Nutritive Value of Canola Meal and Full-Fat Canola Seeds in Swine

Final Report

P. Leterme, C. Montoya and P. Kish

Prairie Swine Centre Inc.
P.O. Box 21057- 2105 8th Street East
Saskatoon SK S7H 5N9 CANADA

TABLE OF CONTENTS

ACKNOWLEDGEMENTS

The authors acknowledge with gratitude the financial support provided by the Canola Council of Canada and the Saskatchewan Canola Development Commission for this project.

We also wish to acknowledge the continuing core financial support of the Prairie Swine Centre received from Sask Pork, Manitoba Pork Council, Alberta Pork and the Saskatchewan Agriculture Development Fund.

LIST OF TABLES

LIST OF FIGURES

1. EXECUTIVE SUMMARY

Canola meal (CM) is used in animal nutrition but has to compete with other protein sources. Currently, it is not used to its full potential in swine nutrition, due in part to a lack of confidence in its nutritional quality. Full-fat canola seeds (FFCS) are expected to be a better energy source, thanks to their high oil content. However, no information is available on their energy value in swine. One way to overcome this problem is to provide nutritional information in which nutritionists have a high degree of confidence.

This project aimed at determining the digestible (DE) and net energy (NE) content of CM and FFCS in growing pigs and adult sows.

The project was divided in two parts. During the first two years, two digestibility trials were carried out on growing pigs and on gestating sows, in order to estimate the DE and NE content of three samples of CM and three of FFCS. A growth study was then carried out during the third year with pigs receiving graded levels of CM or FFCS, in order to evaluate their response to canola intake and validate their respective results of NE in growing pigs.

<u>Digestibility experiment</u>

Two digestibility trials were carried out on 130 growing pigs and 78 adult sows, in order to estimate the DE and NE content of three samples of CM and three FFCS. The CM samples came from different crushers: Bunge, Northern and Cargill. Three samples of canola were bought to canola producers from South Saskatchewan and were processed at Milligan Biotech (Foam Lake, SK) by expelling/extrusion technology: the exterior hull of the seeds was broken and the temperature never exceeded 60 °C.

The animals were fed with a barley-based diet, supplemented with 12.5% or 25% of CM or whole seeds. The DE content of the experimental diets was calculated. The DE content of the CM and FFCS alone was then calculated by difference. They ranged from 1.97 to 3.04 Mcal DE/kg DM for CM and from 3.28 to 4.56 Mcal for FFCS in growing pigs. In gestating sows, they ranged from 2.76 to 4.49 kcal DE for CM and from 4.60 to 5.0 kcal DE for FFCS.

The NE contents of the CM and FFCS samples were then calculated by means of a prediction equation based on DE and a correction for the content in dietary fibre, crude protein and oil. The average net energy (NE) content of the CM ranged from 1.29 to 1.73 kcal NE/kg DM in growing pigs and from 1.83 to 3.05 kcal NE/kg DM in gestating sows. The average NE content of the FFCS ranged from 2.42 to 3.31 Mcal/kg DM in growing pigs and from 3.27 to 3.62 Mcal DE/kg DM in gestating sows.

Such a high variation in DE and NE contents was unexpected since the samples of either CM or FFCS had a similar chemical composition. The high variation is ascribed to methodological problems occurring with digestibility trials. First, due to the high fibre content of CM and high oil content of FFCS, it is not possible to incorporate high levels of CM or FFCS in the experimental diet, which has negative consequences on the accuracy of determination of the digestibility of the feed ingredients alone. The second reason is probably the use of an indigestible marker for the estimation of the faecal dry matter excretion. An interaction may have occurred between the acid-insoluble ash and both the dietary fibre or oil fractions.

Therefore, it was decided to redo the digestibility experiment with the total faecal collection of pigs fed with diets based on CM or FFCS.

Digestibility and growth study

A total of 18 growing pigs (36 ± 1 kg) were used for the digestibility study. Three experimental diets were prepared: a control diet and two diets composed of 2/3 of the control diet and 1/3 of CM or FFCS. Each diet was tested on 6 growing pigs. **The DE content was 3.51 and 4.99 Mcal/kg DM and the NE 2.41 and 3.53 Mcal/kg DM for CM and FFCS, respectively**. The DM and nitrogen digestibility for CM was 74 and 79 % and for FFCS 75 and 74 %, respectively.

Based on the results of NE content of both CM and FFCS, two separate growth studies were conducted with increasing incorporation levels of CM or FFCS. In each study, 72 growing pigs were used and four diets containing graded levels of FFCS (0, 5, 10 and 15 %) or CM (0, 7.5, 15 and 22.5 %) were formulated in order to meet the pig's nutritional requirements. Each diet was tested on 18 growing pigs (9 females and 9 males) for 35 d. The average daily gains (ADG) and feed/conversion (F/C) ratios for the pigs fed with diets containing 0, 7.5, 15 or 22.5% CM were, respectively: 1.09, 1.08, 1.03 and 1.08 kg/d and 1.94, 1.95, 2.06 and 2.00. The ADG and F/C ratios for the pigs fed with diets containing 0, 5, 10 and 15% CM were, respectively, 0.98, 1.00, 0.94 and 0.95 kg/d and 2.07, 2.05, 2.03 and 1.92. No difference in the ADG and F/C ratio was observed when CM or FFCS were included at different levels in the diets ($P > 0.05$).

Conclusion

We thus conclude that our estimation for the DE and NE content of the FFCS and CM (3.51 and 4.99 Mcal/kg DM and the NE 2.41 and 3.53 Mcal/kg DM for CM and FFCS, respectively) is correct. Our results suggest that it is possible to formulate balanced diets for growing pigs that contain up to 15% FFCS and 20% CM but, since a slight decrease was observed with the diets having the highest inclusion rates, rates of 10% FFCS and 15% CM can be suggested in total confidence.

2. INTRODUCTION

With almost 10 millions tonnes of canola produced annually, i.e. 20% of the world production, Canada is the second world producer, preceded only by China.

Canola meal (CM) is used in animal nutrition but has to compete with other protein sources such as soybean meal and peas. Currently, canola meal is not used to its full potential in swine nutrition, due in part to a lack of confidence in its nutritional quality. It is perceived as a poor energy source, due to its low starch and oil content and high protein and fibre contents. One way to overcome this problem is to provide nutritional information in which nutritionists have a higher degree of confidence. Energy content is a major determinant of usage, but currently, due to lack of confidence in existing data, DE values used by nutritionists range from 2.80 to 3.15 Mcal DE/kg. The difference of these values represents a significant and probably unnecessary discount in the value of CM.

Full-fat canola seeds (FFCS) can also be incorporated into the pig diet and are expected to be a valuable energy source, due to their fat content, completed by a good quality protein.

3. OBJECTIVES

General

The **general objective** of the project is to improve our knowledge on the energy content of CM and FFCS for swine.

Specific

The **specific objectives** of the project are:

1. To determine the DE and NE contents of CM and FFCS in growing pigs and adult sows.
2. To evaluate the accuracy of the NE estimation of canola meal and canola seeds through growth experiments in pigs

The experiments described below aimed to estimate the DE and NE content of CM samples obtained from three different crushers and of three different samples of FFCS, to ensure they are representative of the products available in the marketplace.

4. MATERIALS AND METHODS

4.1. Purchase and analysis of canola meal and canola seeds

Six samples (± 250 kg) of canola of intentionally diverse quality were obtained from:

- 3 crushers: ADM (Lloydminster), Bunge Canada (Nipawin) and Cargill Ltd (Clavet)
- 3 canola producers from the region of Leross, selected by Dave Kish, producer.

The samples of full-fat canola seeds were crushed at MILLIGAN BIOTECH, Foam Lake. The seeds were processed by expelling and extrusion technology: the exterior hull of the seeds was broken and the temperature was kept below 60 °C.

