Journal of Animal and Feed Sciences, 24, 2015, 53–60
The Kielanowski Institute of Animal Physiology and Nutrition, PAS, Jabłonna

The chemical composition of selected dried fruit pomaces and their effects on the growth performance and post-slaughter parameters of young turkeys

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KEY WORDS: apple pomace, blackcurrant pomace, strawberry pomace, nutritive value, turkey

Received: 29 August 2014
Revised: 9 January 2015
Accepted: 16 March 2015

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ABSTRACT. The objective of this study was to verify the hypothesis that adding dried fruit pomaces differing in their polyphenol contents to diets for young turkeys does not compromise bird performance. Young turkeys aged up to 15 weeks were fed diets containing a cellulose preparation (C) or 5% dried apple pomace (AP), blackcurrant pomace (BCP), strawberry pomace (SP), or seedless strawberry pomace (SSP). The crude protein content of AP was 6.64% and exceeded 15% in the remaining pomaces. In comparison with soyabean meal protein, the value of the essential amino acid index was lowest in AP (78.6%), higher in SP and SSP (approximately 85%) and highest in BCP (93.4%). The crude fat content ranged from 2.63% in AP to 13.8% in BCP, whereas the dietary fibre content was found to be in the range of 56.5% in AP to 62.9% in SP. AP, BCP, SP and SSP were characterized by different polyphenol concentrations: 5.75, 12.43, 11.51 and 32.81 g · kg^{-1} of gallic acid, respectively. Dietary inclusion of 5% of dried fruit pomaces that increased the polyphenol content of the experimental diets by a maximum of 0.3 g · kg^{-1} relative to the control diet did not affect feed intake at the beginning or at the end of the feeding trial. In comparison with the cellulose-supplemented diet, the inclusion of fruit pomaces that increased the dietary polyphenol content did not impair the growth performance of turkeys or feed conversion. Production parameters, including slaughter results, were not affected by the higher polyphenol content or the higher antioxidant potential of blackcurrant and strawberry pomaces, compared with apple pomace.

Introduction

In intensive poultry production, excessive concentrations of indigestible structural carbohydrates (non-starch polysaccharides, NSPs) can lower feed intake and nutrient availability (Mateos et al., 2012). The crude fibre content of standard cereal-soyabean diets for young chickens and turkeys is relatively low at approximately 3.5% (Jankowski et al., 2009; Mateos et al., 2012), which is significantly below the 6% threshold tolerated by fast-growing birds (Zduńczyk et al., 2010). For this reason, moderate addition of selected high-fibre components to cereal-soyabean diets enhances gastrointestinal functions in birds (Mateos et al., 2012). Dried fruit pomaces, a rich source of NSPs and biologically active compounds, could be recommended supplements for poultry diets.

The antioxidant properties of fruit provitamins and vitamins (β-carotene, vitamins C and E) and the presence of folic acid in fruit prevent the development of various diseases in humans (Esfahani et al., 2011). Many of these compounds are retained in pomace, which is why fruit pomaces are used in various biotechnological processes to produce health-promoting phytochemicals (Kołodziejczyk et al., 2007; Kandari and Gupta, 2012).

The growth of horticulture industries worldwide generates enormous quantities of fruit wastes, mostly pomaces from juice pressing, whose amount is estimated at 25% to 40% of total processed fruits (Bhushan et al., 2008). More than 1.5 million tons of apples are used in juice production in Poland (Kołodziejczyk et al., 2007). Only 20% of the resulting thousands of tons of pomace is used in animal nutrition (Dhillon et al., 2013). To date, fruit pomace has been used in poultry nutrition only locally, mostly in developing countries, to reduce feed costs (Matoo et al., 2001). Fruit pomace can be used more extensively in dried form.

