

Effect of dietary fiber level and source of fat on faecal excretion, digestive performance and level of serum cholesterol in weaned piglet

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RESUMO

Para se estudar o efeito do aumento do teor de glúcidos parietais em função do grau de insaturação da gordura do regime, sobre a digestibilidade total aparente (CUD_T), a composição da excreção fecal e o metabolismo lipídico dos leitões, constituíram-se 6 blocos de 4 animais de raça Large White, desmamados aos 21 dias de idade. Os leitões de cada bloco, provenientes da mesma ninhada, foram colocados em gaiolas metabólicas individuais e receberam em alimentação igualizada um dos quatro regimes experimentais. Os regimes foram formulados para dois níveis de fibra (10 ou 16% NDF) e duas fontes de gordura, de acordo com um arranjo factorial 2×2 . A sêmea de trigo foi utilizada nos níveis de 0 ou de 15% e o sebo ou o azeite no nível de 5% no fabrico dos regimes experimentais. Após um período de adaptação aos regimes, o CUD_T foi medido durante dois períodos consecutivos de 7 dias. No final desta fase, os leitões foram submetidos a uma intervenção cirúrgica para colocação de um cateter na veia jugular. As recolhas de sangue foram praticadas com os leitões em jejum e durante 5 horas após a ingestão de uma quantidade controlada de alimento. No final do ensaio os leitões foram abatidos com recolha do pâncreas e da mucosa intestinal para análise da actividade das enzimas digestivas.

A inclusão de 15% de sêmea de trigo baixou em 10 unidades percentuais o CUD_T dos lípidos, aumentando em 50% a excreção diária fecal de gordura. Apenas no caso dos regimes à base de azeite, a inclusão de sêmea de trigo aumentou respectivamente o CUD_T do azoto e do NDF em 5 e 12 unidades percentuais. A digestibilidade aparente dos lípidos foi de 73,8 e de 65,8 com os regimes à base de azeite e de sebo respectivamente ($P < 0,05$). O aumento do teor de fibra do regime aumentou ($P < 0,05$) em 11 e 52% a excreção fecal de matéria seca e de NDF. A excreção fecal de gordura, expressa em $g \cdot kg^{-1}$ de peso vivo, aumentou em

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40% com a inclusão de sebo no regime. O teor pós-prandial de ureia plasmática aumentou em cerca de 45% com a inclusão de 15% de sênea de trigo no regime. Finalmente, os níveis sanguíneos de triglicéridos, de colesterol e de colesterol associado às lipoproteínas mostraram ser independentes da composição dos regimes experimentais.

Palavras-chave: leitão, fibra, lípidos, enzimas digestivas, colesterol sanguíneo.

RÉSUMÉ

Vingt quatre porcelets male de race Large White, sevrés à 21 jours, ont été répartis en 6 blocs de 4 animaux. Les porcelets de chaque bloc ont reçu un des quatre régimes expérimentaux pour étudier l'effet du taux de fibre (10 ou 16% de NDF) et de la nature des lipides sur les performances digestives et le métabolisme des lipides. Le son de blé a été incorporé à 0 ou 15% et le suif ou l'huile d'olive à 5% dans le régimes. La digestibilité totale apparente (CUD_T) des composants du régime a été mesurée pendant deux périodes consécutives de 7 jours. Après cette période les porcelets ont été opérés (cathétérisation jugulaire) permettant ainsi un prélèvement sanguin à jeun et pendant 5 heures après le repas. Deux jours après les porcelets ont été abattus avec prélèvement du pancréas et de la muqueuse intestinale. L'inclusion de 15% de son de blé a réduit de 10 points percentuels le CUD_T des lipides en augmentant de 50% l'excrétion fécale journalière de lipides. De plus, le son de blé en association à l'huile d'olive a augmenté de 5 et de 12 points percentuels le CUD_T de l'azote et du NDF, respectivement. L'inclusion de glucides pariétaux dans le régime a augmenté le poids frais des fèces et l'excrétion fécale de matière sèche et de NDF de 23, 11 et 52% respectivement. Le taux de fibre et la nature des lipides du régime ont été sans effet sur l'activité des enzymes digestives du pancréas et de la muqueuse intestinale. Le son de blé a augmenté de 45% le niveau postprandial d'urée mais n'a pas changé les taux sanguins de triglycérides, de cholestérol et de LDL- et HDL-cholestérol.

Mots-clés: Porcelet, fibre, lipides, enzymes digestives, cholestérol.