A proximal analysis was carried out on all samples. The latter were also be analysed for their content in minerals (Ca and P) and in gross energy.

- **Dry matter** (weight of sample after drying at 105 °C for 24 h);
- **Ash** (weight of sample after combustion at 550 °C for 6h);
- **Nitrogen** (combustion method). Crude protein will be N x 6.25;
- **Ether extract** (Soxhlet method using petroleum ether);
- **NDF** and **ADF** (van Soest method, using the Ankom technique with nylon bags;
- **Gross energy** (IKA adiabatic calorimeter).
- **Minerals** P (colorimetry by the molybdo-vanadate method), Ca (atomic absorption)

4.2. Nutritional value of canola meal and canola seeds in growing pigs

Two different digestibility experiments were performed in growing pigs. In the first experiment, different type and incorporation level of CM and FFCS were evaluated using an indigestible marker in the diet. In the second, the DE and NE were measured collecting the total faeces and the values validated by a growth trial.

4.2.1. Type and incorporation level of CM and FFCS (experiment 1)

4.2.1.1. Rooms

This experiment was conducted in an intensive room at PSCI. Each room contains 76 pens of pigs housed individually, measuring 0.91 x 1.83 m. The 4 extreme corner pens were not used. Floors are fully slatted. Feeders are single space, dry feeders located at the front of each pen. Water is delivered through a nipple drinker located on the centre of the back wall of the pens.

4.2.1.2. Animals

A total of 130 barrows, divided into 2 groups of 65 and weighing 35 ± 3 kg on average, were used for the study. The pigs were already in place, since they had been used in a previous experiment destined to evaluate the nutritional value of peas. The pigs were blocked in 5 groups according to bodyweight. Within each block, pigs were randomly assigned to one of 13 experimental diets. Animal stayed on test for 2 weeks: 9 days of adaptation to the diet followed by 3 days of faecal sample collection. At the end of the experiment, the pigs were removed from the room, the latter was cleaned and another group of 65 pigs was installed.

4.2.1.3. Treatments

The canola meals were ground by means of a hammer-mill, through a 3 mm-mesh screen. The canola seeds were crushed just before being used, in order to avoid any problem of oil rancidness.

Since it is not possible to feed pigs with CM or FFCS only, a basal diet is formulated and its digestibility determined. Part of the diet was then replaced by CM or FFCS and the digestibility of the mixture was measured. By difference, the digestibility of the canola alone was then calculated. In order to verify if the intake of large amounts of canola meal or seeds (25%) affects the digestive processes, we also decided to test two levels of canola in the diet: 12.5 and 25%.

A basal diet, composed of 962 g barley/kg, 34 g mineral/vitamin premix (35% dicalcium phosphate, 22% limestone, 14% salt, 14% mineral premix, 14% vitamin premix) and 4 g/kg Celite (= indigestible marker) was prepared. Twelve diets, containing 125 or 250 g canola meal/kg diet, at the expense of barley, were also formulated (Table 1).

Table 1. Composition and nutrient content of experimental diets used for digestibility determination of different types and levels of CM and FFCS.

	Control	Canola meal diets (%)		Full-fat canola seed diets (%)	
		125	250	125	250
Diet ingredients (g/kg)					
Barley	962.2	844.1	721.6	846.6	724.1
CM	0	125	250	0	0
FFCS	0	0	0	125	250
Minerals	4.8	4.8	4.8	4.8	4.8
Vitamins	4.8	4.8	4.8	4.8	4.8
Limestone	12.5	10.0	5.0	7.5	7.5
diCa phosphate	0	0	5	0	11.9
Salt	4.8	4.8	4.8	4.8	4.8
Celite	4	4	4	4	4
Diet analysis[1] (g/kg DM)					
Crude protein	118	153-181	156-189	118-141	121-127
NDF[2]	22.1	216-242	212-217	194-226	169-222
GE[3] (Mcal/kg DM)	4.41	4.44-4.46	4.41-4.46	4.70-5.00	4.71-4.96

[1] Range of variation for the 3 diets [2] NDF, neutral detergent fibre [3] GE, gross energy

4.2.1.4. Methodology

The experimental scheme was a randomized complete block design. The pigs were randomly allocated to one of the diets (5 barrows/treatment/period x 13 treatments x 2 periods = 130 barrows and 10 pigs/treatment) and were fed ad libitum.

The barrows were kept in individual pens for 2 weeks: after an adaptation period of 9 days to the experimental diet, faecal samples were collected for 3 days by grab sampling and stored at -18 °C. An aliquot of faecal sample was prepared, freeze-dried and ground prior to analysis.

Afterwards, the animals were removed from the pens and replaced by another group of 65 barrows and the experiment was repeated.

4.2.1.5. Analyses

The diets of the all experiments were analyzed for DM (AOAC 930.15), ash (AOAC 942.05), nitrogen (AOAC 968.06 using an elemental analyzer LEICO FP528, St Joseph MI, USA), ether extract (AOAC 920.39 using Soxhlet apparatus and petroleum ether), gross energy (PARR 1281 calorimeter, Moline IL, USA), NDF and ADF (van Soest et al., 1991). Acid-insoluble ash was obtained after treatment of the samples with 3N HCl, followed by filtration on cellulose paper, combustion (550 °C for 4h) and weighing of the residue. The faeces were analyzed for DM, acid-insoluble ash, N, ether extract (fat), ash and gross energy.

4.2.1.6. Calculations

The digestibilities of DM, nitrogen (N) and energy of the diets were calculated by means of an indigestible marker (acid insoluble-ash, coming from Celite). For the second experiment, the digestibility was also measured directly by difference between the amount of DM ingested and excreted. The digestibility calculated by means of the indigestible marker was calculated as follows:

$$AD = \{1 - [(IA_D/IA_F) / (N_F/N_D)]\} \times 100\%$$

where AD is the apparent digestibility, IA_D and IA_F the insoluble ash in the diet and in the faeces, respectively, N_F and N_D the nutrient content in the faeces and in the diet, respectively.

The digestibility measured directly was calculated as follows:

$$AD = (N_{ingested} - N_{excreted}) / N_{ingested}] \times 100\%$$

where AD is the apparent digestibility, $N_{ingested}$ the amount of DM or any nutrient ingested and $N_{excreted}$, the amount of DM or any nutrient excreted.

The DE content of the diets or ingredients (CM or FFCS) was calculated using the following equation:

$$DE = D_{GE} \times GE$$

where D_{GE} is the digestibility of energy and GE the gross energy content of the diet.

The apparent digestibility of the CM or FFCS alone was calculated as follows:

$$AD_{CM/FFCS} = [AD_{CM/FFCS\text{-}based\ diet} - (AD_{Basal\ Diet} \times \%\ basal\ diet)] / \%\ CM\ or\ FFCS$$

where $AD_{CM/FFCS}$ is the apparent digestibility of CM or FFCS alone, $AD_{CM\text{-}based\ diet}$ the digestibility of the diet (containing 87.5 or 75 and 67% basal diet and 12.5 or 25 and 33% CM or FFCS in the first and the second experiment, respectively). The $AD_{Basal\ Diet}$ the apparent digestibility of the control diet alone. % basal diet and % CM or FFCS are the inclusion level of basal diet and the CM or FFCS (as mentioned above), respectively, in the CM- or FFCS-based diet.

The NE was calculated using Noblet's equation (Noblet et al., 1994):

$$NE = 0.70 \times DE + 1.61 \times EE + 0.48 \times Starch - 0.91 \times CP - 0.87 \times ADF$$

where DE is digestible energy, EE the ether extract (fat), CP crude protein and ADF acid detergent fibre of CM or FFCS.

