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Factors affecting the nutritional value of pea (*Pisum sativum*) for broilers

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ABSTRACT: In a trial carried out on broiler chickens, the nutritive value of five pea cultivars (coloured-flowered: Turnia, Sokolik, Milwa, and white-flowered Muza and Cysterski) was determined. A total of 60 male Ross 308 17-day-old chickens were assigned to six experimental groups (10 replications per treatment). Apparent ileal digestibility of amino acids (AID AA) and the value of apparent metabolizable energy (AME_N) were determined. Pea cultivars vary in their contents of tannins (Sokolik 0.48 g · kg^{-1}, Cysterski 0.05 g · kg^{-1}), raffinose family oligosaccharides (Milwa 72.4 g · kg^{-1}, Turnia 88.5 g · kg^{-1}), as well as phytic-P (Muza 4.4 g · kg^{-1}, Turnia 2.1 g · kg^{-1}). The study showed positive correlations between starch content and AID AA ($P \leq 0.05$), as well as negative correlations between total tract dry matter retention, AME_N value, AME_N/gross energy ratio and phytic-P content in pea ($r = -0.52$, $r = -0.31$, $r = -0.42$, $P \leq 0.05$, respectively).

Introduction

The rising prices of soyabean meal over recent years have created an opportunity for other leguminous plants to be incorporated into feed mixtures for poultry on a much wider scale. According to Castell et al. (1996), pea (*Pisum sativum*) due to its promising nutritive values (relatively high concentrations of protein, lysine and starch) can be an alternative for soyabean meal. In comparison with other leguminous plants, pea seeds have the highest starch content (over 40%). Additionally, pea starch is characterized by very slow degradation in the gastrointestinal tract of birds compared with maize starch, which may affect protein deposition (Weurding et al., 2003). Notwithstanding, pea seeds are known to contain antinutrients that may negatively impact the production results of broiler chickens. The major antinutritional factors in peas are tannins and trypsin inhibitors (Smulikowska et al., 2001; Konieczka et al., 2014). Several researchers report that tannins can negatively influence nutrient digestibility by their ability to form complexes with proteins (Griffiths and Moseley, 1980; Gdala et al., 1992). The other commonly recognized antinutritional substances occurring in pea seeds include trypsin and chymotrypsin inhibitors (Konieczka et al., 2014), which significantly reduce the activity of enzymes responsible for protein digestion and, as a consequence, result in deterioration of production results (Gatel and Grosjean, 1990). Two subspecies of pea are cultivated in Poland: *P. sativum hortense*, which is white-flowered, and *P. sativum arvense*, which has coloured flowers (pink, red, or purple). According to some authors (Gdala et al., 1992; Smulikowska et al., 2001), the colours of pea flowers are related to the concentration of tannins in pea seeds. White-flower peas produce seeds containing less tannins than peas with coloured flowers. Other antinutritional substances occurring in pea seeds comprise oligosaccharides (raffinose, stachyose and verbascose) (Igbasan et al., 1997). Due to the absence of α-1,6-galactosidase in the intestinal mucous membrane of chickens, the above compounds are not degraded and thus able to interfere with the absorption of nutrients (Gitzelmann and Auricchio, 1965). The detrimental influence of high oligosaccharide concentrations, in particular raffinose, on nutrient digestibility was investigated by Kaczmarek et al. (2014b) in lupin meal and by Perryman and Dozier (2012) in soyabean meal. They found that oligosaccharides (raffinose, stachyose or verbascose) may deteriorate nutrient digestibility.

In recent years, some new pea cultivars have been developed in Poland. Current literature provides no information on the influence of the chemical composition of currently cultivated pea cultivars on broiler chickens, or even reports on their consumption by these birds. The impact of pea cultivar on its nutritional usefulness was investigated by Gdala et al. (1992) and Smulikowska et al. (2001). They concluded that tannins in pea seeds are the main factor negatively affecting protein digestibility and that the chemical composition of pea differs widely among both white- and coloured-flower peas.

The aim of this study was to evaluate the nutrient digestibility and metabolizable energy (AME_N) levels in Polish cultivars of pea for broiler chickens.