SYNOPSIS

Twenty four male piglets weaned at 21 days of age were randomly assigned by blocks to four treatments in order to study the effect of two levels of fiber (10 or 16% NDF) and two sources of fat on the digestive performances and lipid metabolism. Diets contained either 0 or 15% wheat bran and 5% of either tallow or olive oil. Total tract apparent digestibility (TTAD) of dietary components including fat and fiber were measured during two successive periods of 7 days. At the end of the experiment, animals were fitted with a jugular catheter for blood sampling prior and after a test meal. Two days later they were slaughtered to obtain samples of the pancreas and the mucous of the small intestine. The addition of 15% of wheat bran decreased by 10 percentage units the TTAD of fat, increasing by 50% the daily average faecal excretion of fat. Moreover, it increased by 5 to 12 percentage units the TTAD of nitrogen and NDF, respectively, only in the case of an addition of olive oil to the diet. The addition of dietary fiber increased the daily excretion of fresh weight of faeces, dry matter and NDF by 23, 11 and 52%, respectively and did not significantly increase the total activity of pancreatic and intestinal enzymes. The postprandial level of serum urea was increased by 45% on average but the level of triglycerides, total cholesterol or cholesterol binded to lipoproteins was not affected by the level of dietary fiber.

Keywords: piglet, fiber, lipids, digestive enzymes, serum cholesterol.

1. Introduction

Wheat bran is a valuable source of cell wall constituents for early weaned piglets (Peiniau, 1984; Bengala Freire *et al.*, 1990). It is recommended to stimulate the development of their digestive tract. The gut microflora of a young piglet is able to digest up to 50% of the wheat non starch polysaccharides (NSP) (Longland *et al.*, 1994) depending on their level and their origin. Nevertheless, increasing the level of NSP in the diet may induce several drawbacks: it typically reduces the digestibility of dietary dry matter and fat (Stanogias and Pearce, 1985; Graham *et al.*, 1986). This effect is associated with a low digestive utilization of crude fiber (Drochner, 1984) and a more difficult access of digestive pancreatic enzymes to their substrates (Jeraci and Horvath, 1989). Opposite to that, it is thought that NSP may have beneficial physiological effects, namely they can reduce the incidence of diarrhea associated with the weaning process (Peiniau, 1984). However, the favourable effect of NSP on the digestive transit time reduced the putrid fermentations in the large bowel (Fonty and Gouet 1989). In addition NSP added to the feed increased both the fresh and the dry weight of faeces in pig (Bach Knudsen and Hansen, 1991), as well as in man (Stephen, 1989). The higher dry weight excreted is related to higher excretions of bile salts (Corring *et al.*, 1989) and endogenous lipids, and nitrogenous compounds (Anugwa *et al.*, 1989). According to Low (1989), both the increase in dietary NSP and the substitution of cereal NSP for purified cellulose stimulated pancreatic activity, perhaps by stimulating the secretion of secretin. From a metabolic point of view, the cholesterol-lowering effect of gel-forming dietary fibers was observed in man (Stephen, 1989). Dietary fiber increased also cholesterol excretion in the faeces of pig (Corring *et al.*, 1989), and man (Judd and Truswell, 1981), with a beneficial effect on lowering blood cholesterol level. The addition of NSP to the feed may also reduce the post-feeding peaks of glucose and insulin (Bengala Freire *et al.*, 1990), thereby possibly affecting feed intake of the piglet.

Combining energy rich materials, such as fats, with fibrous ingredients, has been usual recommended when formulating post-weaning diets for piglets. However, the energy value of fats depends on their origin: vegetable fats are more easily digested by the young piglet than animal fats (Braude and Newport, 1973), explaining a lower energetic value for the latter (Just, 1982). It is also known that an increase in the lipid content of the diet stimulates pancreatic lipase activity (Corring *et al.*, 1989), but it is still not clear whether this activity is affected by the source of fat. According to Reis de Souza (1992)

lipase activity is not affected when beef tallow or rape seed oil is added to the diet, but the effect of olive oil is not known. Animal fats, which contain saturated fatty acids, are usually considered to increase serum cholesterol levels in man (Sethi *et al.*, 1993), but it has never been investigated in the pig. Furthermore phytosterols present in certain oils reduced the absorption of cholesterol, and the level of serum cholesterol in the rat (Mourot and Debry, 1991; Laraki *et al.*, 1993). In general, data of literature concerned only total cholesterol instead of cholesterol bounded to high density lipoproteins (HDL) or low density lipoproteins (LDL) (Beynen *et al.*, 1990), so information is lacking on the effect of NSP and fat source on the metabolism of cholesterol. The aim of the present experiment is to study the effects of a single source of fiber, wheat bran, associated with a saturated or an unsaturated fat, on faecal digestibility, faecal excretion and blood metabolites in the weaned piglet.

2. Materials and methods

2.1. Animals and diets

Successive blocks of 4 Large White piglets weaned at 3 weeks of age, were used in a 2×2 factorial design including 6 replicates. Within each block, piglets originated from the same litter, equalized for sex and liveweight, were placed in individual metabolic cages in a room regulated at constant temperature of $25 \pm 2^\circ\text{C}$, and were offered one of the four diets (Table 1). They contained the same gross energy, crude protein, and essential amino acid levels, and were distributed as pellets of 3 mm of diameter on a pair-feeding basis within a block.