4.3. Nutritional value of canola meal in gestating sows

4.3.1. Rooms

This experiment was conducted in a gestating room at Prairie Swine Centre.

4.3.2. Animals

A total of 78 sows were used. Their bodyweight ranged from 160 to 260 kg. Every week, from 10 to 14 sows were placed on trial between 35 and 80 days of gestation.

4.3.3. Treatments

A basal diet, composed of 962 g barley, 34 g mineral/vitamin premix/kg (35% dicalcium phosphate, 22% limestone, 14% salt, 14% mineral premix, 14% vitamin premix) and 4 g Celite/kg was prepared. Twelve diets (see Experiment on growing pigs) were also prepared. However, unlike the experiment on pigs, soybean meal was added to the diets, in order to offer a balanced diet to the gestating sows.

4.3.4. Methodology

The experiment was designed as a completely randomized design. The available sows were assigned to one of the 13 diets as they went along. When the 13 diets had been distributed, the process was repeated until all the diets had been tested on 6 sows. The sows received from 2.5 to 2.9 kg diet/day, according to their bodyweight and provided in one meal. After an adaptation period of 10 days to the diet, the feces were collected for 3 days as grab samples, pooled and an aliquot was kept at -18 °C until freeze-drying and grinding.

The samples and calculations were analysed as previously described.

4.4. Validation of the net energy content of CM and FFCS in growing pigs (Experiment 2)

4.4.1. Digestibility

4.4.1.1. Animals

18 male pigs, weighing on average 36 ± 1 kg at the beginning of the experiment, were used. They were placed in a metabolic cage and randomly assigned to one of the treatments.

4.4.1.2. Treatments

Three diets were prepared: a control diet and two diets composed of 2/3 of the control diet and 1/3 of either CM or FFCS (Table 2).

4.4.1.3. Methodology

The experiment was a randomized complete block design. The pigs were randomly allocated to one of the 3 diets. They were fed 90 g DM/kg $W^{0.75}$ with constant feed intakes. After an adaptation period of 8 d to the diet, the faeces were totally collected for 10 d. An aliquot corresponding to 10% of the total was prepared and kept at -18 °C. At the end of the experiment, the samples were freeze-dried and ground with a lab mill and passed through a 1 mm-mesh screen.

4.4.1.4. Statistical analyses

All statistical analyses were performed using the General Linear Model procedure of SAS version 8.0 (SAS Institute Inc., Cary, NC, USA). An analysis of variance of the data was conducted in order to test the effect of "diet" and "method" (total faecal collection and indigestible marker) of digestibility and energy values determination (PROC GLM procedure of SAS). When the F-value was lower than 0.05 ($P < 0.05$), the means were compared using the Duncan's multiple range tests.

Table 2. Composition and nutrient content of experimental diets used for digestibility determination of canola meal (CM) and full-fat canola seed (FFCS).

Diets	Control	CM	FFCS
Composition (g/kg)			
Barley	736	491	491
Soybean meal	220	147	147
CM	-	333	-
FFCS	-	-	333
Limestone	5.0	3.3	3.3
Dicalcium phosphate	5.0	3.3	3.3
Salt	5.0	3.3	3.3
Minerals PSC	5.0	3.3	3.3
Vitamins PSC	5.0	3.3	3.3
Celite	5.0	3.3	3.3
Lysine-HCl	6.0	4.0	4.0
Threonine	3.0	1.9	1.9
Methionine	3.0	2.0	2.0
Tryptophan	2.0	1.3	1.3
Analysis (g/kg DM)			
DM (g/kg)	874	891	902
Crude protein (N x 6.25)	238	283	235
Ash	62	66	55
Extract ether	17	24	157
ADF	70	106	87
NDF	164	180	169
Crude fibre	48	76	65
Gross energy (Mcal/kg)	4.34	4.44	5.12

4.4.2. Growth study

Two separate studies were conducted with either CM or FFCS but with identical protocols.

4.4.2.1. Animals

For each study, 72 pigs of both genders, weighing on average 31 ± 2 kg at the beginning of the experiment, were used. They were divided in blocks according to weight and gender and randomly assigned to one of the treatments, with an equal number (9) of males and females in each group.

4.4.2.2. Treatments

For each study, 4 balanced diets were formulated to be balanced in digestible amino acids and net energy. They contained 0, 75, 150 or 225 g CM/kg or 0, 50, 100 or 150 g FFCS/kg, at the expense of barley, wheat and/or soybean meal (Table 3). The decrease in NE content caused by the increase in CM was compensated for by increased wheat vs barley and the addition of canola oil.

4.4.2.3. Methodology

The experiment was a randomized complete block design. The pigs were randomly allocated to one of the 4 diets for a period of time of 35 d. The feed and water intake were *ad libitum.* Feed intake and bodyweights were recorded weekly. Fecal samples were collected from 5 pigs per treatment in order to double-check the energy value (digestible energy) of the diets. At the end of the study, the average daily gain and the feed-to-gain ratio were calculated.

4.4.2.4. Statistical analyses

For the growth trial, we tested the effects of CM or FFCS diets, time (weekly) and "diets x time" interaction using a block design to repeated measures (PROC MIXED procedure of SAS). For the digestibility and energy values, the effect of CM or FFCS inclusion level in the diet was tested for linear, quadratic and cubic variations using polynomial orthogonal contrast (PROC GLM procedure of SAS). When the F-value of the analysis of variance was significant ($P < 0.05$), the means were compared using the Duncan's multiple range tests.

Table 3. Composition and nutrient content of experimental diets used for growth trial of different levels of canola meal (CM) and full-fat canola seed (FFCS).

	Canola diets (%)				Full fat canola seed diets (%)			
	0	7.5	15	22.5	0	5	10	15
Diet ingredients (g/kg)								
Barley	180	180	180	180	151	300	450	644
Wheat	571	562	552	540	600	403	231	-
Soybean HP	200	140	80	20	200	200	173	159
Canola meal	-	75	150	225	-	-	-	-
Canola seeds	-	-	-	-	-	50	100	150
Lysine HCl 75%	3	3	4	4	3	2	3	3
DL-Methionine 98%	0.4	0.1	-	-	0.4	0.3	0.3	0.2
L-Threonine 98%	1.6	0.9	1.0	1.0	1.6	0.7	0.7	0.8
Limestone	8	8	7	6	8	7	7	7
Dicalcium phosphate	9	7	4	4	9	10	11	12
Salt	5	5	5	5	5	5	5	5
PSC minerals	5	5	5	5	5	5	5	5
PSC vitamins	5	5	5	5	5	5	5	5
Canola oil	12	9	7	5	12	12	9	9
Calculated diet analysis[2] (g/kg)								
Dry matter	880	879	879	877	880	883	884	886
Crude protein	175	179	183	187	175	179	175	175
Lipid	27	25	23	22	27	48	66	87
SID lysine	9.50	9.54	9.49	9.50	9.50	9.50	9.50	9.50
SID threonine	6.90	6.27	6.17	6.18	6.84	6.18	6.18	6.18
SID methionine	2.70	2.58	2.71	2.93	2.69	2.65	2.66	2.65
SID SAA	5.61	5.72	6.09	6.55	5.61	5.64	5.61	5.61
SID tryptophan	1.89	1.88	1.86	1.85	1.89	1.93	1.85	1.82
Ca	6.50	6.62	6.62	6.50	6.50	6.50	6.50	6.50
P total	5.50	5.50	5.50	5.85	5.50	5.50	5.50	5.50
DE[1] (Mcal/kg)	**3.30**	**3.26**	**3.22**	**3.18**	**3.31**	**3.33**	**3.33**	**3.34**
NE[1] (Mcal/kg)	**2.34**	**2.34**	**2.34**	**2.34**	**2.35**	**2.35**	**2.35**	**2.35**
Diet analysis (g/kg)								
Dry matter	890	890	886	886	890	893	890	891
Crude protein	222	215	224	220	214	222	218	219
Starch	476	425	430	442	466	415	380	353
Neutral detergent fibre	132	138	147	159	116	146	161	194
Acid detergent fibre	45	58	70	78	45	61	72	84
Ash	55	53	54	52	54	56	59	60
Gross energy (Mcal/kg)	4.43	4.42	4.45	4.45	4.42	4.52	4.66	4.82

