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Digestibility and energy value of co-products derived from the production of pea starch in growing pig diets

Project managers: Jean Noblet and Yolande Jaguelin-Peyraud, INRA, UMR SENAH, 35590 St-Gilles.

Scientific collaboration: Christian Delporte, ROQUETTE Frères Company, 62080 Lestrem.

Technical collaboration: Anne Pasquier, Georges Guillemois, Raymond Vilboux, Francis Le Gouevec, Benoît Janson, Vincent Piedvache, Yves Lebreton, Hervé Demay.

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Introduction

In conjunction with the development of its starch-related activities, the ROQUETTE Frères company has developed a process to extract pea starch. As a result, various co-products derived from this process are now being made available. These co-products include pea bran (constituted mainly from the external envelopes and fragments of pea grains), pea protein (a protein concentrate which takes the form of a fine cream-coloured powder with a neutral odour), wet pea pulp (with 20% dry matter and composed mainly of cell walls and residual starch), and lastly, pea solubles or "pea mash" (with 35% dry matter).

The various co-products were incorporated at 20 to 25% of the total ration into a wheat-soybean meal based diet fed to growing pigs. The purpose of the study performed at the INRA's UMR SENAH was to estimate the digestive utilization of nutrients and the energy value of each of these co-products; peas were also included in the study.

Experimental design and methods

The study was performed at the INRA's UMR SENAH[1] at Saint-Gilles, in July 2004 for the animal measurements and in the autumn of 2004 for the laboratory analyses and calculations. The study was carried out using a factorial design based on the principle of incorporating 25% peas (D2) or pea bran (D3), 20% pea protein concentrate (D4) and the equivalent of 20% (based on a DM content of 87%) wet pea pulp (D5) or pea solubles (D6) into a basal diet (D1; wheat + soybean meal); five pigs per diet were used; an additional pig was assigned to diet 1. The digestive utilization of each diet was obtained using the difference method with measurements taken on the basal diet (wheat/soybean meal) and on the diets containing a portion of the basal diet and one of the products to be tested. Two of the products (pea pulp and pea solubles) have a very high moisture content and were introduced into the feed at the time of distribution; the rest

[1] Livestock Production Systems, Animal and Human Nutrition

of the ration was prepared at the same time as the other diets. The characteristics of the raw materials and the percentage and chemical composition of the diets are reported in tables 1 and 2, respectively.

Diets D1, D2, D3 and D4 were produced entirely at the INRA's experimental mill at St-Gilles. The co-products with a dry matter content of less than 35% (wet pea pulp and pea soluble), were introduced into the basal diet (D1) at the time of the distribution of the diet to the growing pigs. These two products (pea pulp and pea soluble) were maintained at 4°C for the duration of the trial.

Each diet was distributed to five castrated male Pietrain * pigs (Large White * Landrace) weighing approximately 50 kg at the start of the experiment; the animals were divided up into five blocks of six comparable animals on the basis of their live weight and in some cases their genetic origin (littermates). In order to increase the accuracy of the difference calculation, six animals were fed diet 1. The pigs were placed in digestibility cages and the experiment lasted 22 days with two successive periods of 12 and 10 days each, the first for the adaptation to the cages and to the experimental diets and the second for the precise measurement of ingested feed and the total daily collection of faeces and urine. The faeces were accumulated while the urine was weighed daily and an aliquot portion sampled.

Feed intake was increased gradually during the adaptation period reaching ingested quantities of approximately 2 kg per day at the start of the collection period. This feed intake was increased slightly during the collection period (to 2.2 kg the last four days). The average live weight was 54 kg at the start of the collection period and 63 kg at the end. At the end of the collection period, the faeces were weighed, homogenized and (i) freeze-dried for laboratory analysis and (ii) dried for the determination of dry matter content. Two samples of each diet were taken at the time of their distribution to the animals for the measurement of their dry matter content and for laboratory analysis.

Laboratory analysis of the raw materials, diets, faeces and urine was performed according to the methods normally used by our laboratory (Noblet et al., 1989).

The apparent digestibility coefficients of the organic matter, nitrogen and energy and the digestible energy (DE) and metabolizable energy (ME) content of the six diets were determined according to the usual methods (Noblet et al., 1989). The data on each diet were subjected to analysis of variance, taking feed effect (n=6) and block effect (n=6) into account. SAS software (1990) was used.

