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Ileal digestibility of pea and faba bean carbohydrates in growing pigs*

Jolanta Gdala and Lucyna Buraczewska

The Kielanowski Institute of Animal Physiology and Nutrition,
Polish Academy of Sciences
05-110 Jabłonna, Poland

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ABSTRACT

The experiment was carried out on six pigs with an initial body weight of about 34 kg. The pigs were fitted with a simple T-shape cannula and fed on six semisynthetic diets containing sucrose and legume seed meal as the main components. Faba bean (cvs Kamir and Alen), white-flowered pea (cvs Kwestor and Sol) and coloured-flowered pea (cvs Fidelia and Vatra) seeds were the only source of polysaccharides and protein for the experimental animals.

Ileal digestibility of pea starch ranged from 85 to 87% and was similar for all the tested cultivars. The starch digestibility of faba bean was 86% for cv Alen and 82% for cv Kamir. Digestibility of pea and faba bean protein varied from 70 to 74%, α-galactosides of faba beans were microbiologically hydrolyzed up to 83%, and those of pea seeds up to 93% in the small intestine. Digestibility of non-starch polysaccharides averaged 39% for faba beans and from 27 to 43% for the pea cultivars. No differences were found between the two types of pea, indicating that tannins of the coloured-flowered pea did not interfere with ileal digestion of major nutrients fed to pigs.

KEY WORDS: pea, faba bean, ileal digestibility, pigs, carbohydrates

INTRODUCTION

Dietary nutrients, except cell wall polysaccharides, are extensively digested and absorbed in the small intestine of pigs. Most cell wall polysaccharides can be degraded only by microbial enzymes, mainly in the hindgut. The extent of the

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pre-caecal and post-ileal digestion of nutrients results in differences in the utilisation of energy. In pigs energy utilisation falls as the proportion of post-ileal fermentation to pre-caecal digestibility raises (Just et al., 1983).

Starch is thought to be completely digested up to the end of the small intestine of monogastric species. However, in the observations of Gdala et al. (1991) on digestibility of polysaccharides in pigs fed on diets containing 52 and 42% barley and pea seeds, respectively, ileal digestibility of starch ranged from 85 to 93 per cent. Assuming that cereal starch is highly digestible, over 97% according to Bach Knudsen (1991), these results can suggest much lower digestibility of pea starch as compared to cereal starch. Also the results of assessing starch bioavailability in the upper gastrointestinal tract of colectomized rats indicated highly significant differences in food starch digestibility. It was reported that 15.2% of pea starch, but only 0.2% of that from rice, was recovered in the ileal digesta of rats (Hildebrandt and Marllet, 1991).

Pea and faba bean are known to contain different factors that affect their nutritional value. Among them tannins have often been described as the most important from the nutritional point of view. They are known to form complexes with dietary protein reducing its digestibility and/or inhibiting the activity of digestive enzymes (Jansman et al., 1992).

The aim of the present experiment was to study the ileal digestibility of starch and other carbohydrates of pea and faba beans in pigs fed on diets in which the legume seeds were the only, except sucrose, source of carbohydrates. For comparison, enzyme susceptible starch was determined *in vitro*.

MATERIAL AND METHODS

Seeds

Seeds of two cultivars (Kamir and Alen) of faba bean (*Vicia faba* L.), two cultivars (Kwestor and Sol) of white-flowered pea (*Pisum sativum hortense*), and two cultivars (Fidelia and Vatra) of coloured-flowered pea (*Pisum sativum arvense*) were used in the present study. Pea seeds originated from the Plant Breeding Stations at Wiatrowo and faba beans from The Plant Breeding Station at Szelejewo. Both stations are located in Western Poland.

Animals

The experiment was carried out on six castrated male pigs (Polish Landrace) from 34 to 64 kg body weight. Following five days adaptation to the cages, the pigs were surgically fitted with a post valvular T-caecum (PVTC) cannula

according to van Leeuwen et al. (1991). After a recovery period of seven days the pigs were fed for two weeks on faba bean diets. Afterwards, the pigs were adapted to pea diets (7 days) and fed on them for the next four weeks. Both experiments were carried out according to a change-over design (each diet was given to 6 pigs). Ileal digesta was collected during the last three days of feeding each experimental diet.