[1] DE, digestible energy; NE, net energy [2] based on PSC's data base

5. RESULTS AND DISCUSSION

5.1. Composition of the CM and FFCS

The composition of the canola seeds before and after processing at the Milligan Biotech plant, a private company specialised in biodiesel production, is detailed in Table 4. The canola seeds collected in farms contained between 45 and 49% oil. These samples were analysed after grinding with an impact grinder: a sample was put in a steel container together with steel balls and shaken. The oil content of CM was measured directly coming from the crusher. The oil content was markedly lower than that of the whole seeds before processing. Several hypotheses can be suggested to explain the difference. It can partly be ascribed to some losses at the plant during processing of the FFCS. It could also be due to the fact that the meal was not finely ground enough after treatment with the impact grinder, which can have impeded the release of oil during the ether extract process.

Table 4. Chemical composition of the canola seeds used in the growing pigs (experiment 1) and gestating sows (g/kg DM).

Origin	Crude Protein	Ether extract 1	Ether* extract 2	ADF
Quantom	201	493	353	162
Dekalb	207	455	356	138

* The fat content (ether extract) of the whole seeds was measured by the Soxhlet method after grinding with an impact grinder. The second ether extract was performed directly on the samples coming from the crusher

The composition of the FFCS used for the digestibility trial and of the CM is detailed in Table 5. The CM contained between 4.6 and 7.6 % of oil, on a DM basis. As expected, all the other components –with the exception of the gross energy- were higher in the CM, as compared to the FFCS.

Table 5. Chemical composition of the FFCS and CM (% DM).

	Canola meal			Full-fat canola seed		
	Cargill	Northern	Bunge	Excel	Quantum	Dekalb
DM (%)	88.7	88.9	88.6	92.7	93.0	92.0
Crude protein	35.9	36.7	37.1	18.8	19.6	16.3
Ether extract	4.6	5.3	7.6	36.4	35.3	35.6
NDF	23.5	23.6	25.6	37.2	40.8	44.5
ADF	15.6	17.0	18.6	31.9	30.6	33.3
Ash	7.6	9.3	7.9	4.2	3.8	3.8
Ca	0.74	1.25	0.74	0.37	0.37	0.45
P	0.9	1.0	1.0	0.48	0.56	0.48
GE (Mcal/kgDM)	4.84	4.83	4.93	6.82	6.83	6.88

5.2. Digestibility and energy content in swine

5.2.1. Digestibility and energy content in growing pigs (Experiment 1)

The digestibilities of the diets obtained in growing pigs are presented in Table 6. On average, the digestibility of the basal diet, based on barley, was higher than that of the canola-based diets ($P < 0.05$). Crude protein digestibility was higher for the CM-based diets whereas oil digestibility was higher for the FFCS-based diets. The DE content of the FFCS-based diets was, on average, 7% higher than that of the CM-based diets. The higher variation in oil digestibility observed for the CM-based diets is ascribed to the fact that those diets are low in oil, as compared to the FFCS-based diets and it is difficult to obtain accurate results of oil content in fecal samples with the Soxhlet method.

Table 6. Digestibility of dry matter, crude protein and energy (%) and DE content (Mcal/kg DM) of diets based on FFCS and CM in growing pigs.

Origin	% canola	Digestibility (%)				DE
		DM	Protein	Oil	Energy	Mcal/kg DM
Basal diet		81.5a	70.7a	37.7a	80.2a	3.46a
Canola meal						
Cargill	12.5	75.7b	68.2a	32.8ab	74.8b	3.33b
Northern	12.5	74.1b	67.0ab	30.1b	73.2b	3.23b
Bunge	12.5	77.2b	66.2ab	41.6a	76.1b	3.38ab
		75.7	**67.1**	**34.8**	**74.7**	**3.31**
Cargill	25.0	74.3b	70.3a	41.6a	73.8b	3.27b
Northern	25.0	75.7b	73.0a	57.8c	75.4b	3.56a
Bunge	25.0	72.3c	67.1ab	34.4a	71.5bc	3.19b
		74.1	**70.1**	**44.6**	**73.6**	**3.34**
Total CM		**74.9**	**68.6**	**39.7**	**74.1**	**3.33**
Full-fat canola seed						
Excel	12.5	75.3b	61.9b	54.4c	73.7b	3.46a
Quantom	12.5	76.9b	63.9b	53.3c	75.2b	3.55a
Dekalb	12.5	77.8b	67.0ab	56.5c	76.4b	3.61ac
		76.7	**64.3**	**54.7**	**75.1**	**3.33**
Excel	25.0	76.3b	64.4b	65.9c	74.5b	3.73c
Quantom	25.0	72.7c	65.4b	56.2c	70.3c	3.51ac
Dekalb	25.0	71.1c	62.1b	53.3c	68.8c	3.42a
		73.4	**64.3**	**54.7**	**75.1**	**3.54**
Total FFCS		**75.0**	**64.1**	**56.6**	**73.2**	**3.55**

a, b, c: means with different superscripts in the same column differ significantly ($P < 0.05$)

No clear difference was observed between the results obtained with diets containing 12.5 or 25% of canola. However, the results are less variable for FFCS and are even remarkably similar between the two FFCS-based diets, with the exception of DE content, whereas there was no difference in DE content between the two CM-based diets.

The DE contents of CM and FFCS alone were calculated by difference. On average, the FFCS contained 55% more DE than CM (Table 7). Important differences were observed between varieties of FFCS or origin of CM but the differences also differed between the diets containing 12.5 or 25%. This can be explained by the fact that the accuracy of digestibility estimation by difference highly depends on the rate of incorporation of the studied ingredient in the diet. Accuracy will increase with the inclusion rate. In this study, the inclusion levels were lower than those usually used in ingredient evaluation (> 30-40%) because we feared that the pigs would not eat diets with high levels of canola seeds or CM and that the high fiber content of the CM would impair the digestibility of the rest of the diet. It was obviously too low to obtain an accurate determination of the DE content of the canola products.

No marked difference was observed between diets containing 12.5 or 25% canola. However, the variability between the different canola varieties incorporated at the same level was very high. For FFCS, the difference between the results obtained with the 12.5 or 25% diets was limited but variability between FFCS varieties was also high.

Based on these results, we calculated the NE content of the CM and FFCS samples by means of a prediction equation. With that equation (see § 2.1.6), NE is a constant fraction of DE with a correction for the canola content in crude protein, starch (not applicable for canola), oil and dietary fibre. Protein and fibre have a negative impact whereas oil has a positive one.

The results are detailed in Table 7. The NE content of the FFCS was twice that of the CM. The variability between the three samples of either CM or FFCS was as high as that observed for DE. This was expected since NE is mainly explained by the DE value, with only a correction for oil, fiber and protein content and the three samples of both FFCS and CM had similar chemical composition.

Table 7. DE of CM and FFCS alone in growing pigs and NE estimated by means of a prediction equation (kcal/kg DM).