Material and methods

Pea seeds

The seeds of two white-flower (Muza, Cysterski) and three coloured-flower (Turnia, Sokolik, Milwa) cultivars of pea (*Pisum sativum* L.) were used. Pea cultivars Sokolik, Milwa, Cysterski, Muza and Turnia were registered in 2001, 2005, 2008, 2009 and 2011, respectively (COBORU, 2011), and were harvested in 2011. Seeds were obtained from the Plant Breeding Stations in Przebędowo and Wiatrowo, Wielkopolska Voivodeship (Poland).

Diets

The basal diet was prepared as shown in Table 1 and was mixed in an 80:20 (w/w) proportion with the appropriate pea meal. To determined digestibility, 3 g · kg^{-1} titanium dioxide was included as a nonabsorbable marker. All diets were offered in mash form *ad libitum*.

Table 1. Basal diet composition and nutritional value

Indices	g · kg^{-1} of diet
Ingredients	
maize (9% CP)	600.0
soyabean meal (45% CP)	292.7
soya oil	41.5
fish meal (65% CP)	29.4
monocalcium phosphate	10.3
limestone	5.1
Premix[1]	10.0
TiO_2 [2]	3.0
NaCl	2.9
$NaHCO_3$	0.1
methionine	2.7
lysine	1.7
threonine	0.6
Calculated	
ME, MJ · kg^{-1}	12.7
Analysed, g · kg^{-1}	
gross energy, MJ · kg^{-1}	17.6
crude protein	212.0
crude fat	71.8
methionine	6.1
lysine	12.8
tryptophan	2.2
threonine	8.7

[1] provides per kg diet: IU: vit. A 11250, cholecalciferol 2500; mg: vit. E 80, menadione 2.50, vit. B_{12} 0.02, folic acid 1.17, choline 379, D-pantothenic acid 12.5, riboflavin 7.0, niacin 41.67, thiamin 2.17, D-biotin 0.18, pyridoxine 4.0, ethoxyquin 0.09, Mn 73, Zn 55, Fe 45, Cu 20, I 0.62, Se 0.3, salinomycin 60; [2] TiO_2 was added to the diet in the amount of 3 g per kg replacing the same part of maize component after mixing the basal diet with pea meal on day 17 of experiment

Experimental design

The experiment complied with the relevant guidelines of the Local Ethics Commission for Animal Experimentation.

The experiment was conducted on 60, 17-day-old Ross 308 male chickens. The birds were kept in individual cages and randomly assigned to six dietary treatments, 10 replications per group. From days 1 to 16, the birds received *ad libitum* only basal diets without the nonabsorbable marker. From days 17 to 21, in five of the treatments the diets contained pea meal (Turnia, Sokolik, Muza, Milwa and Cysterski) and the basal diet with the nonabsorbable marker in a proportion of 20:80 (w/w). The birds in one treatment were fed only the basal diet. The experimental diets were fed for five days. On days 19 and 20 of age, excreta were individually collected twice per day and frozen immediately (n = 10). On day 21 of age, all chickens were sacrificed by cervical dislocation and the ileum was removed. Digesta were flushed from the terminal ileum (15 cm, adjacent to the ileocaecal junction) and pooled (two birds per sample) to provide enough material for chemical analyses (n = 5).

Chemical analyses

Representative samples of seeds were ground to pass through a 0.5 mm sieve. Pea seeds, diets, ileum digesta and excreta were analysed in duplicate for dry matter, crude protein and crude fat (using methods 934.01, 976.05, 920.39, respectively, according to AOAC, 2007), additionally diets and seeds were analysed for acid detergent fibre (ADF), neutral detergent fibre (NDF) and starch (973.18, 2002.04, 996.11, respectively, according to AOAC, 2007).

The amino acid (AA) content was determined in experimental diets and ileum digesta on an AAA-400 Automatic Amino Acid Analyzer, (INGOS s.r.o., Praha, Czech Republic), using ninhydrin for post-column derivatization. Before analysis the samples were hydrolysed with 6 NHCl for 24 h at 110°C (procedure 994.12; AOAC, 2007). Gross energy (GE) was determined in diets and excreta using an adiabatic bomb calorimeter (KL 12Mn, Precyzja-Bit PPHU, Poland) standardized with benzoic acid. Titanium dioxide in diets, ileum digesta and excreta was estimated according to Short et al. (1996), samples were prepared following the procedure proposed by Myers et al. (2004).