The past decade has witnessed numerous research studies indicating that dried fruit pomaces can be effectively used in poultry nutrition, mostly grape pomaces that are produced in large quantities and can be effectively incorporated in maize-soyabean basal diets for broiler chickens (Goni et al., 2007). Fruit pomaces exerted beneficial effects on pigs by increasing *Lactobacillus* counts in the caecum and improving blood parameters (Sehm et al., 2011). In poultry, long-term administration of dried apple pomace improved the reproductive performance of breeder roosters, including several sperm characteristics (Akhlaghi et al., 2014).

Dried fruit pomaces contain 40% to 80% dietary fibre, and they are a rich source of polyphenolic compounds whose content and composition are determined by the raw material and the applied processing technology (Jarosławska et al., 2011). Animal nutritionists have traditionally regarded polyphenols as antinutrients due to the adverse effects of proanthocyanidin, a type of polyphenol, on protein digestibility, but recent experiments revealed that only a high content of polyphenolic extracts in chicken diets (2.5 g · kg^{-1} or more) significantly reduced ileal digestibility of protein, lowered weight gains and negatively affected feed conversion in birds (Chamorro et al., 2013).

Turkeys' responses to varied polyphenol concentrations in the diet remain fairly unknown due to the general scarcity of research in this area. This is an important consideration in analyses comparing the dietary applications of berry fruit pomaces, including currant and strawberry pomaces, with apple pomaces that are more abundant in polyphenols (Jarosławska et al., 2011; Sójka et al., 2013). Due to their antioxidant properties, polyphenols can prevent lipid oxidation in broiler diets containing high levels of unsaturated fatty acids (Goni et al., 2007).

The objective of this study was to determine whether diets for young turkey poults can be supplemented with 5% dried fruit pomaces, including the most extensively researched apple pomace and lesser-known blackcurrant and strawberry pomaces, without compromising feed conversion and the body weight gains of birds.

Material and methods

Fruit pomaces

Dried apple pomace (AP), blackcurrant pomace (BCP) and strawberry pomace (SP), dried in an SB-1.5 rotary drum dryer for biomass residues, were supplied by Agro-Bio-Produkt Sp. z o.o. (Grądkowice, Poland). Seedless strawberry pomace (SSP) was supplied by Polfarmex (Łódź, Poland) as a by-product of seed separation in the oil production process. SSP had a seed content of less than 5% and was dried in a vacuum dryer at 70°C for 8 h. Each fruit pomace was ground in a hammer mill with a screen size of 4 mm (Jesma Co., Sprout Matador, Denmark), at 3000 rpm.

Birds and management

The experiment was carried out at the Research Laboratory of the Department of Poultry Science, University of Warmia and Mazury in Olsztyn (Poland). All experimental procedures were approved by the Local Animal Care and Use Committee (Olsztyn, Poland) and the study was carried out in accordance with EU Directive 2010/63/EU for animal experiments. The temperature and lighting programmes were consistent with the recommendations of Aviagen™Turkeys Ltd. (2012).

Five hundred and twenty-five Big 7 female turkeys were divided into 5 groups of 105 birds each. Each group was kept in 7 pens of 15 birds per pen (7 replicates per group). Every pen was equipped with an automatic feeder and a bell-type drinker and both water and feed were provided *ad libitum*. The experiment began when the turkeys were 1 day old and ended when the birds reached the age of 15 weeks.

Experimental design and diets

The nutritive value of five experimental diets for three phases of feeding, whose composition is presented in Table 1, was consistent with or somewhat higher than turkey nutrient requirements (NRC, 1994). The levels of protein and amino acids in dried fruit pomaces were taken into account when balancing the diets for total protein and major amino acids. Powdered cellulose (Vitacel®) was used as the control component to bring crude fibre concentrations in the control diet to the level found in the diet containing dried apple pomace. All diets were supplemented with Ronozyme P (0.01%) and Ronozyme Wx (0.02%) as a source of phytase and xylanase.

