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Chemical composition and carbohydrate content of several varieties of faba bean and pea seeds*

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ABSTRACT

The chemical composition of mature whole seeds of four cultivars of faba bean (*Vicia faba* L.), seven cultivars of white-flowered pea (*Pisum sativum hortense* L.) and two cultivars of coloured-flowered pea (*Pisum sativum arvense* L.) was determined with special emphasis on carbohydrates. The average content (per kg DM) of total and enzyme-susceptible starch in faba beans, white- and coloured-flowered peas was 430 and 367 g, 461 and 419 g, and 459 and 390 g, respectively. Faba beans contained less α-galactosides (28 vs. 58 g) than peas. Verbascose was the main constituent (16 g on average) of faba bean α-galactosides, while verbascose (26 g) and stachyose (24 g) were the major α-galactosides in pea seeds. Faba beans contained, on average, 177 g non-starch polysaccharides (NSP), while the level of these polysaccharides in pea seeds amounted to 183 g. In faba beans and in pea seeds, NSP were composed mainly of glucose, arabinose and uronic acids. In general, there were no significant differences among cultivars within each species in terms of NSP content and their chemical composition.

KEY WORDS: faba bean, pea, carbohydrates, composition

INTRODUCTION

Although the nutritional value of faba beans and peas is lower than that of a good quality soyabean meal, these legumes are an important source of supplemental protein in animal diets. The content and amino acid composition

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of protein in faba beans and peas have been widely reported in literature (Marquardt et al., 1975; Thacker and Bowland, 1985). The toxic compounds present in faba beans and peas that adversely affect the availability and utilization of nutrients are also well characterized (Griffiths, 1983; Savage, 1989). But only little information is available on the seed carbohydrate composition (Cerning-Breoard and Filiatre, 1976; Dandanell and Åman, 1993) and their nutritional value (Longstaff and McNab, 1987). Therefore, the present study was undertaken to characterize the chemical composition of faba beans and peas with special reference to carbohydrates. The nutrient contents were evaluated in cultivars of *Vicia faba, Pisum sativum hortense* and *Pisum sativum arvense* for three consecutive years of growth.

MATERIAL AND METHODS

Seeds

Seeds of four cultivars (Alen, Kamir, Martin, Tibo) of faba bean (*Vicia faba* L.), seven cultivars (Diament, Kama, Kwestor, Piast, Sol, Jaran, Ametyst) of white-flowered pea (*Pisum sativum hortense* L.) and of two cultivars (Grapis, Fidelia) of coloured-flowered pea (*Pisum sativum arvense* L.) were used in the present study. With the exception of Jaran pea (a leafless cultivar) and Ametyst (green seeds) other white-flowered peas had typical leaves and smooth, white seeds. Five-kilogram samples of seeds were taken from five Plant Breeding Stations located in different regions of Poland. Every cultivar originated from the same station for three consecutive years of collection.

Analytical procedure

Dry matter (DM), nitrogen (N), fat, ash, crude fibre (CF), and total starch were analyzed using standard methods (AOAC, 1990). Enzyme susceptible starch was determined according to the procedure of Megazyme (TSA 9/92). The samples were heated in the presence of thermostable α-amylase under controlled conditions and the reaction was terminated with 2 ml of 0.2% sulphuric acid. The content of neutral detergent fibre (NDF), acid detergent fibre (ADF), acid detergent lignin (ADL), hemicellulose, cellulose, sucrose, α-galactosides and total NSP and their constituent sugars were determined according to methods described in our earlier publication (Gdala and Buraczewska, 1996). Condensed tannins were analyzed by the vanillin method according to Kuhla and Ebmeier (1981). Activity of trypsin inhibitors was determined by the method of Kakade et al. (1974), as modified by van Oort et al. (1989) for faba been analysis. The results

are expressed in trypsin inhibitor units per mg dry matter (TUI/mg DM) which is defined as the quantity of enzyme which induces an increase of 0.01 in absorbance.

Statistical analysis

The average over three years and standard deviation were calculated for each analyzed component of faba bean and pea seeds. The data were statistically analyzed using multifactorial analysis of variance taking into account as the factors the effect of cultivar within each species and year of growth (Statgraphics Plus v. 7.0, 1993).