Diets

Pigs were fed on semisynthetic diets containing sucrose and legume seed meals as the main components (Table 1). The level of faba bean and pea included into the diets supplied 160 g kg^{-1} of protein. The feeding level was equal to 3 times the pigs' maintenance requirement for metabolisable energy (ARC, 1981). Diets were fed in meal form, twice a day at 8:00 and 20:00 h, mixed with water at a ratio of 1:1.

TABLE 1

Composition of the experimental diets, g/kg

Components	Faba bean		Pea			
	Kamir	Alen	Kwestor	Sol	Fidelia	Vatra
Faba bean	620.00	620.00	–	–	–	–
Pea	–	–	737.70	831.20	782.80	802.40
Sucrose	327.48	327.48	204.79	111.29	159.69	140.09
Soya oil	10.00	10.00	10.00	10.00	10.00	10.00
Mineral-vitamin mixture	38.00	38.00	43.00	43.00	43.00	43.00
Chromium oxide	3.00	3.00	3.00	3.00	3.00	3.00
DL-Met	1.40	1.40	1.26	1.26	1.26	1.26
DL-Trp	0.12	0.12	0.25	0.25	0.25	0.25

Digesta collection

Ileal digesta was collected for 12 h per day (8.00-20.00 h) using plastic bags connected to the cannulas. The bags were changed at least every hour and their contents were immediately frozen in plastic containers at -20^{0}C. After completion of the collections, samples were thawed, pooled per animal within each experimental period, freeze-dried and ground (0.5 mm) before chemical analysis.

Analytical procedures

Dry matter (DM), crude protein (N x 6.25), ether extract, crude fibre (CF), total starch and ash were analysed using standard methods (AOAC, 1990).

Enzyme susceptible starch was determined according to procedure of Megazyme, Australia (TSA/92). The content of neutral detergent fibre (NDF), acid detergent fibre (ADF) and acid detergent lignin (ADL) was determined using Fibertec System M by methods described by Van Soest and Wine (1967) and Van Soest (1973). Sucrose, α-galactosides (raffinose, stachyose and verbascose), total non-starch polysaccharides (NSP) and their constituent sugars were determined according to methods described in our earlier publication (Gdala and Buraczewska, 1996). Condensed tannins were determined according to the procedure of Kuhla and Ebmeier (1981).

Statistical analysis

The ileal digestibility values for dry matter, protein, fibre fractions, oligosaccharides and NSP in faba beans and pea seeds were statistically analysed using analysis of variance taking into account as a factor the faba bean or pea cultivar. Statistical analysis was performed using Statgraphics Plus v. 7.0 (1993).

RESULTS AND DISCUSSION

Chemical composition of faba bean and pea seeds

The chemical composition of the tested faba beans and peas is presented in Table 2. The content of crude protein, total starch and enzyme susceptible starch was similar in the tested cultivars of faba bean and accounted on average for 295, 413 and 355 g kg^{-1}, respectively. As determined, the enzyme susceptible starch constituted 86% of total starch. No significant differences between faba beans were found in the content of NSP, NDF, ADF or ADL. Cellulose, calculated as the difference between ADF and ADL, constituted a considerable proportion (about 92 g kg^{-1} DM) of faba bean cell wall polysaccharides. Hemicelluloses were found at low level of 27 and 28 g kg^{-1} DM for cv Kamir and Alen, respectively. Slightly higher levels of hemicelluloses in faba bean (about 40 g kg^{-1} DM) were reported previously by Cerning-Beroard and Filiatre (1976). The content and chemical composition of faba bean NSP was similar to that presented by Gdala and Buraczewska (1997).

No evident differences in the composition, but tannin content, were observed between white- and coloured-flowered varieties of pea. In comparison with the faba bean cultivars the peas contained less protein (220-224 g) but more total starch (443-501 g) with a similar mean proportion (86%) of the enzyme-susceptible one. The crude protein level in pea seeds was within the range of values (145-280 g kg^{-1} DM) presented by Gdala et. al. (1992). However, the

