and Kogut, J. 2000. The effects of calcium benzoate in diets with or without organic acids on dietary buffering capacity, apparent digestibility, retention of nutrients and manure characteristics in swine. *J. Anim. Sci.* 78: 2622-2632

Mroz, Z., Reese, D.E., Overland, M., Diepen, J.T.M.V. and Kogut, J. 2002. The effects of potassium diformate and its molecular constituents on the apparent ileal and fecal digestibility and retention of nutrients in growing-finishing pigs. *J. Anim. Sci.* 80: 681-690

National Research Council (1998). *Nutrient Requirements for swine.* Tenth edition. National Academy Press. Washington, D.C. p. 189

Omogbenigun, F.O., Nyachoti, C.M. and Slominski, B.A. 2003. The effect of supplementing microbial phytase and organic acids to a corn-soybean based diet fed to early-weaned pigs. *J. Anim. Sci.* 81: 1806-1813

Overland, M. 2001. Simple salt approved as alternative growth promoter. *Feed Mix 9* (4/5): 25-28

Overland, M., Granli, T., Kjos, N.P., Fjetland, O., Steien, S.H. and Stokstad, M. 2000. Effect of dietary formates on growth performance, carcass traits, sensory quality, intestinal microflora and stomach alterations in growing-finishing pigs. *J. Anim. Sci.* 78: 1875-1884

Overland, M., Granli, T., Stein, S.H. and Fjetland, O. 1999. Effect of K-diformate in diets for grow-finish pigs. *J. Anim. Sci.* 77 (Suppl. 1): 66

Overland, M. and Granli, T. 2001. Potassium diformate (Formi^{TM}) - Effect on gut microflora and growth performance. *Proceedings of Workshop on Alternatives to Feed Antibiotics and Anticoccidials in the Pig and Poultry*

Meat Production, October 13-16, 2001 (ed. Bækbo, P.). Quality Savoy Universitetsgt. 11, N-0164 Oslo, pp. 25-29

Overland, M., Kjeldsen, K. and Granli, T. 2002. Acids salts improve enzyme efficiency. *Feed Mix* 10 (5): 10-12

Partanen, K., Jalava, T., Valaja, J., Perttila, S., Siljander-Rasi, H. and Lindeberg, H. 2001. Effect of dietary carbadox or formic acid and fibre level on ileal and faecal nutrient digestibility and microbial metabolite concentrations in ileal digesta of the pig. *Anim. Feed. Sci. Technol.* 93: 137-155

Paulicks, B.R., Roth, F.X. and Kirchgessner, M. 1996. Dose effects of potassium diformate (Formi™ LHS) on the performance of growing piglets. *Agribiol. Res.* 49: 318-326

Paulicks, B.R., Roth, F.X. and Kirchgessner, M. 2000. Effects of potassium diformate (Formi™ LHS) in combination with different grains and energy densities in the feed on growth performance of weaned piglets. *J. Anim. Physiol. Anim. Nutr.* 84 (1): 102-111

Piva, A., Casadei, G. and Biagi, G. 2002. An organic acid blend can modulate swine intestine fermentation and reduce microbial proteolysis. *Can. J. Anim. Sci.* 82: 527-532

Puyalto, M. and Mesia, J. 2002. Fighting gut pathogens – *In vitro* assessment of acid, acid derivatives and combinations. *Feed Int.* 23 (4): 19-22

Radcliffe, J.S., Zhang, Z. and Kornegay, E.T. 1997. The effects of adding citric acid to a low phosphorus corn-soybean meal based diet with or without added microbial phytase for weanling pigs. *J. Anim. Sci.* 75 (Suppl. 1): 184

Radcliffe, J.S., Zhang, Z. and Kornegay, E.T. 1998. The effects of microbial phytase, citric acid and their interaction in a corn-soybean meal-based diet for weanling pigs. *J. Anim. Sci.* 76: 1880-1886

Radecki, S.V., Juhl, M.R. and Miller, E.R. 1988. Fumaric and citric acid as feed additives in starter pig diets : Effect on performance and nutrient balance. *J. Anim. Sci.* 66: 2598-2605

Ranjhan, S.K. 2001. *Animal Nutrition in the tropics.* Fifth edition, Vikas Publishing House Pvt. Ltd., New Delhi, P.576

Risley, C.R., Kornegay, E.T., Lindmann, M.D., Wood, C.M. and Eigel, W.N. 1992. Effect of feeding organic acid on selected intestinal content measurements at varying times post weaning in pigs. *J. Anim. Sci.* 70: 196-206

Risley, C.R., Kornegay, E.T., Lindemann, M.D., Wood, C.M. and Eigel, W.N. 1993. Effect of feeding organic acids on gastro intestinal digesta measurements at various times post weaning in pigs challenged with enterotoxigenic *Escherichia coli*. *Can. J. Anim. Sci.* 73: 931-940

*Roth, F.X., Eckel, B., Kirchgessner, M. and Eidelsburger, U. 1992. Influence of formic acid on pH-value, dry matter content, concentrations of volatile fatty acids and lactic acid in the gastrointestinal tract. 3. Investigations about the nutritive efficacy of organic acids in the rearing of piglets. *J. Anim. Physiol. Anim. Nutr.* 67 (3): 148-156