The tannin content in the pea samples was evaluated according to the method of Kuhla and Ebmeier (1981), while trypsin inhibitor activity (TIA) was analysed according to PN EN ISO 14902:2005. Raffinose family oligosaccharides (RFO) were extracted and analysed by high-resolution gas chromatography, as described previously by Zalewski et al. (2001). Phytate was determined according to the method proposed by Haug and Lantzsch (1983). Briefly, samples were extracted in hydrochloric acid, subsequently iron–ammonium sulphate was added to the supernatant, which was heated and then centrifuged. Bipyridine solution was added to the supernatant. Absorbance was determined at 519 nm using a Media spectrophotometer (Marcel Lamidey S.A., Châtillon, France).

Calculations and statistical analysis

With crude protein calculation as an example, the following equation was used to calculate the digestibility coefficient (DC) of the basal and experimental diets:

$$DC\,(\%) = 1 - [(TiO_{2\ \%\ diet}/TiO_{2\ \%\ digesta/excreta}) \times (CP_{\%\ digesta/excreta}/CP_{\%\ diet})]$$

The following equation was used to calculate the DCs of various dietary components and the AME_N value of pea seeds (crude protein as an example):

$$DC_{CP} = (DC_{CP\ diet} \times C_{CP\ diet} - DC_{CP\ basal} \times C_{CP\ basal} \times 0.20)/(C_{CP\ diet} - C_{CP\ basal} \times 0.20)$$

where: DC_{CP} – digestibility coefficient of crude protein, DC_{diet} – digestibility coefficient of crude protein in diet, C_{diet} – concentration of crude protein in diet, 0.20 – amount of investigated pea cultivar in diet, DC_{basal} – digestibility coefficient of crude protein in basal diet, C_{basal} – concentration of crude protein in diet.

The AME_N of basal and experimental diets was calculated using the above equations and was corrected to zero nitrogen balance using 34.4 kJ · g^{-1} N retained (Hill and Anderson, 1958).

All data were explored earlier to discard any possible outliers. Analyses were performed using the appropriate procedures of SAS (2012) (distribution analyses; outliers were defined as observations whose distance to the location estimate exceeded three times standard deviation). The obtained results were subjected to one-factorial analysis of variance. White- and coloured-flower peas were compared using Student's t-test.

Means from experiments were compared using the Duncan's test and the differences were assumed to be significant at the level of $P \leq 0.05$.

The correlation between pea seed composition and the nutritional value was assessed using Pearson's correlation calculated using the formula:

$$r_{xy} = \mathrm{cov}(x,y)/S_x S_y$$

where: r_{xy} – Pearson's correlation coefficient, cov(x,y) – covariance (covariation between x and y), S_x, S_y – standard deviations of the x and y cultivar. Standard error of the mean (SEM) was adopted as a measure of error.

Results

Substantial variations were found among the examined pea cultivars with respect to their nutritional value and concentrations of antinutritional substances (Table 2). The highest crude protein concentration was found the in Muza cultivar (276.0 g · kg^{-1} DM), which was by about 33% higher in comparison with cv. Turnia (208.0 g · kg^{-1} DM). Crude fat and crude ash concentrations did not exceed 14.0 and 31.0 g · kg^{-1} DM, respectively, and were similar across the investigated cultivars. The analysed pea cultivars varied with regard to their ADF and NDF levels. The cultivars Turnia, Sokolik and Cysterski were characterized by higher contents of these fractions compared with Muza and Milwa. The starch content in all of the examined pea cultivars exceeded 400.0 g · kg^{-1} DM. The highest was in cv. Turnia (442.0 g · kg^{-1} DM), whereas the lowest was in cv. Muza (401.0 g · kg^{-1} DM).