TABLE 2

Chemical composition of faba beans and pea seeds, g/kg DM

Indices	Faba bean		Pea			
	Kamir	Alen	Kwestor	Sol	Fidelia	Vatra
Weight of 1000 seeds, g	610	563	238	256	186	184
Dry matter	878	881	890	875	887	886
Crude protein	298	292	244	220	231	225
Ether extract	15	10	12	15	13	14
Crude fibre	87	101	57	60	60	61
Ash	37	38	31	33	34	301
Total starch	418	408	475	481	443	501
Enzyme susceptible starch	360	350	400	439	383	381
α-Galactosides	24	31	64	48	63	66
Fibre fraction:						
NSP	209	208	167	178	183	163
NDF	142	145	132	139	157	143
ADF	115	117	81	85	88	87
ADL	18	24	4	5	10	8
hemicelluloses	27	28	50	54	68	56
Tannins	6.70	5.92	0.37	0.38	6.29	4.62

TABLE 3

Content of oligosaccharides and non starch polysaccharides (NSP) in faba beans and pea seeds, g/kg DM

Components	Faba bean		Pea			
	Kamir	Alen	Kwestor	Sol	Fidelia	Vatra
Oligosaccharides:						
sucrose	22.8	27.0	21.3	27.6	18.8	14.2
raffinose	2.7	3.7	10.4	10.0	7.9	8.4
stachyose	7.7	9.4	38.3	22.4	33.7	38.6
verbascose	13.2	17.6	14.8	15.9	21.1	18.8
total α-galactosides	23.6	30.7	63.5	48.2	62.7	65.8
NSP:						
rhamnose	2.6	2.3	1.7	1.9	1.2	1.5
fucose	0.1	0.1	0.6	0.7	0.7	0.7
arabinose	35.1	33.5	34.7	33.4	35.9	29.6
xylose	31.5	22.9	15.8	12.2	11.4	11.1
mannose	1.1	1.8	1.3	1.8	1.6	1.5
galactose	17.7	18.8	14.3	14.8	15.8	14.2
glucose	94.0	94.9	75.1	80.9	92.4	79.7
uronic acids	27.2	33.7	23.1	31.9	23.7	24.5
total NSP	209.3	208.0	166.7	177.6	182.6	162.6

content of total starch was higher than that in peas (410-436 g kg^{-1} DM) used in the study of Bengala Freire et al. (1991), but similar to that in peas introduced in pig diets used by Abrahamsson et al. (1993) in a digestibility experiment. Of the fibre fractions, peas contained less NSP (163-183 g), ADF (81-88 g) and ADL (4-10 g) but more hemicelluloses (50-68 g) than the faba beans. Similarly in both species, the monosaccharide residues of glucose, arabinose and uronic acids dominated in the NSP fraction (Table 3). Faba beans contained the relatively lowest level of α-galactosides (24 and 31 g kg^{-1} DM) among legume seeds, which is in agreement with literature data (Sosulski et al., 1982). An α-galactoside level nearly double that of faba beans was found in peas (48-66 g). Some differences were also observed in their composition: verbascose was dominant in faba beans, while stachyose and verbascose in peas, which supports our previous results (Gdala and Buraczewska, 1997).

Ileal digestibility of pea and faba bean nutrients

Ileal digestibility of crude protein of pea seeds and faba beans was similar and ranged from 70 to 74% (Tables 4 and 5), although the content of condensed tannins in seeds of white-flowered peas was significantly lower (on average 0.38 g kg^{-1} DM) than that in coloured-flowered peas (5.46 g kg^{-1} DM) and faba beans (6.32 g kg^{-1} DM). Therefore, it seems that in the present experiment condensed tannins did not considerably affect protein digestibility in seeds of coloured-flowered peas and faba beans. The digestibility coefficients of protein are in agreement with values previously reported by Grala et al. (1993).

The average ileal starch digestibility was 86% in peas and 84% in faba beans. The digestibility values are similar to the proportion of the enzyme-susceptible starch in total digestibility (about 86%). According to Colonna and Mercier (1979) peas are characterized by the presence of about 20% of resistant starch. However, other authors (Bengala Freire et al. 1991a) found under 6% undigested pea starch or about 5% undigested faba bean starch at the ileal level of pigs. Somewhat lower ileal digestibility of starch (about 90%) could be predicted for two peas basing on the data received by Abrahamsson et al. (1993). The low digestibility of pea starch (76%) found by Longstaff and McNab (1987) in an experiment on adult cockerels was attributed to poor contact between enzyme and starch in the birds digestive tract. According to Hildebrandt and Marllet (1991) raw starch of legume seeds may resists digestion to some extent in the small intestine of nonruminant animals. This is probably related to starch nature, physical entrapment of starch within a food and retrogradation through food processing (Würsch et al., 1986; Colonna et al., 1992). Legumes contain 30 to 40% amylose and 60 to 70% amylopectin in their starch granules, while most other carbohydrate foods contain 15 to 25% amylose and 75 to 85% amylopectin

