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The chemical composition of different types and varieties of pea and the digestion of their protein in pigs

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ABSTRACT

Six varieties of white-flowered and three varieties of coloured-flowered peas were analysed for content of nutrients and some antinutritional factors. In a trial on cannulated pigs, ileal and total digestibility of protein and amino acids were estimated. The coloured-flowered varieties of pea contained significantly more NDF ($P<0.05$), Klason lignin and tannins ($P<0.01$) than the white-flowered ones. The trypsin inhibitor activity ranged widely in both white- and coloured-flowered peas. Methionine, cystine and threonine were negatively correlated with the protein content of the tested seeds. The true ileal and faecal digestibilities of pea protein ranged from 66 to 83 and from 74 to 88, respectively. The greatest differences among the peas in ileal amino acid digestibility occurred for methionine, cystine and tryptophane. It was found that among the analysed factors (NDF, tannins, trypsin inhibitor) only NDF significantly decreased the ileal digestibility of protein. The faecal digestibility was mainly reduced by tannin content.

KEY WORDS: pea, pigs, ileal digestibility, amino acids

INTRODUCTION

In recent years an interest in the production of pea as a protein source for pigs has grown considerably. Two subspecies of Pisum sativum are cultivated in Poland: P. sativum arvense which has dark-coloured flowers and is mainly used in animal feeding and white-flowered P. sativum hortense which is used for human nutrition and for monogastic animals, especially for pigs. Since the level of protein and some amino acids, especially methionine, in pea is low, it is important to have accurate knowledge about all of the factors which can influence the protein digestibility and amino acid availability in the pig. Several papers indicate that tannins influence nutrient digestibility by their ability to complex with proteins (Griffiths, 1979; Griffiths and Moseley, 1980), so exerting harmful effect on animal organs (McLeod, 1974). Protease inhibitors may also interfere with protein digestibility (Griffiths, 1984; Leterme et al., 1990a).

The subject of this study was to determine the chemical composition of pea seeds, to compare the true ileal and faecal digestibility of protein and amino acids of both white and coloured flowered spring peas and to find factors influencing these digestibilities. The aim of the research was to look for indicators permitting prediction of amino acid digestibility of peas on the basis of their chemical composition.

MATERIAL AND METHODS

Seeds (sowing grade) of six varieties of white-flowered pea (varieties: Belinda – batches 1 and 2, Kaliski, Mige, Opal, Milewska, Koral) and three varieties of coloured-flowered pea (varieties: Matmal, Mazurska, Gomik) were analysed and used in the experiment, which was carried out on Large White x Landrace castrated male pigs of 30 to 80 kg. The ileum of each of the animals was cannulated with a T-shaped fistula (internal diameter 22 mm) inserted approximately 15 cm anterior to the ileo-caecal junction, according to the method described by Horszczaruk et al. (1972).

The pigs were fed barley diets containing 41.5% of the tested peas (Table 1). For true digestibility estimation a starch-barley (control) diet was prepared. Each diet was offered every 12 h to 4–6 pigs at the level of 3.8% body mass per day.

Ten days after the surgical operation the animals were placed in metabolic cages. After seven days of adaptation period faeces (3 days) and digesta (at least 3×12h) were collected.

The ground pea seeds, diets and freeze-dried samples of digesta and faeces were analysed for content of protein, amino acids and neutral detergent fibre (NDF) according to methods described by Buraczewska et al. (1987).

The tannin content in pea seeds was determined according to the method of Jerumanis (1972) modified by Adams nad Novellie (1975). The trypsin inhibitor activity was estimated by the method of Kakade et al. (1974).

True ileal and total digestibilities of pea total nitrogen and amino acids were

TABLE 1.

Composition of diets, %

Ingredients	Diets	
	Control	Experimental
Barley	51.70	51.70
Maize starch	43.45	2.70
Pea	–	41.50
Min. – vit. mixture	4.40	3.80
Cr_2O_3	0.30	0.30
L-Lys · HCl	0.15	

calculated by the difference method using the digestibility of the barley-starch diet as a reference.