Table 2. Chemical composition of peas (g · kg^{-1} dry matter (DM)) and trypsin inhibitor activity (TIA, mg · g^{-1})[1]

Content, g · kg^{-1} DM	Coloured-flowered			White-flowered		Coloured-flowered	White-flowered
	Turnia	Sokolik	Milwa	Muza	Cysterski		
Crude protein	208.0	212.0	239.0	276.0	222.0	220.0	249.0
Crude fat	13.0	13.0	11.0	13.0	14.0	12.0	14.0
Crude fibre	73.0	74.0	59.0	63.0	73.0	69.0	68.0
NDF	174.0	182.0	129.0	139.0	168.0	162.0	154.0
ADF	101.0	102.0	83.0	80.0	107.0	95.0	94.0
Crude ash	28.0	28.0	29.0	31.0	28.0	28.0	30.0
Starch	413.0	404.0	401.0	442.0	419.0	406.0	431.0
Total oligosaccharides	88.5	80.7	72.4	83.4	78.1	80.5	80.8
Raffinose	10.1	7.3	9.3	8.9	8.3	8.9	8.6
Stachiose	39.4	29.0	30.3	38.6	31.2	32.9	34.9
Verbascose	39.0	44.4	32.8	35.9	38.6	38.7	37.3
Phytic-P	2.1	2.6	2.9	4.4	2.1	2.5	3.3
Tannins	0.34	0.48	0.16	0.17	0.05	0.33	0.11
TIA, mg · g^{-1}	0.4	0.4	0.4	0.5	0.4	0.4	0.5

NDF – neutral detergent fibre, ADF – acid detergent fibre; [1] expressed as mg pure trypsin inhibited per gram product

The examined pea cultivars differed in their tannin concentrations. The highest concentration was found in cv. Turnia, whereas the lowest was in cv. Cysterski. The TIA was similar across cultivars and did not exceed 0.5 g · kg^{-1} DM. The total oligosaccharide content ranged from 72.4 to 88.5 g · kg^{-1} DM and the dominating oligosaccharide was stachyosein in cv. Turnia and Muza, whereas in the remaining cultivars it was verbascose. The lowest oligosaccharide concentration was that of raffinose, but its content was characterized by the greatest variability among the examined cultivars. The pea cultivar with the highest raffinose content was Turnia (10.1 g · kg^{-1} DM), the lowest content was found in cv. Sokolik (7.3 g · kg^{-1} DM). Substantial variation among the examined pea cultivars was also found in the concentrations of phytic-P. Muza was characterized by two-fold higher concentrations of phytic-P (4.4 g · kg^{-1} DM) than cv. Turnia or Cysterski. White-flower pea was characterized by a higher concentration of starch and lower of tannins compared with coloured-flower pea ($P \leq 0.05$).

The apparent ileal digestibility (AID) of dry matter and crude protein (Table 3) did not differ among the cultivars ($P \leq 0.05$); however, a significant ($P \leq 0.05$) influence of cultivar was found on all amino acid AID. Muza and Cysterski were characterized by the highest crude protein AID, whereas the lowest was in cv. Turnia and Milwa. Birds fed diets with white-flower peas were characterized by a higher amino acid AID, crude protein AID and dry matter AID compared with birds fed diets of peas from coloured-flower cultivars ($P \leq 0.05$). The performed trial pointed to a negative correlation between amino acid AID, especially of Lys AID ($r = -0.67$; $P \leq 0.05$), and raffinose content in pea seeds and a positive correlation between amino acid AID and starch content (the average AID for all

Table 3. Apparent ileal digestibility (%) of crude protein and amino acids and dry matter retention, of peas for broilers (n = 5)