RESULTS AND DISCUSSION

Vicia faba

The weight of one thousand beans ranged from 464 to 497 g and was lower than that reported by Griffiths (1981) (425-814 g). Neither cultivar nor year of growth influenced the weight of faba beans (Table 1). In contrast, both factors significantly affected the content of crude protein, which ranged from 277 to 306 g per kg DM. A higher level of crude protein (310-330 g/kg DM) in eight cultivars of faba bean was reported by Marquardt et al. (1975). A comparison of the basic composition of four cultivars of faba bean indicated no significant differences among them in the content of ether extract (13-15 g), ash (33-38 g), total starch (405-445 g), enzyme susceptible starch (347-378 g), NSP (173-181 g), NDF (139-155 g), ADF (110-116 g) and CF (74-83 g). It was observed, however, that the year of growth significantly affected the content of ether extract and ADL in faba beans. Hemicellulose, in comparison with cellulose (about 100 g), constituted only a small proportion (24-45 g) of faba bean dry matter. Cerning-Bernard and Filiatre (1976) found about 40 g of hemicellulose in faba bean cv. Bianka.

Faba beans contain several anti-nutritional factors, mainly tannins and trypsin inhibitors, which may impair animal performance if their dietary level is too high. Tannins (catechin equivalent), located mainly in the seed coats, were found to be present in a range from 7.8 to 9.8 mg/g DM. The level of these undesirable factors depended ($P=0.032$) on the year of growth. The levels of condensed tannins in faba beans reported by Telek and Miklas (1993) ranged from 4.1 to 5.6 mg/g DM. In contrast, Saini (1993) found only 1.01-1.85 mg/g of these compounds in nine cultivars of faba beans. In this case, however, the assay procedure was different than that used in the current study. There is evidence that

TABLE 1

Chemical composition of faba beans, g/kg DM

	Faba bean				SEM	Effect of	
	Alen	Kamir	Martin	Tibo		year	cultivar
n	3	3	3	3		P<	
Weight of 1000 seeds, g	489	497	464	491	11.24		
Dry matter	874	891	894	884	4.40		
Crude protein	297	306	277	282	5.80	0.001	0.012
Ether extract	14	13	15	13	0.21	0.001	
Ash	36	34	33	38	0.51		
Total starch	436	405	445	434	5.50		
Enzyme susceptible starch	378	347	373	377	4.70		
Fibre fraction:							
NSP	177	173	175	181	0.96		
NDF	139	140	155	142	3.46		
ADF	116	112	110	111	2.02		
CF	83	80	79	74	1.20		
ADL	14	10	10	8	0.62	0.002	
hemicellulose	24	27	45	31	3.75		
cellulose	101	102	100	102	2.19		
Antinutritional factors:							
tannins, mg/g	8.2	7.8	9.8	8.9	0.24	0.032	
trypsin inhibitors TIU/mg	1.8	1.8	1.6	1.6	0.40		

the presence of tannins in a diet may decrease the apparent protein digestibility in pigs (Jansman et al., 1992). However, the tannin/protein interactions may be specific for different tannins as well as for different proteins (Asquith and Butler, 1986). One of the main antinutritive effects of trypsin inhibitors in a diet is overstimulation of the exocrine activity of the pancreas (Savelkoul et al., 1992). Trypsin inhibiting activity did not vary considerably (1.6-1.8 TUI/mg DM) among the tested cultivars. Valdebouze et al. (1980), also using the Kakade (1974) method, but with different modifications, reported higher trypsin inhibitor levels (3.3 to 6.2 TUI/mg DM) and their greater variability among cultivars of faba beans.