All statistical tests were performed using Statgraphics version 2.1. Mean values in table 4 and 5 were compared by the one-way Anova test. True ileal digestibilities of amino acids were regressed on true ileal digestibility of protein using a simple linear regression.

RESULTS AND DISCUSSION

Chemical composition of tested peas

The results shown in Table 2 indicate that the protein (N × 6.25) content in dry matter ranged from 21 to 28% with a mean of 24.8% for the white-flowered peas and 23.5% for the coloured-flowered varieties. These results are similar to those obtained by Bajaj et al. (1971), who reported a protein content varying from 21.2 to 28.5%. The values given by Reichert and McKenzie (1982) are even more differentiated (from 14.5 to 28.5%).

As it is seen in Table 2, the coloured-flowered peas contained more tannins ($P<0.01$) than the white-flowered varieties. These results are in agreement with

TABLE 2

Chemical composition of peas

Pea variety	DM	CP[1]	NDF[1]	Klason[1] lignin	Tannins[2]	Trypsin[3] inhibitor
White-flowered						
Belinda 1	87.2	27.7	11.8	0.62	1.84	0.77
Kaliski	85.9	26.3	12.7	0.81	1.57	2.19
Mige	85.7	26.1	11.7	1.10	1.75	8.73
Belinda 2	85.7	26.1	13.4	0.70	1.97	3.12
Opal	85.2	22.4	12.6	0.60	2.63	6.47
Milewska	85.5	22.6	15.7	1.50	2.42	8.27
Koral	86.3	22.1	12.6	0.65	2.09	6.13
$\bar{x}$	85.9	24.8^a	12.9^a	0.85^A	2.04^A	5.10^a
Coloured-flowered						
Matmal	84.5	26.6	17.2	2.10	7.32	6.39
Mazurska	87.5	22.7	14.3	2.56	7.17	4.27
Gomik	85.1	21.1	15.8	1.78	8.02	15.94
$\bar{x}$	85.7	23.5^a	15.8^b	2.15^B	7.50^B	8.87^a

[1] % of DM; [2] mg/g DM; [3] TIU/mg DM

A, B – differences in column significant at $P<0.01$; a, b – at $P<0.05$

TABLE 3

Amino acid composition of pea protein (g/16 g N)

AA[1]	Pea varieties									
	white-flowered							coloured-flowered		
	Belinda 1	Kaliski	Mige	Belinda 2	Opal	Milewska	Koral	Matmal	Mazurska	Gomik
CP	27.7	26.3	26.1	26.1	22.4	22.6	22.1	26.6	22.7	21.1
Lys	7.02	7.22	7.53	7.51	7.98	7.66	7.45	7.32	7.50	7.22
Met	0.87	0.89	1.01	0.98	0.99	1.16	1.06	0.97	1.11	1.11
Cys	1.33	1.49	1.38	1.36	1.42	1.74	1.64	1.42	1.76	1.91
Thr	3.37	3.44	3.82	3.74	3.89	3.97	4.16	3.75	3.88	3.92
Trp	0.84	0.84	0.97	0.90	0.87	1.12	0.96	1.02	1.00	0.99
Ile	3.89	4.02	4.25	4.12	4.29	4.40	4.44	4.28	3.88	3.92
Leu	6.75	6.91	7.38	6.98	7.27	7.39	7.55	7.34	7.47	7.01
Phe	4.23	4.60	5.13	4.71	4.86	5.03	5.12	4.83	4.88	4.68
Val	4.48	4.65	4.84	4.76	4.81	4.97	4.98	4.94	4.87	4.78
Tyr	2.75	2.92	3.17	2.99	3.06	3.34	3.43	3.15	3.19	3.03

[1] amino acids

the results obtained by Griffiths (1981) who found on average twice more polyphenols (tannic acid equivalents) in seeds of coloured-flowered peas than in those of white-flowered ones.