Nutrient, %	Coloured-flowered			White-flowered		SEM	*P*	Coloured-flowered	White-flowered	*P*
	Turnia	Sokolik	Milwa	Muza	Cysterski					
Dry matter	58.9	57.7	56.6	62.1	62.3	0.9	0.139	57.7	62,2	0.011
Crude protein	71.7	73.2	71.9	75.7	74.4	1.1	0.282	72.3	75.1	0.036
Lys	47.9^{b}	60.2^{a}	50.8^{b}	59.7^{a}	61.4^{a}	1.3	<0.001	53.0	60.6	0.001
Thr	60.9^{bc}	68.3^{ab}	55.4^{c}	71.1^{a}	70.7^{a}	1.4	<0.001	61.5	70.9	<0.001
Ile	67.6^{b}	75.4^{a}	63.5^{b}	79.6^{a}	77.3^{a}	1.4	<0.001	68.8	78.5	<0.001
Val	64.6^{c}	71.8^{b}	60,6^{c}	78.3^{a}	75.9^{ab}	1.5	<0.001	65.7	77.1	<0.001
Leu	72.5^{b}	79.9^{a}	68.6^{b}	83.9^{a}	80.4^{a}	1.3	<0.001	73.6	82.2	<0.001
Phe	72.2^{b}	79.7^{a}	67.8^{b}	82.6^{a}	79.1^{a}	1.3	<0.001	73.2	80.9	0.001
His	40.8^{b}	48.3^{ab}	42.6^{b}	50.8^{a}	50.6^{a}	1.3	0.032	43.9	50.7	0.009
Arg	80.5^{bc}	91.4^{a}	78.6^{c}	95.4^{a}	85.1^{b}	1.5	<0.001	83.5	90.3	0.012
Gly	59.2^{b}	68.3^{a}	54.5^{b}	69.9^{a}	70.5^{a}	1.5	<0.001	60.7	70.2	0.0004

^{abc} means with different superscipts within a row are significantly different at $P \leq 0.05$; SEM – standard error of the mean

Table 4. Total tract apparent crude fat digestibility, dry matter and nitrogen retention, apparent metabolizable energy (AME_N) value and metabolizability of gross energy (GE) of peas (n = 10)

Indices	Coloured-flowered			White-flowered		SEM	*P*	Coloured -flowered	White -flowered	*P*
	Turnia	Sokolik	Milwa	Muza	Cysterski					
Crude fat digestibility, %	80.1^{a}	81.1^{a}	79.7^{a}	77.4^{a}	69.1^{b}	1.0	<0.001	80.3	73.3	<0.001
Dry matter retention, %	64.4^{b}	60.6^{c}	61.8^{bc}	59.8^{c}	67.1^{a}	1.0	<0.001	61.9	63.5	0.306
Nitrogen retention, %	54.6^{a}	45.7^{b}	52.9^{a}	53.1^{a}	50.4^{ab}	1.0	0.003	51.1	51.8	0.748
AME_N, MJ · kg^{-1}	9.30^{ab}	8.83^{c}	8.85^{c}	8.95^{c}	9.46^{a}	0.1	0.006	8.99	9.21	0.122
AME_N/GE	51.5^{b}	48.9^{c}	48.9^{bc}	49.5^{c}	54.5^{a}	0.1	<0.001	49.8	52.0	0.061

^{abc} means with different superscipts within a row are significantly different at $P \leq 0.05$; SEM – standard error of the mean

Table 5. Pearson's correlation coefficients between pea seed components, apparent ileal digestibility (AID), apparent total tract retention (ATTR) and apparent metabolizable energy (AME_N) values for broilers (AID, n = 24; AME_N and ATTR, n = 48)

Pea component	Response	Correlation coefficient (*r*)	*P*
Starch	Thr AID	0.56	0.001
	Val AID	0.67	<0.001
	Ile AID	0.62	<0.001
	Leu AID	0.62	<0.001
	Phe AID	0.59	<0.001
Raffinose	Thr AID	−0.46	0.014
	Gly AID	−0.50	0.007
	Val AID	−0.42	0.025
	Ile AID	−0.42	0.013
	Leu AID	−0.45	0.016
	Tyr AID	−0.48	0.010
	Phe AID	−0.45	0.015
	Lys AID	−0.67	0.001
Tannins	DM ATTR	−0.30	0.022
	AME_N/GE	−0.35	0.007
	N ATTR^{2}	−0.26	0.050
Phytic-P	DM ATTR	−0.52	<0.0001
	AME_N	−0.31	0.032
	AME_N/GE	−0.42	0.001

GE – see Table 1; the remaining correlations coefficient between nutrients, antinutritional factors and determined parameters were not statistically significant

amino acids was $r = 0.60$; $P \leq 0.05$) (Table 5). The correlation between crude protein AID and starch content equaled 0.36 and was not statistically significant ($P = 0.054$).