The content and chemical composition of oligosaccharides and non-starch polysaccharides is given in Table 2. The mean sucrose values for cultivars ranged from 14.1 to 16.7 g/kg DM, which on average constituted 36% of the determined oligosaccharides. It was shown that cultivar and year of harvest highly influenced the sucrose content. A similar content of sucrose (16.7 g/kg DM) was found in dehulled beans (Dandanell Daveby and Åman, 1993). In the present study

TABLE 2
The content and chemical composition of oligosaccharides and non-starch polysaccharides (NSP) in faba beans, g/kg DM

	Faba bean				SEM	Effect of	
	Alen	Kamir	Martin	Tibo		year	cultivar
n	3	3	3	3		P<	
Oligosaccharides:							
sucrose	15.1	14.1	15.1	16.7	0.25	0.005	0.053
galactopinitol	1.5	1.4	1.4	1.8	0.05		
galactoinositol	1.0	0.9	0.9	1.0	0.03		
raffinose	2.1	1.8	2.3	2.2	0.06		
stachiose	6.6	5.9	7.3	6.8	0.10	0.006	0.016
verbascose	15.8	13.8	17.8	18.1	1.14		
total α-galactosides	26.9	23.8	29.8	29.8	1.26		
total oligosaccharides	42.0	37.9	44.9	46.6	1.98		
NSP:							
rhamnose	2.3	1.3	1.5	1.9	0.10	0.023	0.041
fucose	0.9	0.7	0.9	0.9	0.10		
arabinose	23.8	23.3	24.3	22.3	0.64		
xylose	12.3	13.8	15.3	14.8	0.33	0.023	
mannose	6.2	2.7	2.1	3.1	0.55		
galactose	12.8	10.8	10.6	10.3	0.76		
glucose	92.6	95.9	94.4	102.1	1.15		
uronic acids	25.8	24.8	25.4	25.6	0.65		
total NSP	176.8	173.3	174.5	181.2	0.96		

verbascose accounted for 59% and stachyose for 24% of total α-galactosides in faba beans. The level of stachyose in beans depended on both the cultivar and the year of harvest. The raffinose content was low (about 8% of α-galactosides) and similar in all cultivars. The results of a study by Dandanell Daveby and Åman (1993) indicated that verbascose and raffinose were the dominating α-galactosides in dehulled faba beans. The tested beans also contained small quantities of galactopinitol and galactoinositol, which is in agreement with the results of Sosulski et al. (1982). Fifty-five percent of whole faba bean NSP was glucose. The average proportions of other NSP constituents, uronic acids (14%), arabinose (13%), xylose (8%) and galactose (6%) were in the intermediate range, while mannose (2%), rhamnose (1%) and fucose (0.5%) were minor sugar residues. In dehulled faba beans, arabinose, glucose and uronic acids were the main NSP residues, while hull fibres were chiefly composed of glucose and, to a lesser extent, of uronic acids, xylose and Klason lignin (Dandanell Daveby and Åman, 1993).

Pisum sativum

Pisum sativum hortense. The chemical composition of smooth seeds of white-flowered peas is presented in Table 3. The weight of 1000 seeds ranged from 146 to 272 g and significantly differed among cultivars. The seeds contained from 220 to 273 g/kg DM of crude protein, and the difference among cultivars was significant. The crude protein content reported by Hove et al. (1978) ranged from 205 to 226 g/kg DM. There are numerous causes of variability in the content of crude protein, including genetic (variety), cultural and environmental (soil, climate) origins (UNIP-ITCF, 1995). Starch is the most abundant component of peas. The content of total (444-520 g/kg DM) and enzyme susceptible (391-447 g/ kg DM) starch in pea seeds significantly differed among cultivars. Despite this, the average total starch level was similar to that (480 g/kg) determined by Cerning-Bernard and Filiatre (1976). According to Colonna et al. (1992) pea starch contained 33.2% amylose and 64.7% amylopectin.

Significant differences in the content of ether extract were observed among harvest years of peas. Pea seeds contained from 160 to 201 g of NSP and from 106 to 132 g of NDF per kg of dry matter, but the differences in the content of the fibre fractions either among cultivars or years were not significant. Statistically significant differences among cultivars were observed in the content of ADF and CF. Similarly, the level of cellulose (55-80 g/kg DM) in seeds was influenced by both cultivar and year of growth. Peas had from 24 to 49 g/kg DM hemicelluloses. Cerning-Bernard and Filiatre (1976) determined somewhat more (50.6 g/kg DM) hemicelluloses in pea seeds.