The seeds of Gomik, Mige and Milewska peas had high trypsin inhibitor activity, which is usually attributed to winter varieties (Valdebouze et al., 1980; Gatel and Grosjean, 1990). Leterme et al. (1990a) reported that trypsin inhibitor activity of spring type of peas ranged from 1.71 to 8.40 TIU^{-1} DM, while that of winter varieties varied from 11.4 to 16.8 TIU^{-1} DM. There is no evidence explaining such large differences between peas. Probably, growing conditions and degree of ripeness of seeds could influence their chemical composition (Holl and Vose, 1980), including trypsin inhibitor activity. Analysis of fibre fractions showed higher contents of NDF ($P<0.05$) and Klason lignin ($P<0.01$) in coloured-flowered peas than in white-flowered ones.

Amino acid analysis of the pea protein (Table 3) showed a relatively low level of methionine from 0.87 to 1.16 g and high content of lysine from 7.02 to 7.98 g per 16 g N. Seeds of white-flowered peas Milewska and Koral and coloured-flowered varieties Mazurska and Gomik contained comparatively higher levels of methionine and cystine than other varieties. It was found that methionine ($r=-0.84$), cystine ($r=-0.826$), threonine ($r=-0.806$), alanine ($r=-0.810$), glycine ($r=-0.706$) and serine ($r=-0.675$) were negatively correlated with the protein level. Reichert and McKenzie (1982), who analysed the amino acid composition of 198 samples of pea, obtained a similar correlation for these amino acids. In addition, they found a significant negative correlation for lysine and a positive one for glutamic acid. Evans and Boutler (1980) have found a negative correlation between sulphur-containing amino acids and the protein content for both peas and beans.

True ileal and faecal digestibility of pea protein and amino acids

The true ileal digestibility of protein (Table 4) was higher for white-flowered peas than for coloured-flowered ones and ranged from 71 to 83 and 66 to 69, respectively. Calculations showed that the protein digestibility was negatively correlated with content of NDF, tannins and trypsin inhibitor in pea seeds. However, the effect of NDF was highest and statistically significant at $P<0.05$.

Żebrowska et al. (1981) reported that increasing the level of straw or cellulose in diets (5% or 10%) decreased the apparent ileal and faecal digestibility of nitrogen. Stanogias and Pearce (1985) found that not only the amount but also the type of dietary fibre significantly influenced the apparent digestibility of dry matter, nitrogen and energy.

The highest digestibilities of amino acids were found for arginine (72–93), histidine (65–88) and lysine (69–85), which is in agreement with the results obtained by Leterme et al. (1990b). The lowest digestibilities were found for cystine (48–68) and for tryptophane (53–69). Knabe et al. (1989) reported that arginine was the most digestible essential amino acid, while threonine and tryptophane were the least digestible ones in 30 samples of different feedstuffs. In our trials, threonine was digested from 63 to 84 per cent. The low apparent digestibility of this amino acid can be influenced by high concentriaton of thereonine in endogenous secreta reaching the end of the ileum (Taverner et al., 1981; Leterme et al., 1990b). Among the tested peas the greatest differences in ileal digestibility of amino acids occurred for methionine, tryptophane and cystine (25, 24 and 20 percentage units, respectively). Results of simple regression analysis indicate a relationship between ileal protein digestibility (x) and ileal amino acid digestibilities (Y):

1. $Y_{Lys}=15.84+0.82x\pm2.7$ $r=0.869$ $P<0.01$
2. $Y_{Met}=-41.03+1.44x\pm4.8$ $r=0.892$ $P<0.01$
3. $Y_{Cys}=0.75+0.83x\pm6.9$ $r=0.562$ $P<0.01$
4. $Y_{Thr}=-11.10+1.12x\pm3.1$ $r=0.899$ $P<0.01$

However, the obtained data suggest that ileal protein digestibility can not be used with a high degree of accuracy to predict ileal sulphur-containing amino acid digestibilities, especially cystine.