After a preexperimental period of 7 days, faeces were collected twice a day during two successive periods of 7 days and stored at 4°C . Dry matter was analyzed by drying at 105°C , ash by incineration at 550°C . Nitrogen in feed and faeces was analyzed according to the Kjeldahl method, crude fat by extraction with petrol ether in a Soxtec apparatus (Tecator 1043, Höögönas, Sweden) after a one hour-acid hydrolysis with 3N HCl in a Soxtec apparatus (Tecator 1048, Höögönas, Sweden). Energy was measured with a adiabatic calorimeter (Parr, Moline Ill., USA). The cell wall constituents were analyzed according to Van Soest *et al.* (1991), for NDF and ADF determination in a Fibertec apparatus (Tecator 1020, Höögönas, Sweder).

Table 1

Composition of the weaning diets as $g.kg^{-1}$
and chemical analysis as percentage of dry matter

Source of fat:	Olive oil		Beef tallow	
	Wheat bran:	-	+	-
Ingredient composition				
Wheat	580	460	580	460
Wheat bran	—	150	—	150
Soybean meal	290	290	290	290
Olive oil	50	50	—	—
Beef tallow	—	—	50	50
L-Lysine HCl	4	4	4	4
DL-Methionine	1	1	1	1
CaCO ₃	10	18	10	18
CaHPO ₄ , 2H ₂ O	25	17	25	17
Vitamin trace mineral mix ⁽¹⁾	10	10	10	10
Bentonite	30	—	30	—
Chemical composition (% DM)				
Dry matter (%)	89.6	90.4	90.7	90.5
Crude protein (Nx6.25)	24.1	24.9	23.6	24.6
Fat	7.3	7.4	7.4	8.4
NDF	10.1	16.6	10.8	15.4
ADF	3.24	3.43	2.54	3.73
ADL	1.25	1.53	1.45	1.26
Gross Energy (Mj/kg DM)	18.90	18.92	18.94	18.97
Digestible Energy (Mj/kg DM) ⁽²⁾	15.04	15.10	15.64	14.97
Cholesterol (mg/kg DM) ⁽²⁾	—	—	55.1	55.3

⁽¹⁾ Mineral and vitamin mixture supplied per kg of diet: vit. A: 5400 IU; vit. D₃: 1080 IU; vit. E: 7.5 mg; vit. K₃: 0.725 mg; vit. B₁: 0.2 mg; vit. B₂: 1.125 mg; vit. B₆: 0.0650 mg; Biotine: 0.01 mg; Folic acid: 0.175; Nicotinic acid: 7.75 mg; Pantothenic acid: 7.75 mg; Fe: 47.5; Cu: 10 mg; Mn: 21.5 mg; Zn: 50.0 mg; Mg: 50.0 mg; I: 0.195 mg; Co: 10 mg; Se: 0.055 mg; Choline: 500 mg.

⁽²⁾ Calculated values on the basis of experimental values and average content of dietary tallow, respectively.

2.2. Analysis of blood parameters and enzyme activities

When piglets were 42 days old, a 2 mm/1 mm diameter silicon catheter was introduced into the jugular vein, under general anesthesia. Under this procedure, blood can be collected two days after surgery, as animals showed no signs of trauma or disturbance in feed intake (Bengala Freire *et al.*, 1990). Blood collections of 5 ml samples at each time were made under heparin, during a period of 5 hours prior and after a 90 mn meal: at 30 mn, 60 mn, 90 mn, 3 h, 4 h and 5 h after the meal. A fasting period of 16 h, was observed prior to the experimental meal. At 49 days of age after a similar fasting period, piglets were slaughtered, and their livers, pancreas, and different parts of the digestive tract were weighed prior and after emptying. The pancreas was then placed in liquid nitrogen and stored at -70°C to be analyzed for protein and major digestive enzymes. The mucus of the small intestine was also sampled by scrapping before analysis for their protein content and the total and the specific activities of maltase and sucrase.

Blood metabolites were measured by colorimetry on serum samples prepared by centrifugation at 5.000 rpm at 4°C during 10 mn. Glucose was determined by the glucose oxidase-peroxidase method (Biomérieux, ref. 61271), urea by the Berthelot reaction to urease (Boehringer, ref. 777510), and triglycerides after lipase, glycerokinase, glycerol-3-phosphate oxidase and peroxidase reaction (Biomérieux, ref. 61236). Cholesterol was measured with cholesterol esterase, cholesterol oxidase and peroxidase (Biomérieux, ref. 61224), LDL-cholesterol by LDL precipitation followed by solubilization of cholesterol and its enzymatic determination, and HDL-cholesterol by LDL elimination and enzymatic determination of HDL bound to cholesterol (Biomérieux, ref. 61351). Lipase and chymotrypsin were determined by titration according to the methods of Rathelot *et al.* (1975) and Reboud *et al.* (1975), respectively. Amylase and trypsin were measured by spectrophotometry according to the methods of Métais and Bieth (1968) and Bergmeyer and Gawehn (1978), respectively. Intestinal disaccharidases were measured by colorimetry according to Dahlquist (1964). Data on the activity of enzymes were expressed as total international units for the pancreas and international units (IU) per g of mucus and specific activity was expressed as IU/mg tissue protein as described by Bengala Freire *et al.* (1990).

