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FAT UTILIZATION BY THE YOUNG PIG

BY

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A THESIS

SUBMITTED TO THE FACULTY OF GRADUATE STUDIES AND RESEARCH

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Dr. J. P. Bowland

Dr. A. Horak

DATE: 15/X/1985

This work is dedicated to all my family
but particularly to Pablo
for understanding the importance
of this and Damarys' "book".

ABSTRACT

Two experiments were undertaken with 28 day old weaned pigs to study their ability to utilize fat efficiently, when constant nutrient to calorie ratios were maintained.

In the first experiment the effects of fat addition to the diet upon performance and body composition were studied. Diets contained 0 or 8% added mixed fat. The results indicated that the pigs fed fat-supplemented diets had a higher ($P<0.05$) average daily gain, a reduced ($P<0.05$) total feed intake, an improved ($P<0.001$) feed per gain ratio and required fewer ($P<0.07$) days to reach the target weight of 20 kg. liveweight than pigs fed diets with no added fat. Significant changes in the empty body composition (EBC) occurred between pigs slaughtered at weaning and seven days after weaning. No difference in the EBC of pigs were observed between seven days after weaning and 20 kg. liveweight or between dietary treatment groups.

In the second experiment fat digestibility was determined by the ileal and fecal methods. Diets containing 0, 4 or 8% added fat were fed to ileal cannulated pigs and non-cannulated pigs received diets containing 0 or 8% added fat. Fat digestibilities increased ($P<0.001$) with the level of fat added to the diets. Ileal fat digestibilities were higher ($P<0.001$) than those estimated by the fecal method. These results suggest that weanling pigs are able to efficiently utilize supplemental fat in their diet .

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CHAPTER I

INTRODUCTION

Whittemore (1984) suggested that the young pig has a greater potential for lean tissue growth than is currently being achieved. This could be due to a low postweaning feed intake and inadequate management and care of the young pig (Whittemore, 1984). Improving the quality and increasing the energy density of the diet of weaned pigs and maintaining constant nutrient to energy ratios could contribute significantly to better the performance of weaned pigs. In this regard, supplemental fat could play an important role in the nutrition of the young pig.

Fat is the nutrient of highest energy content (2.25 times higher than carbohydrates). In addition, fat offers other unique qualities when added to the diet, as summarized by Siegl et al. (1984):

1- It improves mixing of feed ingredients;
2- It avoids volume loss of feedstuffs;
3- It makes the pig feel satiated;
4- It is quickly and well absorbed (3 to 4 hours) and therefore causes very little stress to the intestine;
5- It improves utilization of fat soluble vitamins;
6- It aids in the absorption of calcium and phosphorus;
7- It aids, even in small amounts, in the pelleting characteristics of diets (maximum fat level, 4%);

8- It improves palatability; and

9- It has some technological advantages too:

i- lower equipment wear,

ii- less feed loss from the feeder and

iii- less dust formation when diets are handled.

However, fat as a feed ingredient has some potential disadvantages. The pig can only absorb fats that are not oxidized or polymerized (Veen, 1984). Unsaturated fatty acids are absorbed more easily than saturated fatty acids, but are also more subject to oxidation. This means that fats used in diets need to meet some quality standards. Diets containing high levels of fat, particularly fats with high levels of unsaturated fatty acids, which are exposed to warm temperatures should contain antioxidants and should not be stored for extended periods of time.

For decades fat has been added to the diets of weaned pigs to evaluate their ability to utilize it efficiently but still no clear consensus has emerged. Lloyd et al. (1957) and Scherer et al. (1973) reported that the young pig did not utilize fat efficiently but digestibility of fat did increase with age. These results are not consistent with the fact that sows' milk is digested with approximately 100% efficiency (Fowler, 1980) and contains up to 40% lipids on a dry matter basis (DeMan and Bowland, 1963). Aumaitre (1972) reported that the suckling pig secretes large amounts of pancreatic lipase . Possible fat emulsification problems were studied by Frobish et al. (1969), but they observed no difference in the performance of pigs fed diets containing added fat with or without emulsifying agents. Allee et al. (1971) and Wolfe et al. (1978) studied the young pigs' ability to metabolize absorbed fat. Their observations indicated that the key fat metabolic enzymes are present and that they increase in activity when pigs are fed fat. Therefore, the observation that pancreatic lipase activity increased with age (Scherer et al. 1973) may be a result of enzyme adaptation to diet change or change of fat in the diet and not an inability of the young pig to utilize fat.

Since there appears to be no digestive or metabolic reason for the weanling pig not to use added fat efficiently, two experiments were conducted to study the effects of added fat in the diet, while maintaining constant nutrient to energy ratios, on the performance and body composition of weaned pigs and on the digestibility of dietary fat measured in ileal digesta and feces of weaned pigs.

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CHAPTER II

THE EFFECTS OF FAT SUPPLEMENTATION ON PERFORMANCE AND BODY COMPOSITION OF WEANED PIGS.

INTRODUCTION

Sows' milk contains 30 to 40% fat on a dry matter basis (DeMan and Bowland, 1963) and on such a diet the suckling pig is able to double his birthweight and increase body fat from 1.2 to 10% in the first week of life (Manners and McCrea, 1963; Wood and Groves, 1965).

At weaning, changes in the physical form of the diet and feeding regimen lead to lower feed intake for the first three to five days and result in a postweaning growth check (Braude and Newport, 1977; Leibbrandt et al. 1975a; Lecce et al. 1979; O'Grady and Bowland, 1972; Okai et al. 1976). This growth check can be reduced by increasing the palatability and energy density of the diets (Campbell et al. 1975; Speer, 1976). Fat has 2.25 more energy per unit weight than carbohydrate and its addition to a diet increases the diets palatability (Speer, 1976). However, when fat was substituted on an equal weight basis for carbohydrate in a diet at weaning, average daily gain decreased (Frobish et al. 1969; 1970; and 1971). In contrast, average daily gain and feed to gain ratio improved for weaned pigs fed a fat supplemented diet in which nutrient to energy ratios had been held constant with

respect to a control diet (Aherne et al. 1982; Allee and Hines, 1972; and Menge and Frobish, 1976).
Several recent studies have suggested that the lysine requirement of the 5-10 kg. pig is approximately 1.15 % and not 0.95% as recommended by the National Academy of Sciences-National Research Council NAS-NRC (1979) (Aherne and Nielsen, 1983 and Campbell, 1977). In the experiments in which a response was observed to fat supplementation the diets contained higher lysine levels than the control diet but the control diets only met the NAS-NRC (1979) lysine levels.

The objectives of this experiment were to determine if average daily gain and feed to gain ratio are improved with dietary fat supplementation when nutrient to energy ratios are maintained constant between diets with higher lysine levels in the control diet and to monitor the changes in empty body composition of weaned pigs fed diets with or without fat supplementation.

MATERIALS AND METHODS

Fifty-three (Yorkshire x Landrace) pigs were weaned at 28 days of age and were assigned on the basis of weaning weight to an initial slaughter group (3 barrows and 3 gilts) or to one of two dietary treatments. Three additional pigs per sex from each treatment group were slaughtered after one week on test. The remaining thirty-five pigs were on test until they reached approximately 20 kg. liveweight. At that time, five barrows chosen at random from each treatment group and six gilts from the control group and five gilts from the fat supplemented group were slaughtered.