Origin	% canola	Digestible energy	Net energy
Canola meal			
Cargill	12.5	2.46a	1.52ab
Northern	12.5	2.54a	1.38ab
Bunge	12.5	2.71ab	1.52ab
		2.57	**1.47**
Cargill	25.0	1.97b	1.16a
Northern	25.0	3.04b	1.73b
Bunge	25.0	2.38a	1.29ab
		2.47	**1.39**
	Total CM	**2.52**	**1.43**
Full-fat canola seed			
Excel	12.5	3.47xz	2.56x
Quantom	12.5	3.81x	2.78x
Dekalb	12.5	4.63y	3.37y
		3.97	**2.90**
Excel	25.0	4.56y	3.31y
Quantom	25.0	3.89x	2.84x
Dekalb	25.0	3.28z	2.42x
		3.91	**2.86**
	Total FFCS	**3.94**	**2.88**

Higher results of DE and NE were expected for the FFCS since their oil content was very high. It seems that the low values can be explained by a relatively poor digestibility of the oil: around 56% (Table 6). Considering the fact that the control diet was almost devoid of oil, it can be estimated that the oil digestibility of the FFCS studied here did not exceed 60%. The poor digestion by the pig is confirmed by the high levels of oil found in the faecal samples of the pigs fed 25 % of FFCS (Figure 1). This confirms other observations in Australia and France. Noblet & Champion (2003), for example, measured a digestibility of 21% for the oil of ground FFCS.

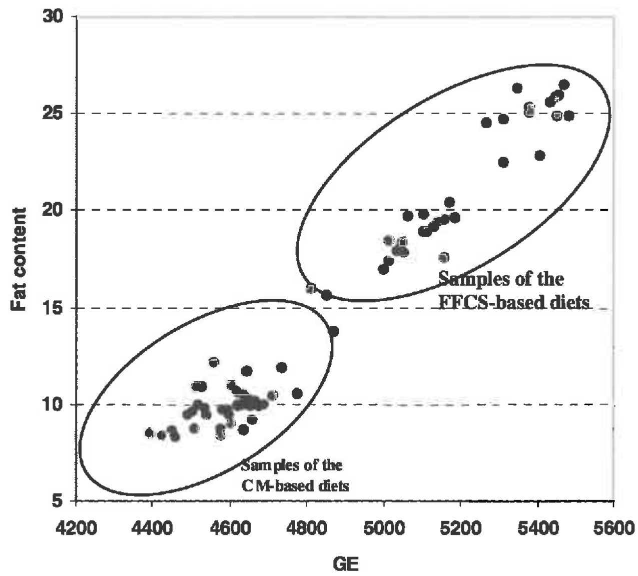

Figure 1. Relationship between the oil content of the faeces of pigs fed with canola meal (low oil content) or canola seeds (high content) and their gross energy content.

5.2. Digestibility and energy content in gestating sows

The results of digestibility and DE of CM and FFCS obtained in gestating sows are detailed in Table 12. The digestibility values of DM and protein were higher than those observed in growing pigs but the oil digestibilities were slightly lower. As a consequence, the DE contents were 3-3.5% higher than those obtained for growing pigs or ± 0.1-0.12 Mcal DE/kg. This is in agreement with the French tables of nutritional value of feed ingredients in pigs (INRA et al., 2004).

Table 12. Digestibility of dry matter, crude protein and energy (%) and DE content (kcal/kg DM) of diets based on FFCS and CM in gestating sows.

Origin	% canola	Digestibility (%)				DE
		DM	Protein	Oil	Energy	kcal/kg DM
Basal diet		79.0	71.0	24.0	79.5	3.43
Canola meal						
Cargill	12.5	81.2a	83.9a	43.2a	79.4a	3.56a
Northern	12.5	81.1a	83.4a	32.0b	79.3a	3.51a
Bunge	12.5	80.9a	78.7b	44.4a	78.7a	3.45a
		81.1	**82.0**	**39.9**	**79.1**	**3.51**
Cargill	25.0	76.3b	75.9b	35.3b	74.4a	3.26b
Northern	25.0	78.2ab	80.0ab	46.0a	76.6a	3.42a
Bunge	25.0	78.9ab	79.5b	44.5a	79.9a	3.43a
		77.8	**78.5**	**41.9**	**77.0**	**3.37**
Total CM		**79.4**	**80.2**	**40.9**	**78.1**	**3.44**
Full-fat canola seed						
Excel	12.5	80.3a	77.7b	54.4a	77.1a	3.58a
Quantom	12.5	79.6a	76.3b	50.1a	75.6ab	3.53a
Dekalb	12.5	78.6ab	73.4b	48.8a	75.0ab	3.55a
		79.5	**75.8**	**51.1**	**75.9**	**3.55**
Excel	25.0	79.3a	77.9b	64.1a	76.2a	3.82c
Quantom	25.0	80.1a	82.3a	50.8a	76.2a	3.81c
Dekalb	25.0	77.0b	76.3b	55.1a	73.4b	3.70ac
		78.8	**78.8**	**56.7**	**75.3**	**3.78**
Total FFCS		**79.2**	**77.3**	**53.9**	**75.6**	**3.66**

a, b, c: means with different superscripts in the same column differ significantly ($P < 0.05$)

Table 13. DE of CM and FFCS alone in gestating sows and NE estimated by means of an equation of prediction (kcal/kg DM).

Origin	% canola	Digestible energy	Net energy
Canola meal			
Cargill	12.5	4.10	2.77
Northern	12.5	3.44	2.33
Bunge	12.5	3.59	2.44
		3.71	**2.52**
Cargill	25.0	2.76	1.83
Northern	25.0	4.49	3.05
Bunge	25.0	3.38	2.27
		3.54	**2.38**
	Total CM	**3.63**	**2.45**
Full-fat canola seed			
Excel	12.5	4.38	3.19
Quantom	12.5	4.20	3.06
Dekalb	12.5	4.95	3.58
		4.51	**2.90**
Excel	25.0	5.00	3.62
Quantom	25.0	4.50	3.27
Dekalb	25.0	4.60	3.35
		4.70	**3.41**
	Total CM	**4.61**	**3.35**

No marked difference was observed between the results of digestibility, DE or NE obtained with the 12.5 or 25% diets, although lower variability was obtained with 25% diets. On the contrary, wide variability was observed between the three varieties of either CM or FFCS, for reasons difficult to explain, since they have roughly the same chemical composition. Interactions between nutrients such as dietary fibre and the indigestible marker used in this experiment (acid-insoluble ash) cannot be excluded but this hypothesis cannot be verified. However, the low oil digestibility of the FFCS has likely negatively affected the accuracy of the measurement. The large quantities of oil found in the faeces of pigs fed with whole seeds attest that oil digestibility is be the major factor that can affect the nutritional value of FFCS.

The results obtained for the growing pigs (experiment 1) are lower than those mentioned in the literature: 2.59 Mcal DE/kg DM on average for CM vs 3.11 Mcal DE in the literature (INRA, 2004). The results obtained in sows were more comparable: 3.54 Mcal DE/kg DM in the present case vs 3.35 Mcal DE in the literature. The differences for NE were more important: 1.39 Mcal NE/kg DM in growing pigs here vs 1.70 Mcal NE in the literature. The difference for sows was important too: 0.54 Mcal NE between the two.

The differences were even higher for the FFCS: the DE values published in the literature exceed 5.70 Mcal DE/kg DM for growing pigs and sows vs <4.00 Mcal DE/kg DM here. The difference can be explained by the fact that: 1) our seeds contained only 35% oil after processing whereas those presented in the tables contain between 45 and 50% and 2) the oil digestibility mentioned in the tables is 85% whereas here, it was lower than 60%. Seed processing is thus essential to explain the results.

However, a series of observations can be made.