2.3. Statistical analysis

Average values were statistically compared for total tract apparent digestibility (TTAD) by analysis of variance applied to a $2 \times 2 \times 2$ factorial arrangement considering 2 levels of fiber (F), 2 sources of dietary fat (L), 2 collection periods (P) and the interactions between these factors. Values expressing the faecal excretion, the digestive organs weight and the activity of digestive enzymes were compared by analysis of variance according a 2×2 factorial design, for testing the effects of fiber level (F), fat source (L) and the interaction $F \times L$. Data on metabolic parameters in the serum were compared by analysis of variance according a split plot design considering block error as a residual variance to test the effect of the diet. The Duncan's multiple range test was used to compare means when the F value of the analysis of variance was significant ($P < 0.05$). All statistical analysis were performed using the GLM procedure of SAS (1989).

3. Results

3.1. Nutritional and digestive balance

In pair-feeding conditions, the introduction of 15% of wheat bran in the diet induced a 45% reduction of daily growth rate ($P < 0.01$) and a 40% increase in the feed conversion ratio ($P < 0.01$). Values for total tract apparent digestibility (TTAD) reported in Table 2 did not show a significant effect of the level of fiber or the source of fat on the digestibility of dry matter and energy. In addition wheat bran caused a reduction of about 10 percentage units ($P < 0.01$) in the digestibility of fat, irrespective of the source. The digestibility of fat was 8 percentage units higher for olive oil than for tallow based diets. Only in case of the diets containing olive oil, the inclusion of wheat bran improved ($P < 0.05$) the TTAD of NDF and hemicellulose expressed as NDF-ADF by 12 and 16 percentage units, respectively. The addition of wheat bran reduced significantly ($P < 0.05$) and markedly the digestibility of ADF. In the second period, the TTAD of energy and nitrogen were increased by 2 ($P < 0.05$) and 4 ($P < 0.01$) percentage units, respectively.

Table 2

Effect of dietary fiber level, fat source and period
on total tract apparent digestibility (TTAD) of dietary components

Source of fat:	Olive oil		Tallow		Period		Statistical Analysis				(1)	
	Wheat bran:	-	+	-	+	1	2	F	L	P	F × L	RSD
Feed intake (g.d ⁻¹)	293	302	319	305	276	340			**			48.0
Feed conversion ratio	2.12 ^{ab}	2.69 ^a	1.73 ^b	2.65 ^a	2.21	2.37	**					0.6
TTAD (%)												
Dry matter	79.2	79.1	82.6	79.2	79.1	80.9			•			3.5
Nitrogen	72.1 ^a	77.6 ^b	79.3 ^b	79.9 ^b	75.2	79.3	*	**	**	•		4.5
Fat	78.5 ^a	69.0 ^b	70.8 ^b	60.7 ^c	68.8	70.7	**	**				9.0
NDF	55.8 ^a	67.7 ^b	66.4 ^{bc}	62.3 ^c	62.1	64.0	*			**		6.0
ADF	50.1 ^a	27.6 ^b	46.2 ^a	34.0 ^b	38.6	40.3	**					11.2
NDF-ADF ⁽²⁾	59.0 ^a	76.5 ^b	73.1 ^{bc}	71.1 ^b	68.8	71.0	**	*		**		5.7
ADF-ADL ⁽²⁾	44.2 ^a	7.9 ^b	13.7 ^b	28.9 ^c	22.3	25.1	**	*		**		16.2
Energy	79.6	79.8	82.6	78.9	79.1	81.3			*	•		3.6

(1) Effects: *F*: Fiber level, *L*: Source of fat, *P*: Period, NS: Non significant,

•: $P < 0.10$, *: $P < 0.05$, **: $P < 0.01$;

Interactions: $F \times P$, $L \times P$ are not significant at $P < 0.05$;

RSD: Residual standard deviation of the model;

^{a, b, c}: for diets, means with the same letter in the same line are not significantly different ($n = 12$ in each treatment).

(2) NDF-ADF and ADF-ADL are hemicellulose and cellulose, respectively according to Van Soest *et al.* (1991).

Wheat bran increased by 8.5 and 2.5 g.kg⁻¹ liveweight the daily excretion of faeces expressed by both fresh weight and dry matter, respectively (Table 3). Fecal excretion of fat was almost doubled ($P < 0.01$), while the amount of NDF and ADF excreted in the faeces were increased by 50%, approximately. Moreover faecal excretion of fat, expressed in g.kg⁻¹ liveweight, was 40% higher ($P < 0.01$), and that of nitrogen 20% lower in diets supplemented with beef tallow, compared to olive oil.