TABLE 4

True ileal digestibility of protein and amino acids of different peas fed to pigs

	Pea									
	white-flowered							coloured-flowered		
	Belinda 1	Kaliski	Mige	Belinda 2	Opal	Milewska	Korak	Matmal	Mazurska	Gomik
N × 6,25	82,5^{C}	78,1^{BC}	75,9^{BC}	74,0^{ABC}	73,2^{ABC}	70,5^{AB}	73,5^{ABC}	65,8^{A}	68,0^{AB}	68,4^{AB}
Lys	84,7^{C}	81,5^{BC}	79,5^{BC}	75,0^{ABC}	75,6^{ABC}	72,6^{AB}	77,0^{ABC}	72,4^{AB}	74,2^{AB}	69,0^{A}
Met	78,9^{B}	71,1^{BCD}	73,5^{CD}	66,2^{ABCD}	59,7^{ABC}	59,9^{ABCD}	63,9^{AB}	60,0^{AB}	56,6^{A}	54,1^{A}
Cys	68,2^{B}	67,5^{B}	59,0^{AB}	63,4^{B}	52,1^{A}	65,8^{B}	65,9^{B}	47,9^{A}	59,2^{AB}	60,1^{AB}
Thr	83,9^{B}	74,9^{AB}	74,6^{AB}	72,6^{AB}	69,9^{A}	69,2^{A}	69,3^{A}	64,7^{A}	64,9^{A}	63,0^{A}
Trp	76,8^{D}	69,1^{CD}	68,7^{BCD}	68,1^{D}	59,3^{ABC}	66,4^{BCD}	64,3^{ABCD}	57,7^{ABC}	54,9^{AB}	53,1^{A}
Ile	87,7^{C}	77,8^{BC}	74,7^{AB}	74,7^{AB}	73,6^{AB}	69,8^{AB}	75,1^{AB}	77,5^{AB}	67,7^{AB}	67,5^{A}
Arg	93,3^{D}	89,2^{CD}	88,0^{BCD}	88,2^{CD}	85,8^{BC}	83,4^{ABC}	88,4^{CD}	72,2^{AB}	82,9^{AB}	79,9^{A}
His	87,7^{C}	82,2^{ABC}	80,6^{ABC}	79,9^{ABC}	77,5^{AB}	80,3^{ABC}	85,3^{BC}	65,3^{A}	76,3^{AB}	72,9^{A}
Leu	86,2^{C}	79,9^{BC}	76,3^{BC}	76,0^{BC}	74,8^{AB}	68,8^{AB}	74,1^{AB}	68,7^{AB}	69,0^{AB}	64,3^{A}
Phe	87,2^{D}	79,3^{CD}	76,1^{ABCD}	77,1^{CD}	74,9^{ABC}	72,4^{ABC}	76,6^{BCD}	83,9^{A}	66,9^{ABC}	65,5^{AB}
Val	84,4^{B}	75,5^{AB}	73,3^{AB}	72,2^{A}	71,9^{A}	69,4^{A}	70,6^{A}	64,8^{A}	66,6^{A}	65,1^{A}
Ala	83,1^{C}	75,3^{ABC}	72,5^{ABC}	67,1^{BC}	69,6^{AB}	64,2^{AB}	65,2^{AB}	63,6^{AB}	63,1^{AB}	62,1^{A}
Asp	89,0^{F}	83,5^{EF}	80,0^{BCDE}	81,2^{CDE}	80,0^{BCDE}	75,5^{ABC}	82,5^{DEF}	75,8^{ABCD}	73,1^{AB}	72,6^{A}
Glu	86,4^{C}	78,6^{ABC}	81,0^{ABC}	79,4^{ABC}	77,3^{ABC}	72,4^{A}	81,4^{BC}	72,6^{AB}	71,6^{A}	71,9^{A}
Gly	76,9^{B}	70,7^{AB}	63,4^{AB}	56,7^{AB}	55,7^{A}	70,2^{AB}	70,1^{AB}	56,0^{A}	64,8^{AB}	59,1^{AB}
Pro	83,6^{CE}	74,6^{CDE}	55,2^{ABCDE}	49,3^{AB}	53,7^{ABCD}	62,4^{ABCDE}	64,8^{ABCDE}	41,6^{A}	74,4^{BCDE}	52,9^{ABC}
Ser	84,6^{C}	77,0^{BC}	74,6^{AB}	75,5^{B}	71,9^{AB}	71,7^{AB}	72,9^{AB}	65,9^{A}	68,3^{AB}	67,2^{A}
Tyr	87,7^{EG}	80,5^{DEFG}	76,8^{BCDE}	76,9^{CDEF}	74,5^{ABCD}	72,5^{ABCD}	76,3^{BCD}	68,8^{ABC}	65,0^{A}	67,1^{AB}