First, a correct grinding or processing of the FFCS is essential for the release of their oil. This will be essential for the DE content and especially of the NE content since oil is the component with the highest energy level among the different nutrients. In the present case, the canola seeds were processed by expelling and extrusion technology with the disruption of the hulls but the maintenance of the seeds at low temperature (< 60 °C). The process was obviously not sufficient to release all the oil since our digestibility coefficients indicate than only 50-60% of the canola oil was digested. Other authors have mentioned low oil digestibility in canola products (20%; Noblet & Champion, 2003). Further research is thus required to obtain a maximal NE content of the canola seeds.

Second, the higher value obtained for gestating sows, as compared to growing pigs, confirm previous observations (Le Goff et al., 2002) that higher DE and NE values should be provided for sows and that large animals better digest raw ingredients.

5.3. Validation of the net energy content of CM and FFCS in growing pigs

5.3.1 Digestibility

The faecal apparent digestibilities and DE content of the experimental diets and the ingredients alone (CM and FFCS) are shown in Table 8. The control diet presented the highest DM, N and energy digestibilities ($P < 0.001$ to $P < 0.026$). The DE of the diets was higher for FFCS ($P < 0.001$), influenced by the highest gross energy content (+ 15 %). Similar values of digestibility of DM, N and energy were obtained for CM and FFCS alone (Table 8). The N and energy digestibility of CM were slightly higher than data previously reported for rapeseed meal (79 and 74 % vs. 73 and 67 %; Noblet et al., 1993).

The DE and NE values found here for CM (3.51 and 2.41 Mcal/kg DM; Table 8) and FFCS (4.99 and 3.53 Mcal/kg DM) are higher, as compared to previous data (NRC, 1998; Noblet et al., 1993). It could be ascribed to lower energy digestibilities (74 vs. 67 %) and differences in nutritional composition (e.g. 170 vs. 307 g NDF/kg). In previous experiments conducted with different CM types, we observed similar values of DE and NE (3.62-3.95 and 2.48-2.72 Mcal/kg, respectively).

No significant difference was observed between the apparent digestibilities of diets measured with the total faecal collection or the indigestible marker ($P > 0.05$; Table 8). For the ingredients alone, the apparent faecal digestibilities and the DE and NE content were lower with the indigestible marker method. However, the difference was significant for the digestibility of DM and energy ($P = 0.021$ and $P = 0.023$, respectively).

Table 8. Digestibilities and energy values of diets and ingredients (CM or FFCS) in growing pigs.

	Diets[1]				
	Control	CM	FFCS	RSD[2]	P
Diets					
Total collection					
Dry matter	84.9a	81.1b	81.4b	1.7	0.004
Nitrogen	84.9a	82.8ab	81.2b	2.1	0.026
Energy	84.1a	80.7b	80.3b	1.9	0.006
Digestible Energy (Mcal/kg)	3.65b	3.59b	4.11a	93	0.001
Indigestible marker (celite)					
Dry matter	87.1a	80.9c	81.6b	0.5	0.001
Nitrogen	87.1a	82.6b	81.5b	1.1	0.001
Energy	86.5a	80.5b	80.4b	0.6	0.001
Digestible Energy (Mcal/kg)	3.74b	3.57c	4.12a	29	0.001
Ingredients					
Total collection					
Dry matter	-	74	75		
Nitrogen	-	79	74		
Energy	-	74	73		
Digestible Energy (Mcal/kg)	-	**3.51**	**4.99**		
Net Energy (Mcal/kg)	-	**2.41**	**3.53**		
Indigestible marker (celite)					
Dry matter	-	69	71		
Nitrogen	-	74	70		
Energy	-	69	69		
Digestible Energy (Mcal/kg)	-	3.26	4.58		
Net Energy (Mcal/kg)	-	2.23	3.24		

[1] Control, basal diet; CM, canola meal-based diet; and FFCS, full-fat canola seeds-based diet (667 g basal diet and 333 g/kg of CM or FFCS). [2] RSD, residual standard deviation [a,b,c] Values with different letters in the same row differ significantly at $P < 0.05$.

5.3.2. Growth study

The results of the two growth trials are detailed in Figure 2, Tables 9 and 10. In both cases, feed intake increased with time ($P < 0.001$) and was influenced by gender ($P < 0.05$). Feed intake was lower only for the FFCS-15 diet ($P < 0.001$). As expected, the average daily gain (ADG) and feed conversion ratio changed with time (week) ($P < 0.05$). However, no difference in ADG was observed between treatments (inclusion rates) ($P > 0.05$). As a consequence, no difference ($P > 0.05$) was observed for the feed conversion ratio. The later was used as a criterion to evaluate the validity of our estimation of the NE content of both CM and FFCS. We observed a drop in feed conversion ratio only with the FFCS-15 diet, at the limit of significance ($P = 0.068$). This can be ascribed to the drop observed for feed intake with that diet (Table 9). The decrease can possibly be explained by the fact that the capacity of the gastrointestinal tract to digest oil must have been reached. However, the drop was significant only during the fifth week. When only the four first weeks are considered (see statistical parameters, Table 9), the "diet" effect is not significant ($P = 0.807$).

The significance for the "diet x time" interaction for the feed conversion ratio ($P = 0.056$) is also to be ascribed to the lower ratio obtained the 5[th] week for the FFCS-15 diet.

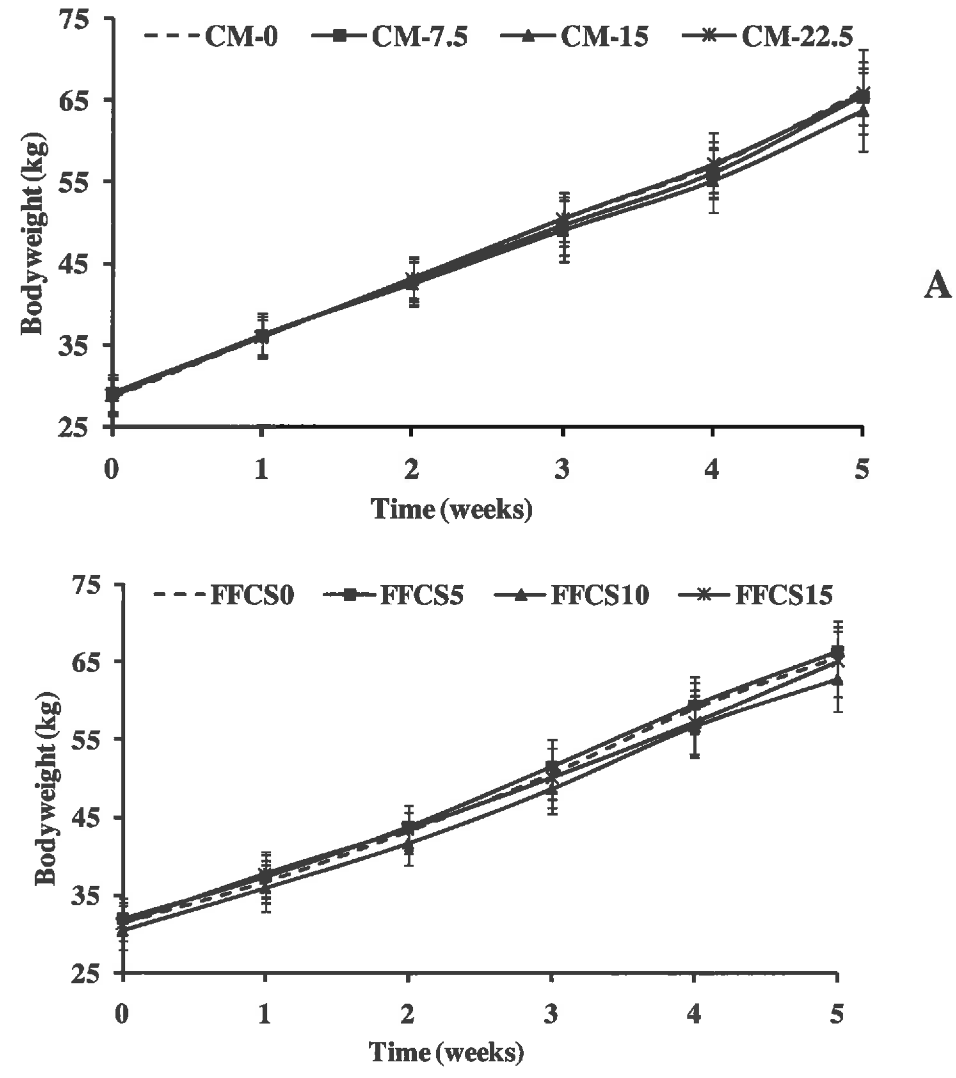

Figure 2. Bodyweight evolution over time of growing pigs fed with diets containing different levels of full-fat canola seeds (A) or canola meal (B). Values are means and SD for 18 pigs (9 female and 9 male).