Table 3

Effect of fiber level and source of fat on the daily faecal excretion expressed as average or in $g.kg^{-1}$ live weight

Source of fat:		Olive oil		Tallow		Statistical Analysis		(1)
Wheat bran:		-	+	-	+	F	L	RSD
Daily faecal excretion								
Fresh weight	(g)	140.9	174.1	133.3	162.5	•		35.5
	($g.kg^{-1}$)	22.9 ^{bc}	31.0 ^a	19.8 ^c	28.7 ^{ab}	**		5.8
Dry weight	(g)	51.7	57.6	50.2	56.5			11.5
	($g.kg^{-1}$)	8.3 ^{ab}	10.3 ^a	7.5 ^b	10.0 ^a	*		1.8
Fat	(g)	3.9 ^a	6.4 ^b	6.3 ^b	9.0 ^c	**	**	1.6
	($g.kg^{-1}$)	0.62 ^a	1.16 ^b	0.93 ^{ab}	1.61 ^c	**	**	0.27
Nitrogen	(g)	2.7	2.5	2.3	2.2			0.5
	($g.kg^{-1}$)	0.43 ^{ab}	0.45 ^a	0.34 ^b	0.38 ^{ab}		*	0.09
NDF	(g)	10.4 ^a	15.9 ^b	9.9 ^a	15.1 ^b	**		2.7
	($g.kg^{-1}$)	1.68 ^a	2.82 ^b	1.48 ^a	2.67 ^b	**		0.43
ADF	(g)	4.2 ^a	6.4 ^b	3.9 ^a	6.3 ^b	**		1.0
	($g.kg^{-1}$)	0.67 ^a	1.14 ^b	0.59 ^a	1.12 ^b	**		0.16

(1) Effects: F: Fiber level, L: Source of fat, •: $P < 0.10$, *: $P < 0.05$, **: $P < 0.01$, NS: Non significant;

Interaction: $F \times L$: NS;

RSD: Residual standard deviation of the model;

^{a, b, c}: means with the same letter in the same line are not significantly different ($n = 6$ animals in each treatment).

A significant increase was only found for the fresh weight of total small intestine of piglets fed the wheat bran diets (Table 4). The weight of the empty large intestine was differently affected by the source of fat: the significant interaction showed a decrease of $4 g.kg^{-1}$ liveweight with olive oil but an increase of the same amount with beef tallow.

Table 4

Effect of fiber level and source of fat on the fresh weight of liver and digestive organs expressed as $g.kg^{-1}$ live weight

Source of fat:		Olive oil		Tallow		Statistical Analysis			(1)
Wheat bran:		-	+	-	+	F	L	F × L	RSD
Stomach	Total	13.5	12.2	13.9	16.6				5.4
	Empty	9.6	8.8	9.0	9.8				1.7
Small intestine	Total	40.2 ^a	42.0 ^{ab}	38.9 ^a	48.3 ^b	*			5.0
	Empty	35.8	36.6	36.4	41.8				4.7
Large intestine	Total	49.8	41.9	42.8	56.5				10.9
	Empty	29.1 ^a	25.2 ^{ab}	23.8 ^b	27.7 ^{ab}			*	3.1
Liver	—	32.0	31.5	31.8	29.6				4.1
Pancreas	—	2.28	2.49	2.45	2.62				0.21

(1) Effects: *F*: Fiber level, *L*: Source of fat, *: $P < 0.05$;

RSD: Residual standard deviation of the model;

^{a, b}: means with the same letter in the same line are not significantly different ($n = 6$ animals in each treatment).

3.2. Digestive enzymes and changes in serum parameters

The total and specific activities of the digestive enzymes have been reported in Table 5. When associated with olive oil, wheat bran increased the total activity of lipase by 35%. Opposed to that, when combined with beef tallow, wheat bran reduced the total activity of lipase by 35%, this illustrates the significant interaction ($P < 0.05$) between the fiber level and the source of the fat. The addition of wheat bran tended to increase ($P < 0.10$) the total activity of amylase in the pancreas. Similarly the combination of wheat bran with olive oil tended to have the same effects on all pancreatic digestive enzymes, but the differences were not statistically significant. The level

of dietary NSP induced a rise of 35% in pre- or post-meal blood urea level ($P < 0.05$), irrespective of the source of fat in the diet (Fig. 1). But neither the level of fiber nor the source of fat in the diet supported any change in the level of blood glucose. The postprandial blood glucose peak occurred between 60 and 90 minutes after the meal. Blood urea also increased after feeding, reaching a maximum 4 hours after the meal. None of the blood lipid parameters including total cholesterol, HDL-cholesterol, LDL-cholesterol and triglycerides were significantly affected by the meal or the composition of the diet (Fig. 2 and 3).