Seeds of white-flowered pea cultivars contained rather low levels of condensed tannins (about 0.4 mg/g DM). This confirms an earlier observation of Griffiths (1981), who reported 0.6 mg/kg DM of these compounds in seeds of white-flowered peas. Trypsin inhibitor activity was below 4 TUI/mg DM in the tested peas. Similar values (mostly below 3 TUI/mg DM) were determined in spring varieties of pea by Leterme et al. (1990).

Pea contains considerable amounts of oligosaccharides, ranging from 77.0 to 92.4 g/kg DM (Table 4). The major ones are sucrose, representing on average 32% of total oligosaccharides, and the α-galactosides. The latter, of which the principal ones are stachyose (18.1-33.1 g), verbascose (15.9-34.5 g) and raffinose (4.9-9.5 g/kg DM), were found in the range from 53.4-62.6 g/kg DM. This is in accordance with results of Cerning-Bernard and Filiatre (1976), who reported a similar proportion of α-galactosides in smooth peas. These α-galactosides of legume seeds are responsible for flatulence, particularly in pigs. However, while this association has been made in the case of lupins and faba beans, it has not been proved in peas (UNIP-ITCF, 1995).

TABLE 3

Chemical composition of round seeds of withe-flowered peas, g/kg DM

	White-flowered peas							SEM	Effect of	
	Diament	Kama	Kwestor	Piast	Sol	Jaran[1]	Ametyst[2]		year	cultivar
n	3	3	3	3	3	3	3		P<	
Weight of 1000 seeds, g	239	181	249	272	263	146	261	4.66		0.001
Dry matter	897	905	905	869	892	896	899	1.27		
Crude protein	220	273	235	222	226	241	230	3.78		0.039
Ether extract	13	13	12	15	15	15	15	0.39	0.021	
Ash	30	34	32	32	32	34	33	0.36		
Total starch	497	476	470	520	469	444	449	3.48		0.001
Enzyme susceptible starch	447	414	391	461	422	397	403	3.85		0.003
Fibre fraction:										
NSP	160	182	164	201	182	201	183	4.04		
NDF	114	112	128	106	128	132	109	3.54		
ADF	72	75	82	78	82	83	76	1.23	0.016	
CF	55	56	61	59	58	61	59	0.83	0.007	
ADL	3	4	3	5	3	3	2	0.27		
hemicellulose	42	37	46	28	24	49	33	2.83		
cellulose	70	71	79	74	55	80	74	1.08	0.004	0.001
Antinutritional factors:										
tannins, mg/g	0.33	0.34	0.38	0.36	0.43	0.40	0.40	0.01		
trypsin inhibitors, TIU/mg	3.6	2.6	3.0	2.7	2.8	3.7	2.9	0.15		

[1] leafless pea
[2] green seeds

TABLE 4

The content and chemical composition of oligosaccharides and non-starch polysaccharides (NSP) in seeds of withe-flowered peas, g/kg DM

	White-flowered peas							SEM	Effect of	
	Diament	Kama	Kwestor	Piast	Sol	Jaran[1]	Ametyst[2]		year	cultivar
n	3	3	3	3	3	3	3		P<	
Oligosaccharides[3]:										
sucrose	21.0	24.8	29.8	28.9	31.8	23.3	25.5	1.14		
raffinose	4.9	7.8	8.3	6.2	6.9	9.5	7.4	0.46		
stachyose	19.6	31.0	33.1	19.9	18.1	26.9	25.6	1.38		
verbascose	34.5	15.9	21.2	30.1	28.4	22.8	24.2	1.80		
total α-galactosides	55.9	54.7	62.6	56.2	53.4	59.3	57.1	1.10		
total oligosaccharides	77.0	79.5	92.4	85.1	85.2	82.5	82.6	1.74		
NSP:										
rhamnose	2.2	2.5	2.0	2.5	2.2	2.4	2.7	0.11		
fucose	0.8	0.6	0.6	0.8	0.7	0.9	0.8	0.04		
arabinose	34.1	35.5	31.0	42.8	35.0	38.7	39.9	1.12	0.007	
xylose	14.3	16.0	16.1	17.5	13.2	17.9	17.0	0.50	0.002	
mannose	1.5	3.1	1.7	1.2	3.0	1.7	2.3	0.21		
galactose	12.9	13.8	11.7	20.3	11.8	15.1	12.0	0.93		
glucose	72.9	87.6	75.5	94.0	91.1	101.2	87.1	2.50		
uronic acids	21.7	23.2	25.3	22.3	24.8	23.7	21.1	0.73		
total NSP	160.4	182.4	163.9	201.4	181.8	201.4	182.9	4.04		