The control diet was a standard starter diet, based on barley, wheat, oat groats and soybean meal (Table II.1). The second diet contained the same ingredients but also 8% mixed fat and was formulated to contain the same nutrient to digestible energy (DE) ratio as the control diet. To achieve this with practical diets, the proportion of protein derived from cereals and soybean meal varied between diets. With the exception of DE in the control diet, both diets met or exceeded the nutrient requirement recommendations of the NAS-NRC (1979) for starter (5-10 kg.) pigs. The lipid classes and fatty acid composition of the mixed fat are presented in Table II.2. All animals were individually housed in raised type of floor pens with feed and water available ad libitum. Trays were placed under the feeders and weekly feed wastage was determined. The environmental temperature was maintained at approximately 27°C throughout the experiment.

Weight gain and feed intake were recorded weekly until each animal reached 19 kg. and daily thereafter. At the time of slaughter the pigs were stunned with a captive bolt pistol, bled and the blood collected. The dead pigs were then scalded, the hair was removed and the carcass opened to allow emptying of the gastrointestinal tract. Blood, carcass, viscera and emptied gastrointestinal tract were

Table II.1 Formulation and composition of pig starter diets.

DIET	Control	8% Fat
Ingredients (%)		
Mixed fat [1]	0.00	8.20
Barley	20.07	19.51
Wheat	34.79	20.00
Oat groats	19.21	15.00
Soybean meal	21.81	32.40
Calcium Phosphate	1.50	1.70
Ground limestone	1.00	1.20
Iodized salt	0.40	0.50
Starter premix [2]	1.00	1.20
L-lysine (HCl)	0.21	0.28
Composition, analyzed (%)		
Lysine	1.24	1.50
Crude protein	20.8	23.0
Ether extract	1.8	9.2
Composition, calculated		
Digestible energy, Mcal/kg	3.35	3.68
Protein/energy ratio, g/Mcal	62.0	62.5

1 Trade name "Tallow"

2 Starter premix provided the following per kilogram of the control diet:
5000 IU vitamin A, 700 IU vitamin D_3, 22 IU vitamin E, 22 mg riboflavin, 45 mg niacin, 23 mg calcium pantothenate, 30 ug vitamin B_{12}, 500 mg choline, .2 mg biotin, 120 mg Zn, 12 mg Cu, 150 mg Fe, .1 mg Se and 12 mg Mn. The fat supplemented diets contained 1.2 times this level of vitamins and minerals per kilogram.

Table II.2 Composition of mixed fat.

Lipid classes	%	Fatty acids		%
Triglycerides	85.6	Myristic	(14:0)[1]	1.11
Diglycerides	2.7	Tetradecanoleic	(14:1)	0.25
Monoglycerides+ Phospholipids	3.5	Pentadecanoic	(15:0)	0.15
Free fatty acids	3.8	Palmitic	(16:0)	18.67
Choline	4.4	Palmitoleic	(16:1)	2.20
Total	100.0	Heptadecanoic	(17:0)	0.48
		Stearic	(18:0)	12.54
		Oleic	(18:1)	56.72
		Linoleic	(18:2)	5.56
		Linolenic	(18:3)	0.79
		Arachidonic	(20:0)	0.97
		Others		0.56
		Total		100.00

1 Chain length: number of double bonds.

put into a plastic bag, weighed and stored at -20°C. Later, the contents of the plastic bag were ground three times with a heavy industrial grinder (Autio Co., Astoria, Oregon, U.S.A.) through a 5 mm die, using enough dry ice to keep the meat frozen and pelleted. The ground material was then hand mixed for five minutes and three samples were selected randomly from the mix. The samples were weighed and freeze dried. The dried samples were then mixed with a blender for 20 seconds and subsampled to obtain material to determine the percentage of water, crude protein, ether extract and ash.

Tissue and feed were analyzed according to the Association of Analytical Chemists (AOAC 1981) methods. Total amino acid levels of the diets were determined following acid hydrolysis in 6N HCl (Blackburn, 1968), using a Beckman 121 MB amino acid analyser. The amino acid analyses of the diets are shown in Appendix 1. The mixed fat was analyzed for lipid classes with an Iatroscan TH-10 Mark II Analyzer (T.M.A. Scientific Supply, Mississauga, Ont.). Each pentane dissolved lipid sample (1-2 uL) was spotted on a chromatorod, developed for 45 min. in a methylene chloride-chloroform-acetic acid-methanol (98:8:0.5:0.2) solvent system and scanned on the Iatroscan Analyzer to determine the relative amount of each lipid class (Newman, 1978). Determination of the fatty acid composition of the mixed fat was done following the method of Morrison and Smith (1964) as outlined by Thacker (1981).

STATISTICAL ANALYSIS

Analysis of variance, orthogonal comparisons or T-tests were computed according to Steel and Torrie (1980).

RESULTS

Feeding pigs a control diet compared with an 8% mixed fat diet for seven days after weaning resulted in a nonsignificant (P>0.05) improvement in feed intake, weight gain, feed to gain ratio, energy intake and energy required per unit gain (Table II.3). Energy required per unit increase in empty body weight gain (EBG) for the control group of pigs was three times larger than that for pigs fed the 8% fat diet.

At 20 kg. liveweight, pigs fed the control diet and the fat supplemented diet had similar average daily feed intakes (Table II.3). Total feed intake for pigs fed the fat supplemented diet was lower (P<0.05) than that of pigs fed the control diet and it took the pigs fed the fat supplemented diet fewer days (P<0.07) to reach 20 kg.. Average daily gain was greater (P<0.05) and feed to gain ratio was lower (P<0.001) for the pigs fed the mixed fat diet compared with pigs fed the control diet. The energy required per unit of gain was similar for both treatment groups up to 20 kg. liveweight.

Liveweight, empty body weight and weight of gastrointestinal tract contents of pigs at weaning and at seven days after weaning are shown in Table II.4. Empty

Table II.3 Performance of the pigs seven days after weaning and at 20 kg.

	Control	8% Fat	S.E.[1]	Significance
Seven days after weaning				
Number of pigs	6	6		NS[3]
Feed intake, kg.	1.62	1.40	0.162	NS
Energy intake, Mcal DE	5.43	5.14	0.560	NS
Weight gain, g.	717	783	103	NS
Feed/gain	2.26	1.79		NS
Energy/EBG[2], Mcal DE/kg.	45.2	15.1		NS
At 20 kg.				
Number of pigs	17	18		
Average daily feed intake, g/day	574	558	12	NS
Total feed intake, kg.	20.4	18.1	0.53	$P<0.005$
Days to reach 20 kg.	35.9	32.6	1.19	$P<0.07$
Average daily gain, g/day	374	404	9	$P<0.05$
Feed/gain	1.54	1.38	0.025	$P<0.001$
Energy/Gain, Mcal DE/kg.	5.16	5.09	0.08	NS

1 S.E.= ± Standard error.
2 EBG= Empty body gain
3 NS= No significant difference between means.

Table II.4 Liveweight, empty body weight and gut fill of pigs at weaning and at seven days after weaning.