Table 5

Effect of fiber level and source of fat on the total (T) and specific (S) activity of the digestive enzymes

Source of fat:		Olive oil		Tallow		Statistical Analysis			(1)
Wheat bran:		-	+	-	+	F	L	F × L	RSD
Pancreatic enzymes (2)									
Lipase	T	2319	3384	4218	2992			*	963
	S	6.32	8.44	10.96	7.93				3.0
Trypsin	T	6687	8317	6999	7330				1238
	S	19.8	20.0	18.2	19.6				5.3
Chymotrypsin	T	6583	8827	6676	6992				2102
	S	17.4	22.4	18.5	18.1				7.4
Amylase	T	175009	265477	219044	238364	•			56373
	S	500	645	594	625				173
Intestinal enzymes (3)									
Maltase	T	17.6	14.2	17.3	20.6				5.39
	S	0.20	0.15	0.17	0.22				0.07
Sucrase	T	5.7	3.9	4.9	6.7				2.24
	S	0.07	0.04	0.05	0.07				0.03

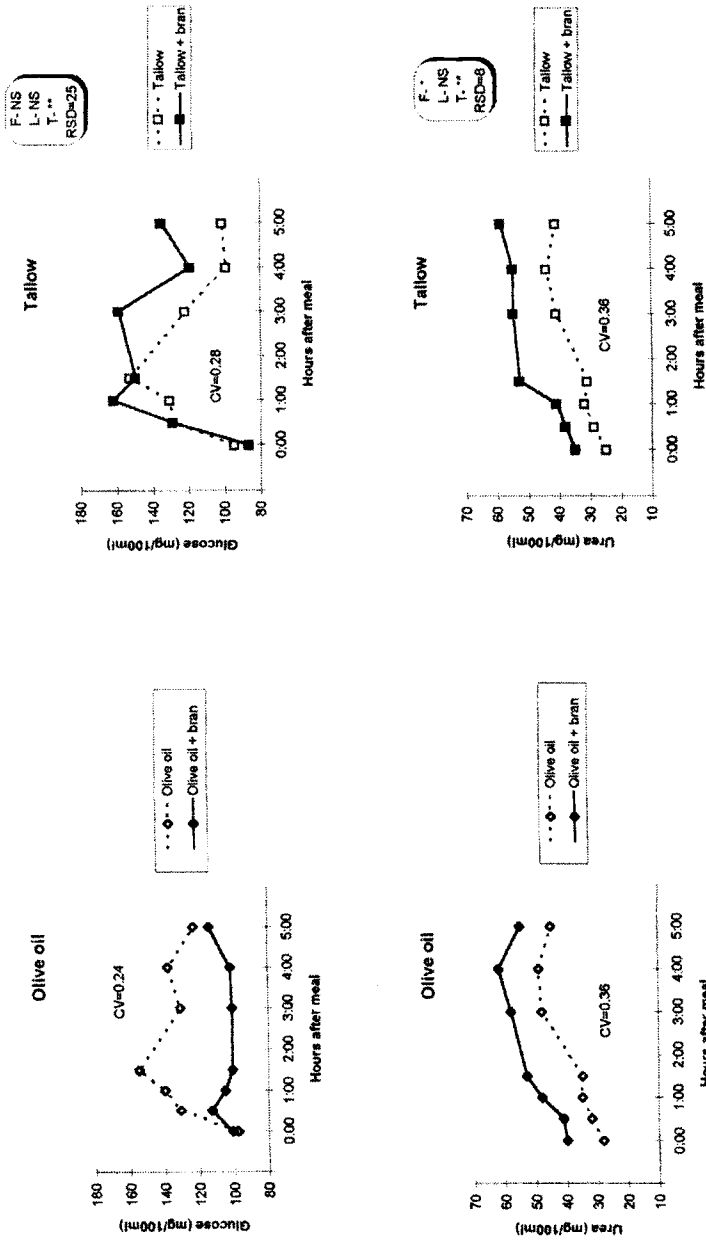
(1) Effects: F: Fiber level, L: Source of fat, *: $P < 0.05$, •: $P < 0.10$;
RSD: Residual standard deviation of the model.

(2) T (IU/pancreas) S (IU/mg of tissue protein).

(3) T (IU/g mucous) S (IU/mg of tissue protein).