Values within a row with the same superscript were not significantly different ($P < 0.01$)

TABLE 5

True faecal digestibility of protein and amino acids of different peas fed to pigs

	Pea									
	white-flowered							coloured-flowered		
	Belinda 1	Kaliski	Mige	Belinda 2	Opal	Milewska	Koral	Matmal	Mazurska	Gomik
N × 6,25	87,7^{D}	81,0^{ABCD}	80,8^{ABCD}	82,4^{BCD}	85,6^{CD}	84,1^{BCD}	79,6^{ABC}	77,6^{AB}	73,8^{A}	75,5^{A}
Lys	84,8^{C}	79,1^{ABC}	78,9^{BC}	80,7^{C}	83,3^{C}	79,4^{BC}	73,5^{AB}	79,1^{BC}	72,2^{A}	71,3^{A}
Met	73,8^{B}	57,6^{AB}	63,9^{AB}	63,7^{AB}	66,3^{B}	71,2^{B}	59,3^{AB}	59,0^{AB}	61,0^{AB}	49,4^{A}
Cys	93,5^{BC}	95,3^{C}	93,5^{C}	92,9^{C}	96,5^{C}	88,7^{ABC}	82,8^{A}	88,1^{ABC}	82,8^{A}	84,8^{AB}
Thr	82,5^{B}	74,2^{ABC}	77,3^{ABC}	80,0^{BC}	80,5^{C}	79,0^{ABC}	76,1^{ABC}	76,3^{ABC}	71,0^{A}	72,1^{AB}
Trp	81,3^{C}	75,2^{ABC}	79,1^{BC}	78,1^{ABC}	79,2^{ABC}	79,4^{C}	70,8^{AB}	75,4^{ABC}	69,0^{A}	72,1^{ABC}
Ile	87,0^{B}	79,8^{AB}	80,4^{AB}	82,3^{AB}	84,7^{AB}	85,6^{B}	82,0^{AB}	78,7^{AB}	76,9^{A}	78,5^{AB}
Arg	97,4^{C}	95,0^{C}	94,3^{C}	95,0^{AB}	95,5^{AB}	88,0^{C}	88,2^{C}	93,7^{BC}	84,4^{A}	85,0^{A}
His	92,6^{BC}	93,0^{BC}	91,6^{BC}	93,9^{C}	94,9^{ABC}	88,6^{AB}	85,8^{C}	91,6^{BC}	81,5^{A}	82,8^{A}
Leu	86,5^{D}	80,3^{ACD}	80,7^{CD}	82,0^{CD}	83,4^{CD}	79,8^{ABC}	76,8^{CD}	79,4^{ACDB}	72,6^{A}	72,6^{AB}
Phe	87,8^{D}	81,6^{CD}	82,1^{CD}	83,1^{CD}	84,9^{CD}	81,2^{BC}	78,0^{D}	77,6^{ABC}	70,5^{A}	71,6^{AB}
Val	85,7^{C}	79,0^{ABC}	81,3^{ABC}	82,7^{C}	83,7^{ABC}	82,4^{ABC}	77,8^{BC}	78,2^{ABC}	73,8^{A}	74,7^{AB}
Ala	80,9^{A}	72,8^{A}	73,0^{A}	77,0^{A}	78,2^{A}	71,5^{A}	66,7^{A}	74,4^{A}	63,9^{A}	61,1^{A}
Asp	89,1^{D}	84,1^{ABCD}	83,0^{ABC}	86,0^{CD}	86,2^{BCD}	84,5^{ABC}	81,1^{CD}	83,8^{ABCD}	77,6^{A}	78,9^{AB}
Glu	94,7^{D}	88,1^{ABC}	90,7^{BCD}	91,2^{BCD}	92,0^{CD}	92,5^{BCD}	91,5^{BCD}	87,2^{AB}	83,0^{A}	87,7^{ABC}
Gly	86,1^{C}	79,5^{ABC}	80,4^{BC}	83,3^{BC}	83,9^{BC}	81,8^{AB}	77,4^{BC}	78,1^{AB}	71,8^{A}	73,6^{A}
Pro	88,8^{C}	86,8^{C}	85,9^{C}	86,8^{C}	89,8^{C}	89,4^{C}	85,3^{C}	70,6^{B}	51,7^{A}	68,3^{B}
Ser	93,8^{BCDE}	88,8^{AB}	89,6^{AB}	90,8^{ABCD}	90,8^{CE}	98,4^{CDE}	95,2^{ABCDE}	87,2^{A}	90,7^{ABC}	93,6^{BCDE}
Tyr	84,5^{D}	77,3^{ABCD}	78,5^{ACD}	80,0^{CD}	80,0^{ABCD}	77,7^{ABC}	75,1^{CD}	77,8^{ABCD}	70,4^{A}	70,6^{AB}