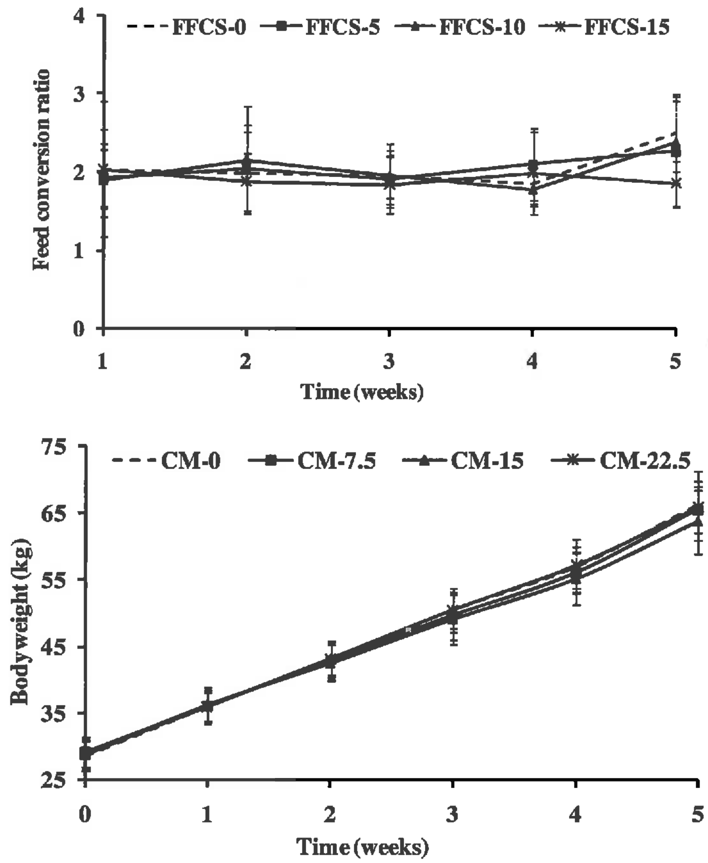

Figure 3. Evolution over time of the feed conversion ratio in growing pigs fed with diets containing different levels of full-fat canola seeds (A) or canola meal (B). Values are means and SD for 18 pigs.

Our estimation of the NE content of the CM and FFCS (respectively 2.41 and 3.53 kcal NE/kg DM) in growing pigs thus seems to be close to the reality. Also, balanced diets can contain up to 15% FFCS or 22% CM, without affecting growth. However, 15% seems to be the maximal acceptable limit, since feed intake seems to have been slightly affected. The results confirm previous studies in which pigs performed well with diets containing up to 292 g CM or 240 g FFCS per kg diet (Brand et al., 1999, 2001; Kin et al., 2001; Mullan et al., 2000).

Table 9. Bodyweight, food intake and growth in growing pigs fed with different levels of full-fat canola seed (FFCS) in the diets.

	Full-fat canola seed[1]				Time		P			
	0	5	10	15	(week)	RSD[2]	Diet	Time	D*T	Sex
Initial BW[3] (kg)	31.5	32.1	30.5	31.2		2.3	0.228	-	-	0.803
Final BW[3] (kg)	65.7a	66.5a	62.9b	64.5ab		3.9	0.042	-	-	0.204
Feed intake (kg/d)										
1	1.55	1.52	1.42	1.42	1.48d					
2	1.77	1.78	1.69	1.55	1.70c					
3	2.06	2.07	1.94	1.82	1.98b					
4	2.20	2.30	2.02	1.99	2.13a					
5	2.29	2.27	2.12	1.96	2.17a					
Total	1.97a	1.99a	1.84ab	1.75b		0.45	0.001	0.001	0.651	0.002 (5 weeks)
							0.002	0.001	0.420	0.002 (4 weeks)
Average daily gain (kg/d)										
1	0.79	0.81	0.78	0.80	0.79c					
2	0.93	0.92	0.82	0.85	0.88c					
3	1.06	1.11	1.00	1.02	1.05ab					
4	1.20	1.13	1.15	1.05	1.13a					
5	0.94	1.06	0.92	1.06	0.99b					
Total	0.98	1.00	0.94	0.95		0.24	0.070	0.001	0.437	0.018
							0.070	0.001	0.820	0.001
Feed conversion										
1	2.04	1.93	1.90	2.04	1.98b					
2	2.00	2.04	2.16	1.88	2.02ab					
3	1.97	1.91	1.96	1.84	1.92b					
4	1.86	2.10	1.78	1.99	1.93b					
5	2.50	2.27	2.38	1.85	2.24a					
Total	2.07	2.05	2.03	1.92		0.56	0.068	0.002	0.056	0.245
							0.877	0.601	0.475	0.509

[1] Diets with different levels of inclusion of full-fat canola seeds.
[2] RSD, residual standard deviation
[3] BW, bodyweight
[a,b,c] Values with different letters in the same row or column (Week) differ significantly at $P < 0.05$.

Table 10. Bodyweight, food intake and growth in growing pigs fed with different levels of canola meals (CM) in the diets.

	Canola meal incorporation[1]				Time		P			
0	7.5	15	22.5		(week)	RSD[2]	Diet	Time	D*T	Sex
Initial BW[3] (kg)	28.7	29.1	28.8	28.9		2.3	0.947	-	-	0.647
Final BW[3] (kg)	66.2	65.6	64.5	65.9		4.2	0.679	-	-	0.290
Feed intake (kg/d)										
1	1.57	1.52	1.58	1.45	1.53e					
2	1.84	1.84	1.83	1.92	1.86d					
3	2.06	2.07	1.96	2.18	2.06c					
4	2.15	2.20	2.30	2.37	2.25b					
5	2.53	2.50	2.36	2.54	2.48a					
Total	2.03	2.02	2.01	2.09		0.55	0.664	0.001	0.122	0.023 (5 weeks)
							0.711	0.001	0.090	0.108 (4 weeks)
Average daily gain (kg/d)						0.25				
1	1.06	1.00	1.07	1.02		1.03b				
2	1.01	0.98	0.90	1.03		0.98b				
3	1.06	1.01	0.96	1.05		1.02b				
4	0.97	1.07	0.99	1.04		1.02b				
5	1.31	1.35	1.22	1.28		1.29a				
Total	1.08	1.09	1.03	1.08			0.483	0.001	0.925	0.360
							0.513	0.462	0.692	0.569
Feed Conversion						0.63				
1	1.52	1.53	1.49	1.46		1.50d				
2	1.85	2.00	2.21	1.87		1.98bc				
3	2.01	2.14	2.09	2.13		2.09b				
4	2.27	2.21	2.45	2.52		2.36a				
5	2.08	1.94	2.15	2.07		2.06b				
Total	1.94	1.95	2.06	2.00			0.190	0.001	0.694	0.814
							0.252	0.001	0.516	0.987

[1] Diets with different levels of inclusion of full-fat canola seeds.
[2] RSD, residual standard deviation
[3] BW, bodyweight
[a,b,c] Values with different letters in the same row or column (Week) differ significantly at $P < 0.05$.