Figure 1

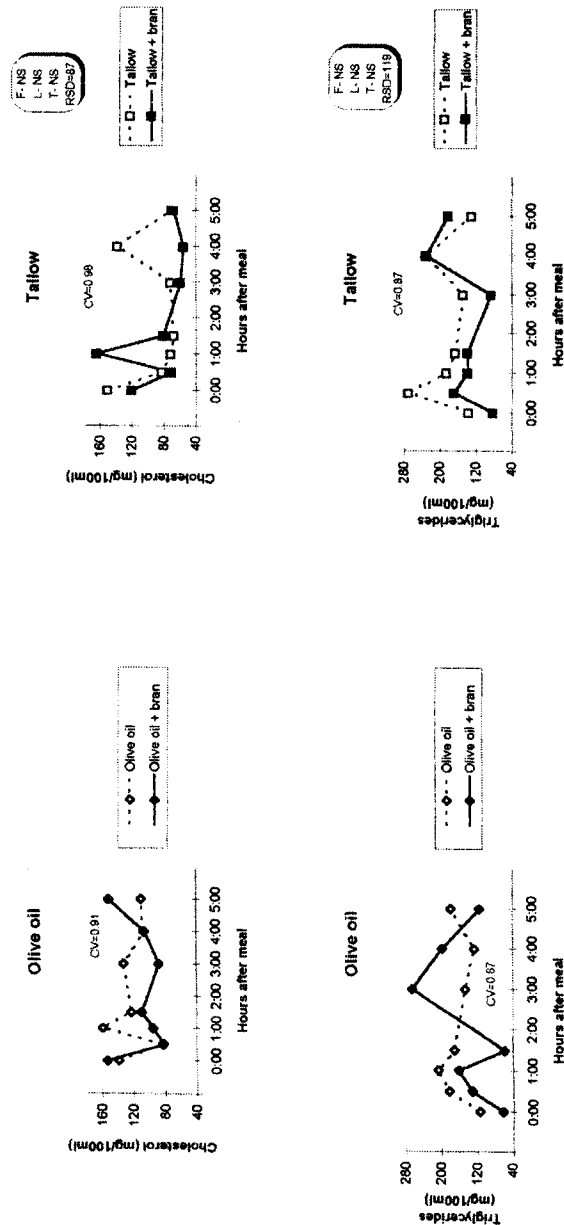
Effect of fiber and source of fat on the pre and postprandial serum glucose and urea level



Effects: F: Fiber level, L: Source of fat, T: Hours after meal, *, p<0.05, **, p<0.01, ***, p<0.001, RSD: Residual standard deviation of the model, CV: Coefficient of variation

Figure 2

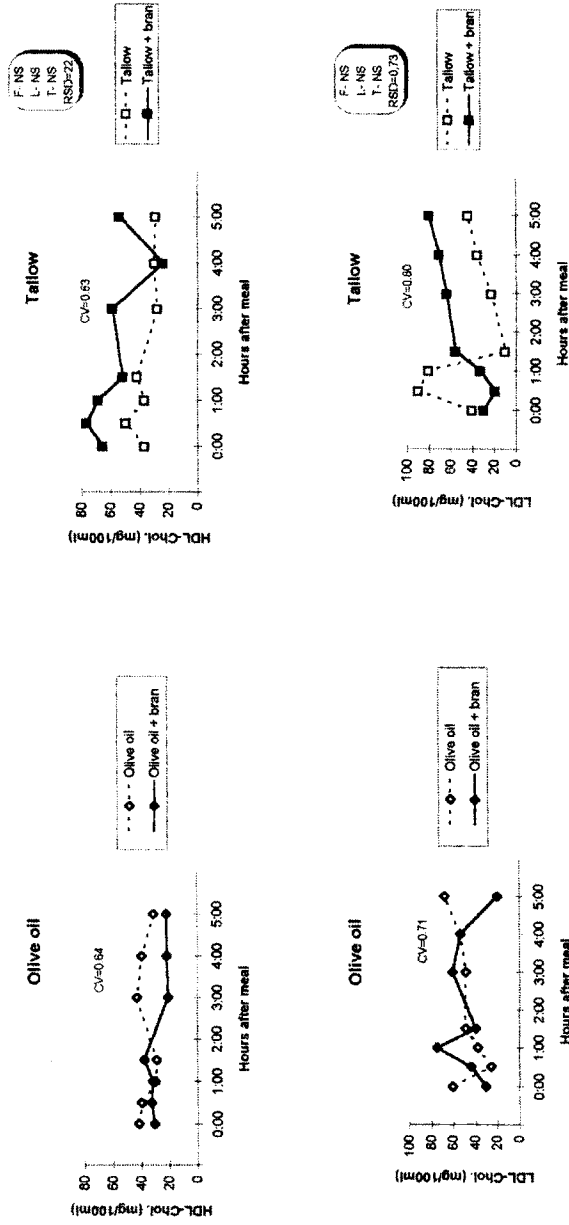
Effect of fiber and source of fat on the pre and postprandial serum cholesterol and triglycerides level



Effects: F: Fibre level, L: Source of fat, T: Time after meal, RSD: Residual standard deviation of the model, CV: Coefficient of variation

Figure 3

Effect of fiber and source of fat on the pre and postprandial serum cholesterol in LDL and HDL level



Effects: F: Fiber level, L: Source of fat, T: Time after meal, RSD: Residual standard deviation of the model, CV: Coefficient of variation