[1] leafless pea
[2] green seeds
[3] average for two years

No notable differences in the composition of non-starch polysaccharides were found in the different peas. They were mainly composed of glucose and arabinose, which accounted on average for 48 and 20% of total NSP monosaccharide residues, respectively. The respective proportions for uronic acids (13%), xylose (9%) and galactose (8%) were much lower. Rhamnose, mannose and fucose were minor components of pea seed NSP. Studies of Ralet and Thibault (1992) showed that dietary fibre of pea hulls (91.5%) was composed mainly of glucose (45.1%), xylose (14.6%) and galacturonic acid (12.7%). Such a chemical composition points to high contents of cellulose, xylans and pectic substances. Arabinose, uronic acids and glucose residues were the dominating dietary fibre components in dehulled peas (Dandanell Daveby and Åman (1993).

Pisum sativum arvense. The weight of 1000 seeds of the two tested cultivars was 165 and 207 g (Table 5). The content of crude protein (222 and 241 g/kg DM), ether extract, ash, total and enzyme susceptible starch was similar in seeds of both cultivars. The level of NSP (182 and 192 g/kg DM) in seeds did not depend

TABLE 5

Chemical composition of seeds of coloured-flowered peas, g/kg DM

	Pea		SEM	Effect of	
	Grapis	Fidelia		year	cultivar
n	3	3		P<	
Weight of 1000 seeds, g	207	165	5.83		
Dry matter	900	904	0.76	0.013	
Crude protein	222	241	3.00		
Ether extract	12	14	1.30		
Ash	30	34	0.78		
Total starch	472	445	10.05		
Enzyme susceptible starch	401	381	2.48		
Fibre fraction:					
NSP	182	192	2.26	0.012	
NDF	137	141	2.08		
ADF	92	97	0.94	0.015	
CF	64	66	1.45		
ADL	5	4	0.55		
hemicelluloses	45	45	1.83		
cellulose	87	93	0.48	0.003	0.026
Antinutritional factors:					
tannins, mg/g	6.0	8.0	0.36		
trypsin inhibitors, TIU/mg	3.3	2.7	0.33		
α-galactosides, mg/g	64	58	1.52		0.017

TABLE 6

The content and chemical composition of oligosaccharides and non-starch polysaccharides in seeds of coloured-flowered peas, g/kg DM

	Pea		SEM	Effect of	
	Grapis	Fidelia		year	cultivar
n	3	3		P<	
Oligosaccharides:					
sucrose	21.7	25.1	1.89		
raffinose	6.1	6.5	0.98		
stachyose	28.3	22.4	3.95		
verbascose	29.4	29.2	3.31		
total α-galactosides	63.7	58.1	1.52		0.017
total oligosaccharides	85.4	83.2	0.73		
NSP:					
rhamnose	2.2	2.1	0.25		
fucose	0.8	0.6	0.06		
arabinose	37.3	36.7	1.46		
xylose	15.9	12.7	0.99		
mannose	1.4	1.7	0.29		
galactose	13.6	15.2	0.99		
glucose	86.9	98.9	2.04	0.030	
uronic acids	23.3	23.7	0.50		
total NSP	181.5	191.6	2.26	0.012	

on the pea cultivar, but on the year of growth. The latter factor significantly influenced ADF and cellulose content. It was found that the seeds of coloured-flowered peas contained significantly more NDF (140 vs. 118 g), ADF (94 vs. 78 g), cellulose (90 vs. 75 g) and condensed tannins (7.0 vs. 0.4 mg) than seeds of white-flowered cultivars (Table 7).