Roth, F.X., Kirchgessener, M. and Paulicks, B.R. 1996. Nutritive use of feed additives based on diformates in the rearing and fattening of pigs and their effects on performance. *Agribiol. Res. 49*: 307-317

Roth, F.X., Windisch, W. and Kirchgessner, M. 1998a. Mineral metabolism (P, K, Ca, Mg, Zn, Mn, Cu) of piglets supplied with potassium diformate (Formi^{TM} LHS). *Agribiol. Res.* 51 (2): 1-8

Roth, F.X., Windisch, W. and Kirchgessner, M. 1998b. Effect of potassium diformate (Formi^{TM} LHS) on nitrogen metabolism and nutrient digestibility in piglets at graded dietary lysine supply. *Agribiol. Res.* 51 (2): 167-175

172128

Roura, E., Gibson, M. and Brennan, J. 2002. Interactive effects of diet complexity and a combination of flavor, acid and enzymes on growth of starter pigs. *J. Anim. Sci.* 80 (Suppl. 1): 393

Schoenherr, W.D. 1994. Phosphoric acid based acidifiers explored for starter diets. *Feedstuffs* 66 (40): 1-4

Snedecor, G.W. and Cochran, W.G. 1985. *Statistical Methods*. Seventh edition. The Iowa State University Press, America. p. 313

Starkey, C.W., Hancock, J.D., Park, J.S., Hankins, C., Herkelman, K., Moody, B. and Odgaard, R.L. 2000. Effect of diet acidification on sow and litter performance. *J. Anim. Sci.* 78 (Suppl. 1): 173

Stein, H.H., Peters, D., Christopherson, B.T. and Cerchiari, E. 2002. The effects of including a blend of incapsulated organic and inorganic acids in diets for weanling pigs. *J. Anim. Sci.* 80 (Suppl. 1): 112

Tossenberger, J., Palmai, L., Karakas, P., Szabo, J. and Horn, P. 1998. The effect of formic acid on ileal digestibility of amino acids and on performance in weaned piglets. *J. Anim. Sci.* 76 (Suppl. 1): 181

Vankol, E.M.R. 2000. The nutraceuticals series organic acid application in feeds without antibiotics. *Feed Mix* 8 (2): 15-17

Windisch, W.M., Gotterbarm, G.G. and Roth, F.X. 2001. Effects of potassium diformate in combination with different amounts and sources of excessive dietary copper on production performance in weaning piglets. *Arch. Anim. Nutr.* 54: 87-100

Wolter, B.F., Ellis, M., Frampton, A.V., Easter, R.A., Roura, E., Brenes, J. and Sola, J. 2000. Effect of nursery diet and supplementation with a combination of dietary acidifiers, enzymes and flavor on pig performance. *J. Anim. Sci.* 78 (Suppl. 1): 189

*Originals not consulted

EFFECT OF DIETARY POTASSIUM DIFORMATE ON GROWTH PERFORMANCE IN LARGE WHITE YORKSHIRE PIGS

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ABSTRACT

A study was carried out to assess the influence of potassium diformate on growth performance, digestibility of nutrients and carcass quality in Large White Yorkshire pigs. Thirty weaned male piglings with an average live weight of 13.0 kg were divided into three equal groups as uniform as possible with regard to age and body weight. Pigs were maintained on three experimental diets viz., T_1 – control standard grower (18 per cent crude protein and 3150 kcal/kg ME) and finisher ration (15.5 per cent crude protein and 3100 kcal/kg ME), T_2 – control diet supplemented with 0.75 per cent potassium diformate and T_3 – control diet supplemented with 1.5 per cent potassium diformate.

The average daily gain of 465, 494 and 519 g were recorded for the groups T_1, T_2 and T_3, respectively. There was no significant difference ($P>0.05$) between the supplemented group and the group fed control diet. However, there was a trend for a higher growth rate of 6.2 per cent and 11.7 per cent, reported for T_2 and T_3 over those fed control diet. The average cumulative feed conversion efficiency were 3.97, 3.74 and 3.55 for the groups T_1, T_2 and T_3, respectively. Addition of potassium diformate at 0.75 and 1.5 per cent level in the diet of growing-finishing pigs had a higher ($P<0.01$) feed conversion efficiency over those fed control diet. There was no significant difference ($P>0.05$) between the supplemented groups. However, there was a trend for a higher feed efficiency for those fed 1.5 per cent potassium diformate supplemented diet. The digestibility coefficients for dry matter, ether extract, crude protein and nitrogen free extract were significantly higher ($P<0.01$) for pigs fed with diet supplemented with potassium diformate at both the levels (0.75 and 1.5 per cent). There was no significant difference between the supplemented groups. Dressing percentage, carcass length, back fat thickness, loin eye area and others were not significantly influenced ($P>0.05$) by the inclusion of potassium diformate at different levels.

The costs of feed per kg live weight gain of pigs were Rs.32.82, 32.05 and 31.50, respectively for T_1, T_2 and T_3. The above results indicate that potassium diformate can be economically incorporated at 1.5 per cent level in the diet of Large White Yorkshire pigs.