	At weaning	Seven days after weaning	
		Control	8% fat
Number of pigs	6	6	6
Liveweight, kg.	7.65	8.12	8.25
Empty body weight, kg.	7.27	7.15	7.43
Gut fill[1], kg.	0.38 a	0.97 b	0.82 b

1 Digestive contents and other losses. The standard error between treatments is ± 0.08.

a,b Means bearing different subscripts within the same horizontal line are significantly different (P < 0.05).

body weight of pigs slaughtered at weaning was not significantly different (P>0.05) from that of pigs slaughtered after seven days on test. However, gut fill of pigs slaughtered seven days after weaning was significantly greater (P<0.01) than that of pigs slaughtered at weaning. Pigs fed the control diet for seven days after weaning had a slightly greater (P<0.07) gut fill than pigs fed the mixed fat diet. Liveweight gain for the first seven days on test was significantly different (P<0.005) from the empty body gains (Table II.5).

The calculated empty body weight gain (0.12 kg.) of the pigs fed the control diet for seven days after weaning was accounted for by a gain of 0.24 kg. of water, 0.06 kg. protein, 0.01 kg. ash and a loss of 0.21 kg. of ether extract (Table II.6). In contrast, the empty body gain (0.33 kg.) of the pigs fed the 8% mixed fat diet was accounted for by a gain of 0.34 kg. of water, 0.05 kg. protein, 0.01 kg. ash and a loss of 0.07 kg. of ether extract. Thus, pigs fed the fat supplemented diets lost considerably less fat but otherwise were similar in body composition to those fed the control diet.

The empty body composition (% of DM) of pigs at weaning, seven days after weaning and at 20 kg. liveweight are shown in Table II.7. Percent dry matter, crude protein and ether extract increased significantly (P<0.01) from weaning to seven days after weaning. Carcass composition at seven days after weaning and at 20 kg. were similar

Table II.5. Liveweight and empty body weight gains seven days after weaning .

	Control	8% fat
Number of pigs	6	6
Liveweight		
Initial weight, kg.	7.40	7.47
Final weight, kg.	8.12	8.25
Gain, kg.	0.72 a	0.78 a
Empty body weight		
Initial weight (estimated[1]), kg.	7.03	7.10
Final weight, kg.	7.15	7.43
Gain, kg.	0.12 b	0.33 b

1 Estimated by multiplying the weaning weights by 0.9503 (correction factor derived from the ratio of empty body weight and liveweight of the pigs slaughtered at weaning).

a,b Means bearing different subscripts within columns are significantly different ($P<0.005$). The standard errors were ± 0.12 and ± 0.05 for the control and 8% fat diet, respectively.

Table II.6 Calculated composition of empty body gain after feeding a control diet or an 8% mixed fat diet for 7 days.

	Empty body weight[1]	Composition of empty body weight				
		Water	Crude protein	Ether extract	Ash	Un-accoun-table
Control						
Estimated weight at weaning, kg.	7.03	4.76	1.11	0.89	0.23	0.04
Weight after 7 days on test, kg.	7.15	5.00	1.17	0.68	0.24	0.06
Gain, kg.	0.12	0.24	0.06	-0.21	0.01	0.02
8 % fat						
Estimated weight at weaning, kg.	7.10	4.80	1.13	0.90	0.23	0.04
Weight after 7 days on test, kg.	7.43	5.14	1.18	0.83	0.24	0.04
Gain, kg.	0.33	0.34	0.05	-0.07	0.01	0.00

1 All values are calculated based on the respective analyzed empty body composition indicated in Table II.7 and the empty body weights from Table II.4.

Table II:7 Empty body composition (% of dry matter) of pigs at weaning, seven days after weaning and at 20 kg. liveweight[1]

Treatment group	Dietary treatment	Empty body compositions % of dry matter				
		DM[2]	CP[3]	EE[4]	ASH	UN[5]
At weaning	None (6)[6]	32.3	49.1	39.1	10.2	1.7
Seven days after weaning	Control (6)	30.0	54.8	31.1	10.9	3.2
	8% fat (6)	30.7	51.7	35.6	10.7	2.1
At 20 kg. liveweight	Control (11)	30.2	54.5	33.1	10.1	2.3
	8% fat (10)	29.6	54.8	32.2	10.3	2.7

1 Orthogonal comparisons, standard errors and significance are shown in Appendix 2.
2 DM=dry matter.
3 CP=crude protein.
4 EE=ether extract.
5 UN=unaccountable.
6 Animals per treatment, in brackets.

(P>0.05). Ash and unaccountable losses did not vary significantly (P>0.05) from weaning to seven days after weaning or to 20 kg. liveweight. Empty body composition of pigs fed the control diet or the mixed fat diet were not significantly different (P>0.05) after seven days on test or at 20 kg. liveweight.

DISCUSSION

Liveweight gain is used widely as an indicator of growth. However, at seven days after weaning it did not indicate accurately tissue growth of the pigs in this experiment. The gut fill increased during the first seven days after weaning masking the actual growth that occurred. The weight of the gut fill increased from 4.97% of liveweight at weaning to 10.84% of liveweight for both treatment groups at seven days after weaning. This is in agreement with observations of Fenton et al. (1985). When compared with liveweight gain for both treatment groups, actual tissue growth (EBG) for the seven days after weaning was significantly lower (P<0.005) (Table II.5). Although the average empty body weight gain for the first week of the test for pigs fed the fat supplemented diet was more than twice that of pigs fed the control diet, it was not significantly different. The pigs fed the control diet lost three times more ether extract and gained one third less water than pigs fed the fat supplemented diet (Table II.6) although the control pigs consumed more energy during the first seven days postweaning (Table II.3). This was directly reflected in the energy conversion efficiency, which was three times poorer for the control pigs. These data suggest that the 35 day old pig can utilize fat at least as efficiently as carbohydrate. The observed loss in body lipid and increased moisture content during the first week after weaning is in agreement with the results of Whittemore et al. (1978; and 1981).

The improved growth rate and feed to gain ratio of starter pigs fed fat supplemented diets in which a constant nutrient to energy ratio has been maintained has also been observed by Aherne et al. (1982); Allee and Hines, (1972); Berschauer et al. (1983); Bowland, (1964); Cline et al. (1977); Menge and Frobish, (1976); Pakhomov, (1979); and Partridge et al. (1983). Allee et al. (1971) suggested that responses to dietary fat supplementation have often been confounded by low intakes of other essential nutrients. Increasing the energy density of a diet without proportionally increasing the protein level has resulted consistently in lower average daily gain (Armstrong and Clawson, 1980; Eusebio et al. 1965; Frobish et al. 1969; 1970; 1971; and Leibbrandt et al. 1975b). Other studies have suggested that protein requirements vary according to energy density of the diet (Becker et al. 1954; Manners and McCrea, 1963; Sewell and Miller, 1965). However, as has been noted by Allee et al. (1971), it is difficult to explain why a depression in gain and energy efficiency has been reported in some factorial experiments in which fat has been added to diets containing high levels of protein and other nutrients (Crampton and Ness, 1954; Crampton et al. 1960; Peo et al. 1957; Smith and Lucas, 1956). More recently, lysine has been reported to be a limiting nutrient in starter diets (Aherne and Nielsen, 1983). In the current experiment, the control diet contained 1.24% lysine, which is above the lysine level recommended for 5 to 10 kg. pigs fed diets based on barley and wheat (Aherne and Nielsen, 1983; Campbell, 1977).