The effect of pea cultivar on apparent total tract (ATT) retention of dry matter, ATT crude fat digestibility, AME_N value as well as AME_N/GE ratio is presented in Table 4. The highest ATT retention of dry matter, AME_N value and AME_N/GE ratio were determined for cv. Cysterski. This cultivar was also characterized by the lowest ATT crude fat digestibility among all the examined pea cultivars. In the case of ATT nitrogen retention, cv. Sokolik was characterized by the lowest value of this parameter ($P \leq 0.05$). Pea cultivars with white flowers were characterized by higher ATT digestibility of crude fat compared with coloured-flower cultivars ($P \leq 0.05$). A negative correlation ($r = -0.52$, $r = -0.31$, $r = -0.42$; $P \leq 0.05$) was determined between ATT dry matter retention, AME_N value and AME_N/GE ratio and the phytic-P concentration. ATT dry matter and nitrogen retention were negatively correlated with the tannin content in pea seeds ($P \leq 0.05$).

Discussion

The nutrient contents in the investigated Polish pea cultivars from the 2011 harvest differed only slightly from those in cultivars examined in previous decades. Presently, the investigated pea cultivars are characterized by a similar crude protein level in comparison with the cultivars studied by Zduńczyk et al. (1997) and Święch et al. (2004). No difference was found in the crude protein content of coloured- or white-flower peas, similarly as determined by Gdala et al. (1992) and Smulikowska et al. (2001). The level of starch in seeds is just negligibly lower than that published by Gdala et al. (1992) or Smulikowska et al. (2001), as well as in Poultry Feeding Standards (Smulikowska and Rutkowski, 2005).

The TIA in the investigated pea cultivars was insignificant and unrelated to flower colour. Similar results were obtained by Zduńczyk et al. (1997) and Smulikowska et al. (2001). On the other hand, Gdala et al. (1992) found significantly higher TIA, which ranged from 2.68 in white-flowered peas to 4.7 g · kg^{-1} DM. According to Huisman and Jansman (1991), the acceptable TIA for soyabean meal ranges from 2 to 5 mg · g^{-1} DM. The TIA determined in the peas used in this study was within the range tolerated for soyabean meal, which is the most commonly used high-protein feed for broilers.

White-flower pea seeds were characterized by lower concentrations of tannins than coloured-flower peas (0.11 vs 0.33 g · kg^{-1} DM). These results are similar to those obtained by Grosjean et al. (1999). Seeds from coloured-flower pea cultivars were characterized by lower tannin concentrations than those investigated by Gdala et al. (1992) and Smulikowska et al. (2001). Castell et al. (1996) found that the antinutrient content in pea seeds could be affected by the growing season and type of cultivar. We argue that the observed inherent variability in the antinutrient content in pea seeds across trials is caused by different vegetation conditions and cultivars.

Over the years, no changes have occurred in the concentrations of phytic-P in pea seeds, but differences can be noticed in raffinose family oligosaccharides (RFO) concentrations. Current pea cultivars are characterized by a higher level of RFO in dry matter (46.8 vs 80.6 g · kg^{-1} DM), with stachyose and verbascose exhibiting the highest increase compared with the results obtained by Zduńczyk et al. (1997). According to some researchers, seed germination capacity depends considerably on oligosaccharide levels (Blöchl et al., 2007). The observed significant increase in oligosaccharide content in pea cultivars can be attributed to genetic improvements aimed at enhancing seed germination capacity.

The obtained amino acid AIDs were low compared with the results obtained by Igbasan et al. (1997). In the present trial, it was found that birds fed coloured-flower pea cultivars were characterized by lower ileal protein digestibility, as well as lower contents of some amino acids and dry matter, compared with white-flower peas. These results are similar to those obtained by Smulikowska et al. (2001) on birds and rats. According to Artz et al. (1987), a high tannin content in peas may depress AA digestibility. The phenolic groups of tannins bind to enzymes and other proteins and form insoluble tannin–protein complexes resistant to the digestive enzymes of gastric animals; hydrogen bonds and hydrophobic interactions appear to be the principal linkages involved. The greater fat digestibility in coloured-flower pea can be explained as a positive impact of a certain amount of tannins on the enhanced activity of lipase in the digestive tract of the chickens (Longstaff and McNab, 1991).