4. Discussion

4.1. Total tract apparent digestibility of dietary components and fecal excretion

The addition of wheat bran because of its NSP content significantly reduced the TTAD of fat whatever the source. An additional excretion of endogenous fat issued from the fermentation of fibrous materials in the large intestine and the net production of solvent extracted substances described by Drochner (1984) in the growing pig could explain these results. Opposed to that, the TTAD of NDF and hemicellulose or NDF-ADF has been increased by the addition of wheat bran and olive oil, but only TTAD of cellulose or ADF-ADL increased in the diet supplied both wheat bran and tallow. As a consequence the TTAD of dry matter and gross energy was not affected by an increase in the level of NDF in the diet. These results demonstrated that, not only the growing pig (Stanogias and Pierce 1985; Graham *et al.*, 1986), but also the weaned piglet was able to digest NSP and partially recover their energy, depending on their degree of lignification (Carré *et al.*, 1990; Bach Knudsen and Hansen, 1991). These data supported our previous results observed on weaned piglets receiving graded levels of NSP (Bengala Freire *et al.*, 1990). Moreover, despite a paradoxically and unexplained low TTAD of nitrogen in the diet supplied with olive oil, the addition of NSP from wheat bran did not reduced the TTAD of nitrogen as demonstrated in our previous results (Bengala Freire *et al.*, 1990) and in those of Longland *et al.* (1994). The most interesting data of the present experiment were associated with the TTAD of fat. A higher TTAD of fat of 8 percentage units in diets supplied with olive oil agreed with classical results obtained on weaned piglets (Braude and Newport, 1973). They could be associated with a lower *in vitro* rate of hydrolysis of triglycerides from tallow compared to those supplied by olive oil (Aumaitre and Rérat, 1968).

The inclusion of wheat bran in the diet increased daily excretion of faeces by 1.7 and 2.4 g fresh weight g^{-1} NDF intake with olive oil and tallow, respectively. Similar results were also obtained by Bach Knudsen and Hansen (1991) in growing pigs and by Stephen (1989) in man having wheat bran in their diets. The increase in the fresh weight of faeces could mostly be explained by an increase in water excretion, due to the high water holding capacity of NSP in wheat bran. The fact that fiber inclusion in the diet increases fat excretion, from 7 to 11% of DM in the olive oil diet and from 12.5 to 16% of DM in the tallow diet agreed with data concerning DM excretion. These results may

be of nutritional importance if the association between dietary fiber and beef tallow increased fecal excretion of cholesterol as hypothesized by Costa *et al.* (1994).

4.2. Development of the digestive capacity of the weaned piglet

The mechanical stimulation due to the presence of fiber in the diet of the pig generally altered the morphology of the gut wall, and increased the fresh weight of gut tissue (Varel, 1987; Graham and Åman, 1991). The short duration of our trial and the high variability of our data did not corroborate these results. Nevertheless, results concerning the fresh weight of the different parts of the digestive tract could not be considered as accurate parameters to describe its digestive potential. Opposed to that, despite they were at the upper limit of the significance, results on the slight increase in the activities of pancreatic enzymes, consecutive to the addition of wheat bran and further to the increase in dietary NSP, could be of physiological importance, as suggested by Low (1989) in the growing pig. In particular, the increase in the activity of trypsin, chymotrypsin and amylase could explain the absence of a deleterious effect of fiber on the TTAD of nitrogen and energy. In addition, the specific behaviour of the activity of lipase adversely affected by the addition of wheat bran according to the source of fat could not be explained. However, the present results failed to demonstrate an effect of the source of fat on the activity of pancreatic lipase in agreement with the data of Reis de Souza (1992).

Our results did not allow to describe the specific contribution of the large intestine in the recovery or the improvement of the digestive capacity of the young animal fed NSP. A further approach on the measurement of the effect of dietary fiber on the ileal and postileal digestibility of the dietary components should be undertaken as recommended by Drochner (1984).

4.3. Effect of fiber on serum glucose, urea and cholesterol levels

The present results corroborate our previous data (Bengala Freire *et al.*, 1990) showing that the intake of NSP included in the meal reduced significantly the postprandial level of serum glucose in monogastric animals (Hagander *et al.*, 1988). Parallel to that the increase in blood urea level was a classical response to dietary fiber. In fact, the stimulation by the dietary fiber of the microflora present in the hindgut of the pig increases protein de-

samination and consequently synthesis and absorption of urea (Rérat, 1978). Blood parameters concerning lipid metabolism were very similar to those reported by Beynen *et al.* (1990) and Lu *et al.* (1994). Because of their very high variability (Coefficient of variation = 0.58–0.80), previously mentioned by several authors, data should be considered with caution. Nevertheless, piglets fed wheat bran exhibited only a slightly lower level of serum cholesterol ($P < 0.05$) in agreement with Baldner-Shank *et al.* (1987).

To conclude, the wheat bran addition to the weaning diet, increasing its NDF level from 10 to 16% on a dry matter basis, reduced the performance of piglets ($P < 0.01$) and the digestibility of fat, producing an increase in the daily fresh and dry weight of faeces and the daily excretion of fat by 0.5 and 0.7 g.kg⁻¹ liveweight. Opposite to that, wheat bran seems to stimulate the total and specific pancreatic proteolytic activities and consequently the digestive capacity of the weaned animals. As a consequence the incorporation of a reasonable amount of fibrous components in the starter diet could be advised for a successful weaning.

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