TABLE 4

Ileal digestibility of dry matter, crude protein and fibre fractions in pigs fed on pea diets, %

Components	Diet				SEM	P≤
	Kwestor	Sol	Fidelia	Vatra		
Dry matter	68.8	65.7	66.4	65.4	0.64	0.142
Crude protein	71.7	74.0	71.3	69.9	0.57	0.110
Total starch	85.6	85.2	87.3	86.6	0.71	0.718
Fibre fraction:						
NSP	36.6^{ab}	43.1^{a}	36.7^{ab}	26.6^{b}	1.34	0.004
NDF	48.9^{a}	48.8^{a}	31.7^{b}	42.5^{a}	1.38	0.001
ADF	25.2	21.0	21.3	21.7	1.32	0.378
hemicelluloses	71.8^{a}	71.0^{a}	48.0^{b}	67.1^{a}	2.00	0.010

^{a,b} – P≤0.05

TABLE 5

Ileal digestibility of dry matter, crude protein and fibre fractions in pigs fed on faba bean diets, %

Components	Diet		SEM	P≤
	Kamir	Alen		
Dry matter	72.4	71.8	0.36	0.376
Crude protein	71.3	70.3	0.67	0.898
Total starch	81.5	86.4	0.91	0.060
Fibre fraction:				
NSP	38.3	39.2	1.80	0.056
NDF	20.2	25.6	1.04	0.066
ADF	16.3	16.8	2.03	0.568
hemicelluloses	31.0	56.4	1.51	0.224

(Nowotny, 1969). Sandstedt et al. (1962) reported that raw wrinkled pea starch with 65% amylose was less susceptible to pancreatic digestion than maize starch containing from 0 to 47% amylose. Moreover, the rate of hydrolysis of high amylose (63%) maize starch *in vitro* was less than that of the normal one (25%). Thorne et al. (1983) suggested that the difference in the digestibility rate between amylose and amylopectin starches may be due to the larger surface area of amylopectin which, therefore, is more available for amylolytic attack. The digestion rate of purified starch from bean and pea *in vitro* was slower than that of rice (Würsch et al., 1986). Also homogenized/autoclaved pea products showed higher levels of undigestible starch than potato products, which is probably related to the higher amylose/amylopectin ratio in pea than in potato starch (Björck and Siljeström, 1992).

TABLE 6

Ileal digestibility of oligosaccharides and non-starch polysaccharides (NSP) in pigs fed on pea diets, %

Components	Diet				SEM	P≤
	Kwestor	Sol	Fidelia	Vatra		
Oligosaccharides:						
sucrose	97.4[ab]	98.1[a]	96.1[a]	94.9[b]	0.33	0.013
raffinose	92.2[a]	85.7[a]	59.8[b]	83.6[a]	1.66	0.001
stachyose	94.6[a]	86.3[ab]	79.7[b]	92.6[ab]	1.63	0.023
verbascose	90.3[a]	88.9[a]	77.5[b]	92.0[a]	1.21	0.003
total α-galactosides	93.2[a]	87.1[a]	73.8[b]	91.3[a]	1.14	0.001
NSP:						
arabinose	34.0[a]	38.7[a]	27.6[ab]	14.1[b]	2.45	0.014
xylose	24.1[ab]	28.4[a]	23.2[ab]	12.7[b]	1.58	0.041
galactose	36.3[b]	53.4[a]	39.6[ab]	48.9[ab]	1.72	0.008
glucose	45.7[a]	53.7[a]	43.1[a]	29.2[b]	1.38	0.001
uronic acids	38.2	33.4	35.2	34.1	1.22	0.574

[a, b] – P≤0.05

TABLE 7

Ileal digestibility of oligosaccharides and non-starch polysaccharides (NSP) in pigs fed on faba bean diets, %