Whether or not pigs have an optimum dietary protein-energy ratio is still not clear (Cuaron et al. 1981; Aherne and Jensen, 1981). The Agricultural Research Council (ARC, 1981), expressed nutrient requirement in relation to energy. Also, the NAS-NRC (1979) infers an optimum dietary nutrient-energy ratio, as all diet recommendations are based on a specific DE level. However, results of experiments have indicated no difference in performance of pigs fed a range of protein-energy ratios (Aherne and Jensen, 1981; Cuaron et al. 1981; and Menge and Frobish, 1976). Despite these observations, there must be some relationship of protein to energy, especially with high energy diets, otherwise performance would not improve when nutrient (protein) levels are increased (Aherne et al. 1982).

Feed to gain ratio is not a precise measure of efficiency of feed or energy utilization because an energy dense diet conveys with less weight the same amount of nutrient and energy to accomplish the same or higher weight gain. Feed to gain ratios of pigs at 20 kg. (Table II.3) illustrate this point. Feed to gain ratios were significantly different ($P<0.001$) between dietary treatment, but energy per unit of gain (Mcal DE/kg.) was the same. However, energy conversion efficiency is not a perfec icator of feed utilization because different carcass components (lipid and protein) require different energy levels for their synthesis (ARC, 1981). Pigs seven days after weaning fed a control diet required three times more energy per empty body weight gain than did pigs fed the fat supplemented diet (Table II.3) and still lost three times more body fat (Table II.6).

Empty body composition (Table II.7) on a percent dry matter basis showed no significant difference ($P>0.05$) at 20 kg. liveweight. This was to be expected, because the animals started and finished the experiment at similar weights, the diets fed had similar nutrient to energy ratios and energy conversion efficiency per kg. of gain was similar.

Empty body composition changes with age (Oslage, 1962; Manners and McCrea, 1963; Wood and Groves, 1965). Body dry matter, lipid and protein increase whereas body water decreases and ash stays constant. In the current study, there was a significant ($P<0.01$) change in empty body composition from weaning to 7 days after weaning, due to reduced nutrient or feed intake for the first few days after weaning.

In summary, the results of this experiment indicate that four-week weaned pigs are able to use dietary fat as a source of energy as efficiently as carbohydrate when nutrient to energy ratios are maintained constant and other nutrients are not limiting.

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CHAPTER III

ILEAL VERSUS FECAL FAT DIGESTIBILITIES BY WEANED PIGS

INTRODUCTION

Traditionally nutrient digestibility has been derived by determining nutrient content of feed and feces. However, this method does not accurately measure the nutrient digestibility, as bacteria in the large intestine may alter products of digestion (Carlson and Bayley, 1972; Hoet et al. 1962; Ozimek et al. 1983; and Sambrook, 1979). Microbial fat synthesis in the large intestine may mask any fat absorption that occurred in the small intestine (Carlson and Bayley, 1972; Hoet et al. 1962; Ozimek et al. 1983; and Sambrook, 1979). In addition the administration of antibiotics has been observed to lower levels of fat in the feces (Eggum et al. 1982; and Mason and Just 1976). Therefore, for accurate fat digestibility estimates, collection of digesta at the terminal end of the ileum of the small intestine, referred to as ileal digestibility, is considered to be more indicative of actual nutrient digestibility than that provided by fecal collection (Carlson and Bayley, 1968).

Some lipids in feces are saponified and fats in ileal digesta may be similarly altered. Ether extraction will not remove these soaps and so fat digestibilities will be overestimated (Just, 1982). By boiling the sample with HCl (Stoldt, 1952, 1957) prior to petroleum ether extraction, higher amounts of crude fat are extracted (Kuhla et al. 1983) and more accurate fat digestibilities result.

The ability of weanling pigs to utilize fat has been a matter of debate for years (Aherne et al. 1982). If, as some reports suggest, weaned pigs do not utilize fat efficiently, pigs receiving supplemental dietary fat cannot grow with the same energetic efficiency as pigs receiving diets without fat supplementation (Mahan and Maxson, 1984; and Stahly et al. 1983). However, Aherne et al. (1982), Berschauer et al. (1983) observed that pigs from weaning to 20 kg. liveweight fed a fat-supplemented diet in which nutrient-energy ratios were maintained had an improved average daily gain, a decreased total feed intake, and an improved feed to gain ratio when compared with pigs fed a diet containing no added fat. Carcass composition of the pigs was not influenced by treatment (Chapter II).

The objective of this experiment was to evaluate the ability of the weaned pig to digest dietary fat. Therefore, ileal and fecal digestibility coefficients for ether extract (fat), energy, dry matter and crude protein were measured with pigs after weaning at 28 days of age.

MATERIALS and METHODS

Twenty-eight (Yorkshire x Landrace) pigs with equal numbers of each sex from four litters were weaned at 28 days of age. The 28 pigs were assigned on the basis of weaning weight, sex and litter to one of seven treatment groups as shown in Table III.1.

Pigs were fed ad libitum for three days and fasted for two days (Table III.2). On the second day of fast, 12 pigs were surgically fitted with simple nylon T-cannulas at the terminal ileum, approximately 5 cm. from the ileocecal junction. The surgical procedures used were similar to those reported by Sauer et al. (1983) for duodenal cannulation, except that the cannulas were exteriorized behind the ribs close to the ileal cannulation site. The T-cannulas were a modification of the cannulas described by McBride et al. (1983). Cannula dimensions and surgical recovery are discussed in Appendix 5..

After surgery these animals were placed under heat lamps for three days in their experimental pens. From day 6 to day 10 after weaning, all pigs were fed small increments of feed twice per day as indicated in Table III.2. Starting on day 11, the pigs were fed ad libitum or at 3% of body weight. Periods II and III differed only in the amount of diet fed to the restricted groups (3.5% and 4.5% of body weight at the start of the respective periods). On day 8 of each of the three periods, feces were collected from all animals. On day 9 and 10 of each of these periods, digesta were collected from the cannulated pigs.

Table III.1 Experimental design.

Feed intake	Treatment groups	Diet	Number of pigs
Restricted	Cannulated	Control	4
Restricted	Cannulated	4% fat	4
Restricted	Cannulated	8% fat	4
Restricted	Non-cannulated	Control	4
Restricted	Non-cannulated	8% fat	4
Ad libitum	Non-cannulated	Control	4
Ad libitum	Non-cannulated	8% fat	4

Table III.2 Feeding and sample collection regimen for the pigs.

DAYS AFTER WEANING	FEEDING LEVEL	PROCEDURES
PRE-TEST		
1-3	Ad. Libitum	
4	Fast	
5	Fast	12 pigs cannulated
6	50 g.	Surgical recovery
7	80 g.	
8	100 g.	
9	130 g.	
10	160 g.	
PERIOD I[1] (10 days)		
11-17 (7 days)	3% of body weight or	Feed adjustment
18 (1 day)	Ad. libitum	Fecal collection
19-20 (2 days)		Digesta collection[2]

1 Periods II and III were identical except that restricted fed pigs were fed at levels of 3.5 or 4.5% of body weight respectively.
2 Collected in two hour intervals.

Total feces and digesta were collected between 8:00am and 8:00pm on each day. Digesta were collected at two hour intervals. On the second day of digesta collection, the two hour collections were made in the alternate two hours to those of the previous day. Feces and digesta were collected in plastic bags, weighed and immediately frozen prior to further treatment.