The digestive utilization of peas and pea co-products was calculated using the difference method, which assumes that the digestive utilization of the basal diet (Wheat/soybean meal) was not modified by the presence of peas and pea co-products.

Results and discussion

No problems were encountered during the experiment. No refusal was observed during the adaptation and collection stages. The average quantity of dry matter ingested was the same for all diets. Statistical analysis revealed a diet effect ($P<0.01$), which is no doubt due to a very slight variability in quantities ingested, in grams per day, for all pigs on each diet (respectively 13, 11, 20, 9, 15 and 7 g for diets D1, D2, D3, D4, D5 and D6). The live weight gain was also affected by the nature of the feed and in relation to both protein and energy intake. The highest value was obtained with diet D4, which is very rich in crude protein (Table 2). The nitrogen balance data (Table 3) are consistent with results obtained for weight gain.

The chemical properties of the diets are entirely consistent with expected values or, conversely, the characteristics of the raw materials calculated according to the difference method from data measured in the diets are consistent with the values measured directly in the raw materials. The preparation of the feedstuff was therefore perfect. The digestibility results obtained on the diets correspond relatively well with the characteristics of the diets: i.e. the lowest value for the diet richest in cell wall content (D3). The pea pulp based diet, which also has very high cell wall content, is nonetheless very digestible.

The digestibility results presented in table 5 were obtained using the difference method. The results obtained for peas agree with the data found in the literature for digestibility of organic matter and energy (INRA & AFZ Tables, 2004). However, the values obtained for nitrogen are distinctly higher than the value given in the tables (90 versus 85). Pea bran, which is rich in crude fibre (24%) and cell wall content, has the lowest level of digestibility for all the nutrients and energy. Pea protein and pea solubles are very digestible since the digestive utilization coefficients of organic matter, nitrogen and energy are respectively greater than 97% and 92%. Pea pulp, with its low protein content (9%), has a relatively low digestibility coefficient for nitrogen (76%), but the coefficients remain high for organic matter and energy (respectively 92 and 90%), (table 5). The combination of the product's energy digestibility data and gross energy content allows to calculate the DE and ME contents of the pea co-products; the NE value has also been calculated. In general, energy values are high, even for products rich in cell wall content. This confirms the relatively high digestibility of pea cell walls, which will be measured shortly.

Conclusions

This study allows us to quantify the faecal digestibility of organic matter, crude protein and energy of the main co-products derived from the production of pea starch. The values are particularly high, even when the products are rich in cell wall content. Pea bran and pea pulp can therefore be considered as very digestible sources of cell walls for pigs (and growing pigs in particular). The ileal digestibility of amino acids still needs to be measured to obtain a clear view of the nutritional value of pea co-products for pigs.

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Report prepared by Yolande Jaguelin-Peyraud and Jean Noblet

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Table 1: Chemical composition of raw materials

	Peas	Pea bran	Pea protein	Pea pulp	Pea solubles
DM content (%)[1]	88.1	88.6	92.9	22.7	32.1
Chemical composition (% DM)					
Mineral matter	3.17	3.44	4.53	2.66	16.22
Organic matter	96.83	96.56	95.47	97.34	83.78
Crude protein	24.16	17.67	85.15	9.27	35.66
Fat	0.93	1.01	4.32	0.45	0.04
Crude fibre	5.63	23.78	0.00	10.21	0.00
NDF	15.3	34.0	0.0	37.8	0.0
ADF	5.9	17.9	0.0	7.6	0.0
ADL	0.29	0.43	0.00	0.03	0.00
TDF (Prosky)	28.2	52.5	0.0	53.5	0.0
Starch (Ewers)	48.8	29.7	0.0	28.4	8.5
Enzymatic starch	43.3	27.4	0.1	32.7	5.2
Total sugars	6.6	3.9	0.0	0.6	37.7
Gross energy (MJ/kg DM intake)	18.44	18.12	23.85	17.85	16.99