Components	Diet		SEM	P≤
	Kamir	Alen		
Oligosaccharides:				
sucrose	97.7	98.7	1.15	0.279
raffinose	68.4	77.7	5.90	0.456
stachyose	72.2	78.4	7.70	0.702
verbascose	73.3	83.2	5.54	0.428
total α-galactosides	75.1	82.7	5.98	0.547
NSP:				
arabinose	45.1	42.3	2.21	0.547
xylose	63.8	55.6	1.57	0.029
galactose	60.9	62.4	1.05	0.503
glucose	31.5	34.0	1.89	0.012
uronic acids	15.6[b]	36.2[a]	2.47	0.003

[a, b] – P≤0.05

As concerns pea fibre fractions, the coloured-flowered peas showed somewhat lower digestibility than the white-flowered cultivars. The lowest NSP digestibility (27%) was observed after feeding cv Vatra, but the lowest disappearance of NDF (32%) and hemicelluloses (48%) was noted for cv Fidelia. The degree of fermentation of faba bean NSP was similar to that observed for peas. However,

NDF and ADF were degraded to a much lesser extent, on average 23 and 17%, respectively. In the study of Shi and Noblet (1994), the mean ileal digestibility of NDF and ADF in pigs (44 kg body weight) fed on six cereal-based diets (the average content of NDF and ADF was 151 and 63 g/kg DM^{-1}) was about 16 and 4%, respectively. Differences between the tested legume species are also reflected in the rate of disappearance of NSP monosugars; that of xylose and galactose was much higher for faba bean than for pea (Tables 6 and 7). In the case of the peas, xylose digestibility appeared to be lower than other NSP components. Drochner (1984), demonstrated a certain breakdown of NSP, such as hemicelluloses and pectic substances in the stomach and in the small intestine of pigs.

All α-galactosides were intensively fermented in the small intestine of pigs. Their digestibility ranged from 74 to 93% for peas and was lowest ($P < 0.001$) for cv Fidelia. Despite the lower level of these oligosaccharides in field beans than in pea seeds, their loss was similar and accounted for 75 and 83% for cvs Kamir and Alen, respectively. Generally, the present results are consistent with those found for peas (Bengala Freire et al., 1991a) and for lupins (Gdala at al., 1997) and prove the intensive breakdown of α-galactosides in the upper part of pig's digestive tract after feeding legume seeds.

CONCLUSIONS

Peas and faba beans are potentially useful sources of energy and protein in pig feeding. The level of starch is high and ranges from 400 to 500 g/kg^{-1} DM, however, from 13 to 18% of the legume seed starch was resistant to enzymatic digestion in the small intestine. The level of α-galactosides is higher in pea seeds than in faba beans and these sugars are easily fermented already in the small intestine, which can be a cause, of flatulence in pigs. Among fibre fractions, ADF, NDF and hemicelluloses of pea varieties were fermented to a greater extent than those of faba beans. Although the level of condensed tannins was much higher in coloured-flowered field beans and peas than in white-coloured peas, no differences were found in protein or starch digestibility between these legumes.

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STRESZCZENIE

Strawność węglowodanów bobiku i grochów do końca jelita cienkiego świń

Doświadczenie przeprowadzono na sześciu świniach o początkowym ciężarze ok. 34 kg. Świnie, z przetokami przy końcu jelita cienkiego, żywiono przemiennie sześcioma półsyntetycznymi mieszankami składającymi się głównie z cukru i ze śrut różnych odmian nasion bobiku (Kamir i Alen), grochu (Kwestor i Sol) lub peluszki (Fidelia i Vatra). Nasiona badanych odmian były jedynymi źródłami wielocukrów i białka w dietach doświadczalnych.

Strawność skrobi grochu i peluszki była podobna (85-87%), a bobiku w odmianie Kamir i Alen wyniosła odpowiednio 82 i 86%. Strawność białka wszystkich strączkowych wahała się od 70 do 74%. W jelicie cienkim α-galaktozydy bobiku uległy fermentacji bakteryjnej do 83%, a grochu i peluszki – do 93%. Strawność jelitowa wielocukrów nieskrobiowych badanych odmian wynosiła średnio około 39%, a grochu i peluszki od 27 do 43%. Ogólnie, nie stwierdzono różnic w strawności jelitowej głównych składników pokarmowych między peluszką i grochem, różniących się zawartością tanin.