The formulation and composition of the experimental diets are shown in Table III.3. The control diet was a standard starter diet based on barley, wheat, oat groats and soybean meal. The second and third diets contained the same feedstuffs in different proportions plus 4 or 8% mixed fat, respectively. The lipid classes and fatty acid composition of the mixed fats are presented in Table III.4.

All diets were formulated to contain the same protein and other nutrient to digestible energy (DE) ratio. To achieve this with practical diets, the proportions of protein derived from cereals and soybean meal varied between diets. With the exception of DE in the control diet, all diets met or exceeded the nutrient requirement recommendations of the National Academy of Sciences -National Research Council (NAS-NRC) (1979) for 5-20 kg. pigs. Dysprosium ($DyCl_3$-$6H_2O$) was added at 10 ppm. to the three diets as a marker to study apparent nutrient digestibility according to procedures described by Kennelly et al. (1980).

Table III.3 Formulation and composition of starter diets.

DIET	Control	4% mixed fat	8% mixed fat
Ingredients (%)			
Mixed fat[1]	0.00	4.00	8.00
Barley	24.76	20.84	16.89
Wheat	29.71	25.00	20.27
Oat groats	15.00	15.00	15.00
Soybean meal	26.39	30.84	35.39
Calcium Phosphate	1.50	1.58	1.64
Ground limestone	1.00	1.05	1.10
Iodized salt	0.40	0.42	0.44
Starter premix [2]	1.00	1.05	1.10
L-lysine (HCl)	0.242	0.220	0.160
Composition, analyzed (%)			
Crude protein	20.5	21.2	22.5
Lysine	1.27	1.30	1.48
Ether extract	2.8	6.6	10.4
Composition, calculated			
Digestible energy, Mcal/kg	3.37	3.54	3.70
Protein/energy ratio, g/Mcal	60.9	59.8	60.8

1 Trade name " Tallow " .

2 Starter premix provided the following per kilogram of the control diet :
5000 IU vitamin A, 700 IU vitamin D_3, 22 IU vitamin E, 22 mg riboflavin, 45 mg niacin, 23 mg calcium pantothenate, 30 ug vitamin B_{12}, 500 mg choline, .2 mg biotin, 120 mg Zn, 12 mg Cu, 150 mg Fe, .1 mg Se and 12 mg Mn. The fat supplemented diets contained 1.05 or 1.10 times this level of vitamins and minerals per kilogram respectively.

Table III.4 Composition of mixed fat.

Lipid classes	%	Fatty acids		%
Triglycerides	85.0	Myristic	(14:0)[1]	1.28
Diglycerides	2.5	Tetradecanoleic	(14:1)	0.30
Monoglycerides+ Phospholipids	2.9	Pentadecanoic	(15:0)	0.16
Free fatty acids	4.9	Palmitic	(16:0)	18.41
Choline	4.7	Palmitoleic	(16:1)	2.36
Total	100.0	Heptadecanoic	(17:0)	0.48
		Stearic	(18:0)	11.38
		Oleic	(18:1)	56.31
		Linoleic	(18:2)	6.29
		Linolenic	(18:3)	0.82
		Arachidonic	(20.0)	1.14
			Others	1.09
			Total	100.02

1 Chain length: number of double bonds.

Animals were individually housed in raised slotted floored pens. The environmental temperature was maintained at approximately 27 °C throughout the experiment. Water was available ad libitum.

The freeze-dried samples were ground with a Wiley mill. Ether extract was analyzed according to the Stoldt method (Stoldt, 1952 and 1957) which consists of boiling the sample in 6N HCl and rinsing it thoroughly with water before ether extraction. Crude protein, ether extract and gross energy levels in the diets, feces and digesta were analyzed according to the Association of Analytical Chemists (AOAC 1981). Dysprosium was determined at the Slowpoke Reactor facilities at The University of Alberta by the procedure outlined by Kennelly et al. (1980). Amino acid composition of the diets were assayed following acid hydrolysis in 6N HCl (Blackburn, 1968), using a Beckman 121-MB amino acid analyzer. The amino acid analyses of the diets are shown in Appendix 4. The mixed fat was analyzed for lipid classes with an Iatroscan TH-10 Mark II Analyzer (T.M.A. Scientific Supply, Mississauga. Ont.). Each pentane dissolved lipid sample (1-2 uL) was spotted on a chromatorod, developed for 45 min. in a methylene chloride-chloroform-acetic acid-methanol (98:8:0.5:0.2) solvent system and scanned on the Iatroscan Analyzer to determine the relative amount of each lipid class (Newman, 1978). Determination of the fatty acid composition of the mixed fat was determined following the method of Morrison and Smith (1964) as outlined by Thacker (1981).

STATISTICAL ANALYSES

The data were analyzed according to Steel and Torrie (1980) using analysis of variance with treatments being a between-subject factor and time being a repeated measure on each animal. Where appropriate, treatment means were tested for significance using Student-Neuman Keuls (SNK) multiple range test when preceded by a significant F-test.

RESULTS

The pigs maintained a positive weight gain throughout the collection periods regardless of their feeding regimen (Table III.5).

The apparent ileal ether extract digestibility of the pigs increased (P<0.001) with the increasing levels of mixed fat added to the diet (Table III.6). Apparent energy, dry matter and crude protein digestibilities were lower for the pigs fed the 4 % mixed fat diet than for the pigs fed the control or 8 % mixed fat diet. Apparent ether extract digestibility determined by ileal collection were higher (P<0.001) than those determined by fecal collection . In contrast, apparent energy, dry matter and crude protein digestibilities based on ileal collection were lower (P<0.001) than equivalent digestibilities based on fecal collection.

Apparent fecal ether extract digestibility for all pigs improved significantly (P<0.001) when 8% mixed fat was

Table III.5 Average daily gain of experimental pigs.

Level of feeding (% of body weight)			3%	3.5%	4.5%
Period			I	II	III
Duration of test, days			10	10	10
Feed intake	Treatment group	Diet	Average daily gain (g.)		
Restricted	Cannulated	Control	130 (19)*	158 (23)	305 (16)
Restricted	Cannulated	4% fat	125 (19)	148 (20)	250 (52)
Restricted	Cannulated	8% fat	143 (7)	190 (11)	345 (17)
Restricted	Non-cannulated	Control	123 (15)	133 (27)	253 (24)
Restricted	Non-cannulated	8% fat	153 (24)	190 (33)	380 (57)
Ad libitum	Non-cannulated	Control	443 (44)	580 (45)	613 (80)
Ad libitum	Non-cannulated	8% fat	387 (19)	627 (55)	748 (68)

* Number in brackets is ± standard error of the mean.

Table III.6 Effect of added fat to the diet and method of collection on apparent digestibility coefficients.

	Apparent digestibilities			
	Ether extract	Energy	Dry matter	Crude protein
Added fat level, %	***[1]	**	**	*
0.0	54.2 a	81.7 a	78.2 a	80.8 a
4.0	63.4 b	73.2 b	71.7 b	76.4 b
8.0	74.0 c	79.1 a	76.0 a	81.6 a
S.E.	2.0	1.4	1.0	1.2
Method of collection	***	***	***	***
Ileal	68.9	72.5	67.1	75.3
Fecal	58.8	83.5	83.4	83.9
S.E.	0.8	1.1	0.4	0.3

1 Within treatment and column asterisks indicate level of significant difference between means.

* $P < 0.05$

** $P < 0.005$

*** $P < 0.001$

a, b, c Means followed by different letters are significantly different within treatment and column at the level indicated by the asterisks.