The determined AME_N value was similar to that presented by Nalle et al. (2006) and lower when compared to the results obtained by Grosjean et al. (1999) and Smulikowska et al. (2001). However, Grosjean et al. (1999) used adult cockerels, while Smulikowska et al. (2001) used broilers fed cold pelleted diets, which may result in higher AME_N values. In our trial, 17–21-day-old chickens were used. High variability in AME_N values was obtained among the analysed pea cultivars, and these values were insignificantly higher in white-flower peas. This result differs from that presented by Grosjean et al. (1999), who found an effect of cultivar on AME_N. The lack of differences among cultivars in our study could be due to a lower concentration of tannins in coloured-flower peas than in the cultivars analysed by Grosjean et al. (1999). The high AME_N variability observed among cultivars can be explained partly by the concentration of phytic-P in pea seeds. We found a negative correlation between AME_N and phytic-P concentration (r = –0.31; $P \leq 0.05$). According to some researchers (Cowieson and Adeola, 2005; Kaczmarek et al., 2014a), phytic-P degradation (by phytase) increases energy utilization in poultry. We do not know what mechanisms are involved that allow phytates to reduce energy utilization. However, there are publications corroborating the involvement of phytic acid in disturbing the process of starch digestion by complexing Ca, which is a cofactor of α-amylase (Cowieson and Adeola, 2005), or starch complexing involving triple-component ion bridges (Cowieson et al., 2004). Since starch is, to a considerable extent, responsible for the energy value of pea seeds, the elevated concentration of phytic-P in individual cultivars could have contributed to the deterioration of its digestibility, as demonstrated by lower AME_N values. Starch digestibility was not assessed in this experiment, nevertheless the negative Pearson's correlation between concentrations of phytic-P and total dry matter retention (r = −0.52; $P \leq 0.05$) could partially explain the AME_N variability across cultivars observed in this study.

One of the main antinutritional substances in pea seeds are oligosaccharides, primarily raffinose, stachyose and verbascose (Igbasan et al., 1997). Numerous articles have been published in recent years describing the negative influence of the oligosaccharides found in soyabean meal on the TME_N value (Baker et al., 2011; Perryman et al., 2013). The deterioration of the TME_N value in soyabean meal is attributed, primarily, to raffinose (Leske et al., 1991). The raffinose concentration in soyabean meal amounts to about 0.6% (Parsons et al., 2000), whereas in pea seeds it can be even as high as 1% (Zduńczyk et al., 1997). The determined greater proportion of raffinose in pea seeds should exert a considerable impact on the energy value of individual pea cultivars. No correlations were found, however, in our trial between raffinose levels and the AME_N value. The performed experiment revealed a statistically significant Pearson's correlation between raffinose concentration and the ileal digestibility of most AAs, in particular Lys (r = −0.67; $P \leq 0.05$). There is no information in the available literature about the effect of RFOs on AA ileal digestibility. Nevertheless, according to previously performed experiments, it may be concluded that oligosaccharides, as well as RFOs, negatively affect nutrient utilization (Jankowski et al., 2009; Baker et al., 2011; Chen et al., 2013; Perryman et al., 2013). The performed trial revealed a positive Pearson's correlation between starch concentrations in pea seeds and ileal digestibility of nearly all amino acids (average $r = 0.60$; $P \leq 0.05$). According to Weurding et al. (2003), due to its structure, pea starch is characterized by very slow degradation in the gastrointestinal tract of birds compared with maize starch. The above authors speculated that diets with rapidly digestible starch may result in elevated plasma glucose levels when other nutrients are not yet absorbed, which may have consequences for protein utilization (Weurding et al., 2003). The higher amino acid AID in the cultivars characterized by higher starch contents determined in the current study is difficult to explain and needs further studies.

Conclusions

The obtained results demonstrated considerable variability in nutritive value among the pea cultivars from the 2011 harvest. The pea cultivar that turned out to be best utilized by broiler chickens was white flowered Cysterski. Our study demonstrated correlations between chemical composition and utilization of nutrients by broiler chickens, the positive impact of higher starch level on apparent ileal digestibility (AID) amino acid, and the negative effect of raffinose and tannin levels on amino acid AID.

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