5.3.3. Validation of the values of DE and NE content of canola meal and full-fat canola seeds obtained by means of an indigestible marker.

The inclusion of a marker in a diet allows for the estimation of the DE and NE content of that diet, based on the sole analysis of the diet and a faecal sample for that marker. The method was used here to estimate the DE and NE content of the experimental diets during the growth study (Table 11).

The DE and NE content of the CM-based diets slightly declined when CM was gradually incorporated in the diet ($P < 0.05$) whereas it increased when FFCS was included ($P < 0.01$). This suggests that the energy values of CM were slightly overestimated and those of FFCS slightly underestimated. This was not sufficient, however, to affect the pig's growth significantly, thanks to constant feed intakes observed for pigs fed CM-based diets.

A quadratic effect of inclusion rate was observed for all the CM-based on digestibility and the energy content. The effect was rather linear for the DE and NE content of the FFCS-based diets ($P < 0.05$). A strong correlation was observed between the digestibility values and the NDF and ADF content of the CM-based diets ($r= -0.93$ to -0.96; $P < 0.05$). The correlation was also strong between the NDF content of the FFCS-based diets and their NE and DE contents ($r= -0.96$; $P < 0.05$).

Table 11. Digestibilities and energy values of the diets containing different levels of CM or FFCS used in the growth study.

	Inclusion level[1]						
Canola meal	0	7.5	15	22.5			
Full fat canola seed	0	5	10	15	RSD[2]	Contrast	[3]P
Canola meal diets							
d DM (%)	82.1[a]	81.7[a]	78.5[b]	77.4[b]	2.1	Q	0.014
d N (%)	80.7[a]	78.6[ab]	75.6[b]	75.1[b]	2.5	Q	0.021
d Energy (%)	81.1[a]	80.6[a]	77.2[b]	76.2[b]	2.3	Q	0.017
DE (Mcal/kg)	**3.59[a]**	**3.56[ab]**	**3.43[bc]**	**3.39[c]**	**103**	**Q**	**0.037**
NE (Mcal/kg)	**2.51[a]**	**2.49[ab]**	**2.40[bc]**	**2.37[c]**	**72**	**Q**	**0.032**
Full fat canola seed diets							
d DM (%)	82.0[a]	81.9[a]	79.7[b]	80.0[b]	1.4	Q	0.028
d N (%)	80.1	80.8	78.6	77.3	2.1	NS	0.081
d Energy (%)	80.7[a]	80.4[a]	78.2[b]	78.7[ab]	1.5	Q	0.044
DE (Mcal/kg)	**3.56[a]**	**3.63[a]**	**3.64[a]**	**3.79[b]**	**70**	**L**	**0.001**
NE (Mcal/kg)	**2.49[a]**	**2.53[a]**	**2.54[a]**	**2.64[b]**	**49**	**L**	**0.002**

[1] Diets with different inclusion levels of canola meal or full-fat canola seeds.
[2] RSD, residual standard deviation
[3] Linear (L) and quadratic (Q) effects of the level of CM or FFCS in the diet. NS not significant ($P > 0.05$).
[a,b,c] Values with different letters in the same row differ significantly at $P < 0.05$.

6. DISCUSSION & CONCLUSION

CM and FFCS are feed ingredients used in swine nutrition. CM has a high dietary fibre content whereas FFCS is very rich in oil. These high levels limit the inclusion levels of these ingredients into balanced diets because dietary fibre prevents digestion whereas the gastrointestinal tract is limited in its capacity to digest oil.

The limitation has also consequences for digestibility trials. Swine nutritionists usually incorporate a maximum of an ingredient in an experimental diet when they want to determine its digestibility by the difference method, in order to increase precision. Due to the high fiber or oil content, it was not possible here. Our second problem was related to the use of an indigestible marker. The latter is required when only a sample of faeces can be collected and not the totality of the faeces excreted. Acid-insoluble ash has been used successfully for the study of numerous feed ingredients found in swine nutrition. Therefore, we decided to use it here too.

Obviously, some interactions occurred between the insoluble ash of the diet and its dietary fiber and/or oil fractions since abnormal variation of DE and NE content was observed for the first experiment digestibility. Therefore, it was decided to repeat the digestibility trial with growing pigs and to collect the faeces totally for 10 d. The accuracy of the estimation improved substantially and we conclude that CM and FFCS have the following DE and NE content:

- Canola Meal: 3.51 Mcal DE/kg and 2.41 Mcal NE/kg
- Full-fat canola seeds: 4.99 Mcal DE/kg and 3.53 kcal NE/kg

Our results are strengthened by the results of our growth study. Normally, if the results of NE were incorrect, we would have seen a significant impact on the feed/conversion ratio, which was not the case. We thus conclude that our results are close to the actual values of DE and NE content of both CM and FFCS.

On the other hand, it is worth mentioning that the energy content of FFCS will mainly depend on its oil digestibility, as attested by the wide range of oil excretion and thus oil digestibility observed here. Our FFCS samples were crushed by a private company specialized in the processing of canola seeds but this opportunity did not prevent the problem of oil release from the seeds. It would deserve further attention in the future.

Based on a thorough analysis of our data, we conclude that CM and FFCS could, without any risk for growth rate, represent respectively 15% and 10% of the pig diet.

7. REFERENCES

Brand T, van der Merwe J, Brandt D (1999) Full-fat canola seed meal as a protein source for weaner and grower–finisher pigs. *Aust. J. Exp. Agric.* **39**, 21-28.

Brand T, Brandt D & Cruywagen (2001) Utilisation of growing-finishing pig diets containing high levels of solvent or expeller oil extrct canola meal. *New Zealand J. Agric. Res.* **44**, 31-35.

Danielsen V, Eggum B, Jensen S, Sorensen H (1993) Dehulled protein-rich rapeseed meal as a protein souce for early weaned piglets. *Anim. Feed Sci. Technol.* **46**, 239-250.

INRA (2004) Tables de composition et de valeur nutritive des matières premières destinées aux animaux d'élevage. INRA Editions, Paris, 244 p.

King R, Eason P, Kerton D & Dunshea F (2001). Evaluation of solvent-extracted canola meal for growing pigs and lactating sows. *Aust. J. Agric. Res.* **52**, 1033-1041.

Le Goff G, Van Milgen J, Noblet J (2002) Influence of dietary fibre on digestive utilization and rate of passage in growing pigs, finishing pigs and adult sows. *Anim. Sci.* **74**, 503-515.

Mullan B, Pluske J, Allen J & Harris D (2000) Evaluation of Western Australian canola meal for growing pigs. *Aust. J. Agric. Res.* **51**, 547-553.

Noblet J & Champion M (2003) Effect of pelleting and body weight on digestibility of energy and fat of two corns in pigs. *J. Anim. Sci.* **81**(Suppl. 1): 140. (Abstr.)

Noblet J, Fortune H, Dupire C. & Dubois (1993) Digestible, metabolizable and net energy values of 13 feedstuffs for growing pigs: effect of energy system. *Anim. Feed Sci. Technol.* **42**, 131-149.

Noblet J, Fortune H, Shi X & Dubois S (1994) Prediction of net energy value of feeds for growing pigs. *J. Anim. Sci.* **73**, 344-354.

Van Soest P, Robertson J & Lewis B (1991). Methods for dietary fiber, neutral detergent fiber, and non starch polysaccharides in relation to animal nutrition. *J. Dairy Sci.* **74**, 3583.

Zijlstra R, & Scott T (2000) Feed evaluation and feed intake. *Advances in Pork Production* **11**, 221-225.