Table III.7 Effects of dietary fat and level of feed intake on apparent fecal digestibility coefficients.

	Apparent fecal digestibilities of			
	Ether extract	Energy	Dry matter	Crude protein
Added fat level, %	***[1]	*	**	N.S.
0.0	48.6	85.4	84.5	82.2
8.0	69.3	83.0	82.8	83.0
S.E.	1.3	0.6	0.4	0.6
Level of feed intake	N.S.	N.S.	**	***
Restricted cannulated	59.3	85.0	85.0 a	85.7 a
Restricted non-cannulated	60.5	85.0	84.0 a	83.6 a
Ad libitum non-cannulated	57.1	82.6	82.0 b	78.6 b
S.E.	1.6	0.8	0.5	0.8

1 Within treatment and column N.S. or asterisk indicate level of significant difference between means.

N.S =no significant difference P>0.05.

* P<0.05

** P<0.01

*** P<0.001

a, b, c means followed by different letters are significant at the level indicated by the asterisks.

S.E. = ± standard error

added to the diet (Table III.7). Apparent fecal energy and dry matter digestibilities for all pigs were lower (P<0.05 and P<0.01 respectively) when fed a diet containing 8 % fat than with a diet that had no fat added. Apparent fecal crude protein digestibility was similar between both diets.

Level of feed intake (restricted cannulated, restricted non-cannulated and ad libitum non-cannulated) did not alter the apparent fecal ether extract and energy digestibilities. Apparent fecal dry matter and crude protein digestibilities were not significantly different between restricted cannulated and non-cannulated pigs, but the digestibilities of these two treatments were higher (P<0.01 and P<0.001 respectively) than the digestibilities of the ad libitum non-cannulated pigs.

DISCUSSION

The improved ileal or fecal apparent ether extract digestibilities by weaned pigs with level of added fat to the diet fed to cannulated (Table III.6) and all pigs (Table III.7), suggests that proportionally more of the added fat was digested than the fat present in the other feedstuffs. This result could be associated with the low fat content of the basal diet (Ewan, 1970) or to the fact that the lipids of the feedstuffs (except mixed fat) are bound or in non-triglyceride form (Leibbrandt et al. 1975).

Most previous determinations of lipid digestibility by weaned pigs ignored the capability of bacteria to alterthe products of digestion in the large intestine. Such bacterial fat synthesis reduces the apparent digestibility of ether extract derived by the fecal method when compared with those digestibilities estimated at the terminal ileum (Table III.6). Similar results have been noted for grower pigs (20 Kg. or more) (Just et al. 1980; and Close et al. 1984). These observations corroborate the suggestion of Carlson and Bayley (1968) that the terminal ileum is a better site than the end of the large intestine for the evaluation of fat utilization of weaner pigs.

Fecal digestibility values estimated for the pigs fed the diets with the highest fat levels in this experiment were lower than those reported in the literature for weaned pigs (Frobish et al. 1971; Eusebio et al. 1965; Leibbrandt et al. 1975; Lowry et al. 1958; and Sewell and Miller, 1965). This may be due to the fat extraction method employed in the present experiment, which makes free fatty acids in soap form extractable and decreases apparent fecal fat digestibility (Just et al. 1982; and Kuhla et al. 1983).

Increases in digestibility coefficients for energy, dry matter and crude protein from ileal vs fecal collection are a consequence of hindgut bacterial modifications and not availability to the pig. Energy is an exception because some of it may be absorbed from the large intestine as volatile fatty acid . Improvement in crude protein between ileal and fecal digestibility value for grower pigs has been reported by Sauer et al. (1979).

Cannulation of pigs did not affect performance (Table III.5) or ether extract and energy digestibility coefficients (Table III.7), indicating that the ileal ether extract digestibility is a valid parameter to evaluate the weaned pigs' ability to utilize added fat to the diet. Other experiments (Huisman et al. 1984; and Close et al.1984) have reported similar effects of cannulation on grower pigs.

In summary, the results of this experiment support the conclusion that the weaned pig is able to efficiently digest dietary fat when a constant protein to calorie ratio is maintained between diets.

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CHAPTER IV

SUMMARY

Performance and digestibility results of these experiments suggest that the weanling pig is able to utilize efficiently added fat to the diet .

In the first experiment, feeding pigs a control diet compared with an 8% mixed fat diet for seven days after weaning resulted in a nonsignificant improvement ($P>0.05$) in feed intake, weight gain, feed to gain ratio, energy intake and energy required per unit gain. Energy required per unit increase in empty body weight (EBW) gain for the control group of pigs was three times larger than that for pigs fed the 8% fat diet.

At 20 kg. liveweight, pigs fed the control diet and the fat supplemented diet had similar average daily feed intakes. Total feed intake for pigs fed the fat supplemented diet was lower ($P<0.05$) than that of pigs fed the control diet and it took the pigs fed the fat supplemented diet fewer days ($P<0.07$) to reach 20 kg.. Average daily gain was greater ($P<0.05$) and feed to gain ratio was lower ($P<0.001$) for the pigs fed the mixed fat diet compared with pigs fed the control diet. The energy required per unit of gain was similar for both treatment groups up to 20 kg. liveweight.

Empty body weight of pigs slaughtered at weaning was not significantly different ($P>0.05$) from that of pigs

slaughtered after seven days on test. However, gut fill of pigs slaughtered seven days after weaning was significantly greater (P<0.01) than that of pigs slaughtered at weaning. Pigs fed the control diet for seven days after weaning had a slightly greater (P<0.07) gut fill than pigs fed the mixed fat diet.

The calculated empty body weight gain (0.12 kg.) of the pigs fed the control diet for seven days after weaning was accounted for by a gain of 0.24 kg. of water, 0.06 kg. protein, 0.01 kg. ash and a loss of 0.21 kg. of ether extract. In contrast, the empty body gain (0.33 kg.) of the pigs fed the 8% mixed fat diet was accounted for by a gain of 0.34 kg. of water, 0.05 kg. protein, 0.01 kg. ash and a loss of 0.07 kg. of ether extract. Thus, pigs fed the fat supplemented diets lost considerably less fat but otherwise were similar in body composition to those fed the control diet.

Percent dry matter, crude protein and ether extract increased significantly (P<0.01) from weaning to seven days after weaning. Carcass composition at seven days after weaning and at 20 kg. were similar (P>0.05). Ash and unaccountable losses did not vary significantly (P>0.05) from weaning to seven days after weaning or to 20 kg. liveweight. Empty body composition of pigs fed the control diet or the mixed fat diet were not significantly different (P>0.05) after seven days on test or at 20 kg. liveweight.

In the second experiment, the apparent ether extract digestibility of ileal cannulated pigs increased ($P<0.001$) with the increasing levels of mixed fat added to the diet. Apparent energy, dry matter and crude protein digestibilities were lower for the pigs fed the 4 % mixed fat diet than for the pigs fed the control or 8 % mixed fat diet. Apparent ether extract digestibility determined by ileal collection were higher ($P<0.001$) than those determined by fecal collection . In contrast, apparent energy, dry matter and crude protein digestibilities based on ileal collection was lower ($P<0.001$) than equivalent digestibilities based on fecal collection.