The contents and chemical composition of oligosaccharides and NSP in seeds of coloured-flowered peas are presented in Table 6. The sucrose content was 21.7 and 25.1 g, that of α-galactosides was 63.7 and 58.1 g/kg DM of seeds. Similarly to white-flowered peas, stachyose and verbascose were major components of α-galactosides. Raffinose was found at a level below 7 g/kg DM. The same proportions of particular NSP residues were observed in coloured-flowered peas as in white-flowered ones (Table 8).

CONCLUSIONS

Although faba beans and pea seeds contain several antinutritional factors, they appear to be a potentially useful source of protein and energy for pigs. The

TABLE 7
Comparison of seed chemical composition between white- and coloured-flowered peas, g/kg DM

	Pea		SEM
	white-flowered	coloured-flowered	
n	7	2	
Weight of 1000 seeds, g	230	185	8.75
Dry matter	898	902	2.03
Crude protein	235	231	4.24
Ether extract	14	13	0.49
Ash	32	32	0.43
Total starch	461	459	8.24
Enzyme susceptible starch	419	390	5.19
Fibre fraction:			
NSP	182	186	4.79
NDF	118[b]	140[a]	2.89
ADF	78[b]	94[a]	1.65
CF	58	65	1.02
ADL	3	4	0.30
hemicelluloses	37	45	2.67
cellulose	75[b]	90[a]	2.11
Antinutritional factors:			
tannins, mg/g	0.4[b]	7.0[a]	0.36
trypsin inhibitors, TIU/mg	3.0	3.0	0.17

a, b – $P \leqslant 0.05$

TABLE 8
Comparison of content and composition of oligosaccharides and non-starch polysaccharides between white- and coloured-flowered peas, g/kg DM

	Pea		SEM
	white-flowered	coloured-flowered	
n	7	2	
Oligosaccharides:			
sucrose	26.4	23.4	1.07
raffinose	7.3	6.3	0.44
stachyose	24.9	25.3	1.54
verbascose	24.9	29.9	1.62
total α-galactosides	57.1	61.5	0.97
total oligosaccharides	83.5	84.9	1.42
NSP:			
rhamnose	2.4	2.2	0.10
fucose	0.7	0.7	0.04
arabinose	36.7	37.0	1.38
xylose	16.0	14.3	0.69
mannose	2.1	1.5	0.21
galactose	14.7	14.4	0.93
glucose	86.3	92.9	2.80
uronic acids	23.1	23.5	0.53
total NSP	182.0	186.4	4.79

crude protein content both in faba bean and pea seeds is intermediate between that in soyabean and grains. The level of starch is high and, in some pea cultivars, it accounts for even 50% dry matter. Enzyme resistant starch is found in somewhat higher amounts in faba beans and coloured-flowered peas (13-16% of total starch) than in white-flowered pea cultivars. Peas, particularly white--flowered cultivars, contain a low level of tannins. α-Galactosides, present at higher levels in pea seeds than in faba beans, can be a cause of flatulence after feeding.

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STRESZCZENIE

Skład chemiczny i zawartość węglowodanów w nasionach różnych odmian bobiku i grochu

Oznaczono skład chemiczny nasion czterech odmian bobiku (*Vicia faba* L.), siedmiu odmian grochu (*Pisum sativum hortense* L.) oraz dwóch odmian peluszki (*Pisum sativum arvense* L.). Nasiona bobiku zawierały średnio 430 g/kg s.m. skrobi ogólnej i 367 g/kg s.m. skrobi podatnej na działanie enzymów (α-amylazy i amyloglukozydazy). W suchej masie nasion grochu i peluszki oznaczono, odpowiednio, 461 i 459 g skrobi ogólnej oraz 419 i 390 g skrobi podatnej na działanie enzymów. Nasiona bobików zawierały mniej α-galaktozydów (28 vs 58 g) niż nasiona badanych grochów. Werbaskoza była głównym składnikiem α-galaktozydów nasion bobiku, natomiast werbaskoza i stachioza dominowały wśród α-galaktozydów nasion grochu. Nasiona bobiku zawierały 177 g/kg s.m. polisacharydów nieskrobiowych (NSP), a grochów – 183 g. Głównym składnikiem NSP nasion bobiku i grochu była glukoza, arabinoza i kwasy uronowe.