[1] At the time of the preparation of feeds or their distribution to the animals

Table 2: Composition of the diets

	Diet					
	1	2	3	4	5	6
Ingredients composition (dry % dry)	82.26	60.88	60.80	64.45	64.93	65.54
Wheat 496	14.08	10.42	10.41	11.04	11.12	11.23
Soybean meal 495	0.00	**25.05**	0.00	0.00	0.00	0.00
Peas 535	0.00	0.00	**25.14**	0.00	0.00	0.00
Pea bran 534	0.00	0.00	0.00	**20.90**	0.00	0.00
Pea protein 536	0.00	0.00	0.00	0.00	**20.31**	0.00
Pea pulp 532	0.00	0.00	0.00	0.00	0.00	**19.56**
Pea soluble 533	1.34	1.33	1.33	1.32	1.33	1.34
Dicalcium phosphate	1.25	1.25	1.25	1.24	1.24	1.26
Calcium carbonate	0.51	0.51	0.51	0.50	0.51	0.51
Salt	0.56	0.56	0.56	0.56	0.56	0.57
Trace minerals and vitamins						
Chemical composition (% DM)						
Mineral matter	5.34	5.42	5.49	5.26	5.37	8.13
Total crude protein	17.97	19.30	17.22	31.94	16.30	21.56
Fat	1.46	1.27	1.25	2.00	1.17	1.04
Crude fibre	3.12	3.49	9.43	2.02	4.36	2.20
NDF	16.3	16.4	22.6	15.4	19.8	12.3
ADF	2.1	2.7	7.8	2.0	3.4	1.8
ADL	0.51	0.23	0.49	0.32	0.37	0.36
TDF	23.2	24.5	31.4	27.0	27.5	16.4
Starch (Ewers)	53.8	53.1	48.9	42.4	49.6	46.6
Enzymatic starch	51.0	50.5	43.6	40.8	48.6	43.6
Total sugars	6.2	5.1	4.1	3.5	3.6	10.1
Gross energy (MJ/kg DM)	17.92	17.98	17.82	19.07	17.82	17.56

Table 3: Growth performance

	Diet						Statistics[1]	
	1	2	3	4	5	6	RSD	Effect
Average live weight of animals, kg	57.9	59.6	59.0	60.9	57.8	58.3	2.3	B**
Dry matter intake, g/d	1872	1880	1879	1896	1882	1869	5.5	R**, B**
Average daily gain, g	842	928	876	1112	848	964	56	R**, B**
Feed conversion ratio (kg dry/kg gain)	2.25	2.04	2.15	1.71	2.25	1.94	0.13	R**, B**

[1] From the analysis of variance which takes into account the diet effect (D) and the block effect (B);
RSD: Residual standard deviation, D = diet effect, B = block effect; level of significance **: P<0.01

Table 4: Nitrogen balance and digestive utilization of the diets

	Diet						Statistics[1]	
	1	2	3	4	5	6	RSD	Effect
Nitrogen balance (g/d)								
Ingested	53.8	58.1	51.8	96.9	49.1	64.5	0.2	R**
Fixed	22.0	27.8	23.7	35.7	22.9	29.7	2.1	R**
Digestibility coefficient (%)								
Dry matter	88.3	88.3	85.6	90.0	88.4	89.2	1.2	R**
Organic matter	90.2	90.2	87.9	91.7	90.4	90.7	1.1	R**
Total crude protein	87.3	87.9	81.7	92.9	85.4	88.5	1.6	R**
Energy	88.2	87.9	84.9	90.5	88.2	88.7	1.3	R**
Energy values (MJ/kg DM)								
Digestible energy	15.79	15.81	15.14	17.25	15.72	15.57	0.24	R**
Metabolizable energy	15.21	15.25	14.65	16.30	15.23	14.82	0.23	R**
Digestible components (g/kg DM)								
Organic matter	854	853	831	870	855	833	11	R**
Total crude protein	157	170	141	297	139	191	3	R**

[1] From the analysis of variance which takes into account the diet effect (R) and the block effect (B);
RSD: Residual standard deviation, D = diet effect, B = block effect; level of significance **: P<0.01

Table 5: Nutritive value of peas and pea co-products

	Peas	Pea bran	Pea protein	Pea pulp	Pea solubles
Digestibility coefficient (%)					
Organic matter	90.7	81.9	97.9	91.8	93.8
Crude protein	90.3	64.6	97.8	75.9	92.0
Energy	88.4	76.7	98.0	89.9	92.6
ME/DE ratio	96.6	98.1	89.9	98.7	90.0
Energy value (MJ/kg DM)					
Digestible energy	16.66	13.97	23.57	16.26	15.56
Metabolizable energy	16.10	13.71	21.18	16.05	14.01
Net energy[1]	11.53	8.78	13.36	11.23	9.65

[1] Calculated from equation EN4 (Noblet et al., 1994)