Apparent fecal ether extract digestibility for all pigs improved significantly ($P<0.001$) when 8% mixed fat was added to the diet. Apparent fecal energy and dry matter digestibilities for all pigs were lower ($P\leq0.05$ and $P<0.01$ respectively) when fed a diet containing 8 % fat than with a diet that had no fat added. Apparent fecal crude protein digestibility was similar between both diets.

Level of feed intake (restricted cannulated, restricted non-cannulated and ad libitum non-cannulated) did not alter the apparent fecal ether extract and energy digestibilities. Apparent fecal dry matter and crude protein digestibilities were not significantly different between restricted cannulated and non-cannulated pigs, but the digestibilities of these two treatments were higher ($P<0.01$ and $P<0.001$ respectively) than the digestibilities of the ad libitum non-cannulated pigs.

A word of caution is warranted at this point. The performance improvements due to supplementing fat in the diet may not necessarily offset the higher price of the diet as can be observed in Appendix 3.

Appendix 1. Essential amino acid analysis (%) of diets from chapter II and essential amino requirements of (%) 5-10 kg. piglets.

	Control	8% fat	NAS-NRC (1979) Requirements
Lysine	1.24	1.50	.95
Methionine + cystine[1]	.57(.33)[2]	.58(.31)	.56
Threonine	.81	.94	.56
Histidine	.56	.63	.23
Isoleucine	.89	.95	.63
Leucine	1.55	1.75	.75
Phenylalanine +tyrosine	1.75	1.90	.88
Valine	1.01	1.04	.63
Arginine	1.33	1.50	.25

1 The hydrolytic procedure of Blackburn (1968) used for protein digestion degrades methionine and cystine when compared with methionine and cystine determination with perfomic acid (Funk and Shires unpublished data). Therefore, the values obtained for the sulfur-containing amino acids are lower than the actual dietary values. Tryptophan was not assayed.

2 Methionine only, in brackets.

Appendix 2. Statistics for Table II.7 Chapter II.

Treatment group	Dietary treatment	1	2	3	4	5	6	7	8
At weaning	None	4	2	2	2	2	0	0	0
Seven days after weaning	Control	-1	-1	0	-1	0	-1	0	1
	8% fat	-1	-1	0	0	-1	1	0	1
At 20 kg. liveweight	Control	-1	0	-1	-1	0	0	1	-1
	8% fat	-1	0	-1	0	-1	0	-1	-1
EMPTY BODY COMPOSITIONS DM[1]	P[5] <	NT	0.000	NT	NT	NT	NS	NT	NT
	S.E.		0.49				0.57		
CP[2]	P[5] <	0.01	0.01	0.01	0.01	0.01	NS	NS	NS
	S.E.	1.28	1.38	1.28	1.32	1.46			
EE[3]	P[5] <	0.01	0.01	0.01	0.01	0.01	0.05	NS	NS
	S.E.	1.42	1.57	1.45	1.44	1.64	1.81		
ASH+UN[4]	P[5]	NS	NS	NS	NS	NS	NS	NS	NS

1 DM=dry matter.
2 CP=crude protein.
3 EE=ether extract.
4 UN=unaccountable.
5 P=probability.
NT=not tested.
S.E.= ± standard error of the difference .

Appendix 3. Cost analyses of pig starter diets of Chapter II.

	Dietary ingredients $/Kg.[1]	Control		8% Fat	
		Composition,%	$/kg.	Composition,%	$/kg.
Ingredients (%)					
Mixed fat [2]	0.893	0.00	-----	8.20	0.073
Barley	0.130	20.07	0.026	19.51	0.025
Wheat	0.165	34.79	0.057	20.00	0.033
Oat Groats	0.317	19.21	0.061	15.00	0.048
Soybean meal	0.310	21.81	0.068	32.40	0.100
Calcium Phosphate	0.535	1.50	0.008	1.70	0.009
Ground limestone	0.090	1.00	0.001	1.20	0.001
Iodized salt	0.220	0.40	0.001	0.50	0.001
Starter premix	0.725	1.00	0.007	1.20	0.009
L-lysine (HCl)	4.420	0.214	0.010	0.284	0.013
TOTAL COST, $/KG.			0.239		0.312
COST/ Mcal. DE, $			0.071		0.084
COST/ kg. of GAIN, $			0.37		0.44

1 Cost for diet ingredients were supplied by:
Erika Weltzien (valid for June 3-7, 1985)
Nutrition Department
Shur-gain, Edmonton, Alta.

2 Trade name "Tallow"

Appendix 4. Essential amino acid analysis (%) of diets from chapter III and essential amino requirements (%) for 5-10 kg. piglets.

	Control	4% mixed fat	8% mixed fat	NAS-NRC (1979) Requirements.
Lysine	1.27	1.37	1.43	.95
Methionine + cystine[1]	.49(.27)[2]	.51(.29)	.60(.32)	.56
Threonine	.78	.87	.96	.56
Histidine	.56	.56	.63	.23
Isoleucine	.82	.90	.97	.63
Leucine	1.47	1.56	1.69	.75
Phenylalanine + tyrosine	1.46	1.56	1.80	.88
Valine	.89	.95	1.09	.63
Arginine	1.29	1.38	1.50	.25

1 The hydrolytic procedure of Blackburn (1968) used for protein digestion degrades methionine and cystine when compared with methionine and cystine determination with perfomic acid (Funk and Shires unpublished data). Therefore, the values obtained for the sulfur-containing amino acids are lower than the actual dietary values. Tryptophan was not assayed.

2 Methionine only, in brackets.

Appendix 5.

A NOTE ON WEANLING PIG CANNULATION.

A cannula was designed to be 75% of the standard size used for pigs from 25 to 90 kg. at the Department of Animal Science, The University of Alberta. The final Delrin nylon intestinal cannula and the dimensions of associated components are shown in Figure App.-5.1. Cannulae were surgically fitted to two four-week old pigs for a one month period. The diameter of the external cannula ring was increased from the first cannula fitted to the second one, to reduce skin irritation. These pigs were utilized to check cannula size in relation to the pigs' digestive tract, the surgical techniques, the pigs' response to cannulation, the pigs' recovery from surgery and the post -surgical feeding regimen. The surgical techniques were similar to those described in Chapter III. Both pigs recovered well from surgery. The treatment and feeding after surgery were similar to those outlined in Chapter III.