Values within a row with the same superscript were not significantly different ($P < 0.01$)

The faecal true protein digestibility ranged from 81 to 88 and from 74 to 78 for white- and coloured-flowered pea, respectively (Table 5). Mathematical analysis showed that it was negatively correlated with pea tannins ($P<0.01$), while the effects of NDF and trypsin inhibitor were negligible.

In experiments with laying hens, Lindgren (1975) obtained a strong correlation between the digestion coefficients of crude protein and the tannin content. Faecal true digestibility coefficients of most of the amino acids were generally higher in comparison with those calculated for the small intestine. However, the total digestibility of methionine was still low and in some cases even lower than the ileal one. This phenomenon was probably caused by the microbiological synthesis of this amino acid in the hind gut of pigs.

In general, the ileal and faecal digestibilities of nitrogen and amino acids of white-flowered peas were higher than that of coloured-flowered peas. However, there were also meaningful differences in digestibilities among varieties belonging to the same type of pea.

CONCLUSIONS

The chemical composition of pea differs widely not only between the two types, white- and coloured-flowered peas, but also from on variety to antoher. Tabular values cannot therefore be accurate.

The protein of white-flowered varieties is digested better than that of coloured-flowered peas in pigs. There was a significant negative correlation between the ileal protein digestibility and the amount of NDF in peas. Tannins were shown to be the main factor negatively influencing the digestibility of protein.

More observations are needed to predict ileal protein digestibility of different peas on the basis of their chemical composition.

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STRESZCZENIE

Skład chemiczny nasion różnych typów i odmian grochu oraz trawienie ich białka przez świnie

Zbadano skład chemiczny, w tym zawartość niektórych czynników antyżywieniowych oraz przebieg trawienia składników pokarmowych nasion sześciu odmian grochu i trzech peluszki. Strawność białka i aminokwasów oznaczono do końca jelita cienkiego i w całym przewodzie pokarmowym rosnących świń. W nasionach peluszki, w porównaniu z nasionami grochu, stwierdzono więcej NDF ($P<0.05$), ligniny Klasona oraz tanin ($P<0.01$). Aktywność inhibitora trypsyny w obu typach nasion wahała się w szerokich granicach i nie różniła się istotnie. Stwierdzono ujemną współzależność między zawartością białka, a oznaczoną w nim ilością metioniny, cystyny i treoniny. Strawność rzeczywista białka oznaczona do końca jelita cienkiego wynosiła od 66 do 83, a w całym przewodzie pokarmowym od 74 do 88. Badane odmiany najbardziej różniły się strawnością jelitową metioniny, cystyny i tryptofanu. Stwierdzono, że spośród występujących w nasionach czynników (NDF, taniny, inhibitor trypsyny), wpływ NDF na strawność jelitową białka był największy, podczas gdy taniny najsilniej ograniczały jego strawność ogólną.