Seven days after surgery ileal samples were collected successfully from both pigs. Several more samples were collected at a later date with the same success. Three weeks later the pigs were stunned using a captive bolt pistol and bled. Necropsy showed that in both pigs the cannulae were well placed at the terminal ileum and the small intestine had healed and adhered well to the cannula

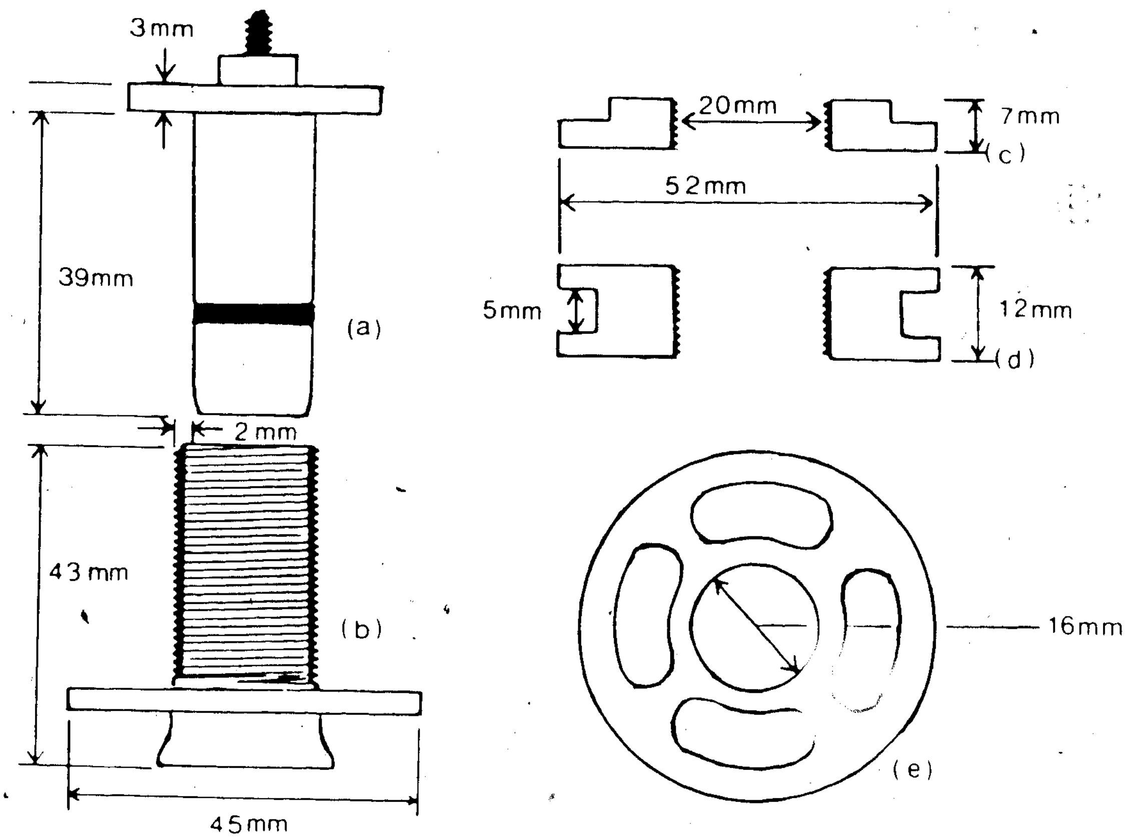

Figure App.-5.1 Nylon intestinal cannula and associated components:
(a) side view of stopper,
(b) side view of threaded barrel,
(c) side view of external ring,
(d) side view of collection ring, and
(e) top view of collection ring.

and the abdominal wall.

Finally, the 12 four week old experimental pigs were cannulated and treated as described in Chapter III. Cannulation did not affect the pigs' growth and fecal digestibilities during the experimental period (Chapter III). Cannulated pigs lost less weight in the six days after surgery than did the non-cannulated pigs that were treated the same over the same period (Table App.-5.1). The use of heat lamps for the cannulated pigs could be responsible for this effect.

For the pigs fed restricted levels of feed, feed intake was restricted on a percentage of body weight basis at the beginning of each collection period . Therefore these pigs tended to gain more weight at the start of a collection period but later in the period daily gain decreased. Because the pigs had lost weight during the pretreatment period, the assigned feed intake to the restricted fed pigs towards the end of all collection periods appeared to be too low as judged by the hunger of the pigs at the time of feeding. Intake also appeared to be too low for the first and second collection periods as judged by the dullness of the pigs' hair coat.

There was very little digesta leakage between the abdominal wall and the cannulae throughout the experiment. It was greater at the beginning of each of the collection periods due to the increased feed intake. The area of skin around the cannula was cleaned daily with water and paper

Table App-5.1 Average gain (g.) of experimental pigs prior to collection periods[1]

Level of feeding Days on regimen			Ad libitum 3	Fast + recovery 7
Feed intake	Treatment group	Diet	Average gain (g.)	
Restricted	Cannulated	Control	300 (183)[2]	-250 (173)
Restricted	Cannulated	4% fat	75 (320)	- 75 (386)
Restricted	Cannulated	8% fat	100 (356)	-100 (316)
Restricted	Non-cannulated	Control	250 (341)	-625 (287)
Restricted	Non-cannulated	8% fat	200 (183)	-250 (173)
Ad libitum	Non-cannulated	Control	225 (263)	-450 (238)
Ad libitum	Non-cannulated	8% fat	225 (320)	-400 (163)

1 Experimental design was described in Chapter III.
2 Number in brackets are ± standard deviations of the mean

towels and coated with a cream containing zinc (Udderfax, Pfizzer).

The decreasing average daily gain per collection period and increased leakage at the beginning of each collection period could have been avoided by weighing the pigs daily and feeding each pig a daily adjusted percentage of their body weight. The size of the pigs would have allowed this adjustment as the pigs needed to be handled daily anyway to clean around the cannula.

Table App-5.2 shows the mean and standard deviation of digesta weight and dry matter, and fecal dry matter collected from cannulated pigs fed three different diets. Higher water content in digesta and feces was associated with increased level of fat addition, but differences were not significant (P>0.05).

The skin around the cannula of three pigs regressed towards the end of the experimental trial. This could have been avoided by increasing the diameter of the peritoneal ring and by reducing the pressure of the external ring against the skin. After the experiment the cannulae were removed from these three pigs. The pigs were continued on a restricted feeding regimen until the wound closed and healed and were then with finished with ad libitum feeding. From one of the remaining cannulated pigs digesta was collected at about 40 kg., suggesting that the small cannula could be used up to that weight. However, at this weight, the threaded barrel of the cannula was too short to

Table App.-5.2 Mean digesta weight and dry matter, and fecal dry matter data collected from cannulated pigs.[1]

Level of feeding (% of body weight)	3%	3.5%	4.5%
Period	I	II	III
Diet		Digesta [illegible]ht g. [2]	
Control	343.9 (82.6)[3]	535.5 (82.2)	552.4 (66.1)
4% fat	372.6 (60.0)	536.5 (59.5)	695.1 (206.2)
8% fat	385.[illegible] (67.6)	529.2 (91.3)	671.4 (98.5)
		Digesta dry matter, %	
Control	8.81 (0.54)	9.56 (0.90)	10.44 (0.93)
4% fat	9.14 (0.77)	9.67 (0.57)	10.26 (1.21)
8% fat	10.04 (0.54)	9.96 (0.59)	10.81 (2.25)
		Fecal dry matter, %	
Control	23.31 (6.07)	29.56 (5.99)	28.56 (3.24)
4% fat	28.82 (1.84)	30.76 (3.56)	27.80 (2.81)
8% fat	31.12 (2.01)	34.34 (4.86)	33.23 (2.47)

1 Experimental design was described in Chapter III.
2 Digesta was collected for two days in three alternate two hour collections.
3 Number in brackets are ± standard deviations of the mean.

keep the external ring in place and to relieve pressure on the skin.

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