The nutrient content of diets was calculated based on the analysed chemical composition of fruit pomaces and according to the Poultry Feeding Standards (Smulikowska and Rutkowski, 2005). The diets contained 5% of the dried fruit pomaces in all feeding phases. In the first two feeding phases (weeks 1–4 and 5–10), the diets contained only soyabean oil to level out their energetic value. In the third feeding phase, part of the soyabean oil (2.5%) was replaced with linseed oil to increase n-3 PUFA concentrations in meat.

Measurements and calculations

A three-phase feeding programme was applied in the study. Diet intake and feed conversion ratio (FCR) were determined in the periods of days 1–28, 1–70 and 71–105; the turkeys were weighed on the last day of each period. Mortality rates, including their causes, were monitored every day. A pen of 32 birds was considered an experimental unit.

The quality of protein in fruit pomaces was determined based on the essential amino acid index (EAAI) and the first-limiting AA, with soyabean protein as the reference standard.

Table 1. Composition and nutritional value of diets fed to turkeys aged 1–4, 5–10 and 11–15 weeks

Indices	Weeks 1– 4					Weeks 5–10					Weeks 11–15				
	C	AP	BCP	SP	SSP	C	AP	BCP	SP	SPP	C	AP	BCP	SP	SSP
Component, %															
wheat	24.92	21.84	23.09	23.01	23.12	31.39	28.27	29.51	29.45	29.56	58.54	55.33	57.61	57.58	57.77
maize	20.00	20.00	20.00	20.00	20.00	18.00	18.00	18.00	18.00	18.00	–	–	–	–	–
soyabean meal	40.86	40.86	40.86	40.86	40.86	36.00	36.00	36.00	36.00	36.00	30.83	31.03	29.40	29.34	29.15
potato protein	5.00	5.10	4.26	4.23	4.12	4.62	4.72	3.88	3.84	3.73	–	–	–	–	–
vitacel	2.32	–	–	–	–	2.31					2.33	–	–	–	–
apple pomace	–	5.00	–	–	–	–	5.00	–	–	–	–	5.00	–	–	–
blackcurrant pomace	–	–	5.00	–	–	–	–	5.00	–	–	–	–	5.00	–	–
seedless strawberry pomace	–	–	–	5.00	5.00	–	–	–	5.00	5.00	–	–	–	5.00	5.00
strawberry pomace	–	–	–	–	5.00	–	–	–	–	5.00	–	–	–	–	5.00
soyabean oil	1.64	1.94	1.53	1.62	1.62	2.92	3.24	2.83	2.92	2.92	2.84	3.17	2.52	2.60	2.60
linseed oil	–	–	–	–	–	–	–	–	–	–	2.50	2.50	2.50	2.50	2.50
sodium bicarbonate	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10
fodder salt	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.14	0.14	0.14	0.14	0.14
limestone	1.78	1.77	1.77	1.77	1.77	1.58	1.58	1.58	1.58	1.58	1.23	1.22	1.23	1.23	1.23
monocalcium phosphate	1.98	2.0	1.99	1.99	1.99	1.79	1.82	1.81	1.81	1.81	0.55	0.57	0.57	0.57	0.57
DL-methionine 99%	0.35	0.35	0.35	0.36	0.36	0.32	0.32	0.32	0.32	0.32	0.18	0.19	0.18	0.18	0.18
L-lysine 99%	0.30	0.29	0.30	0.31	0.31	0.27	0.25	0.27	0.28	0.28	0.29	0.28	0.28	0.29	0.29
L-threonine	–	–	–	–	–	–	–	–	–	–	0.07	0.07	0.07	0.07	0.07
vitamin-mineral premix[1]	0.50	0.50	0.50	0.50	0.50	0.45	0.45	0.45	0.45	0.45	0.40	0.40	0.40	0.40	0.40
Nutritive value															
crude protein	27.50	27.50	27.50	27.50	27.50	25.50	25.50	25.50	25.50	25.50	21.50	21.50	21.50	21.50	21.50
crude fibre	4.10	4.10	5.12	4.67	4.67	3.96	3.96	4.99	4.53	4.53	3.96	3.96	4.94	4.48	4.48
lysine	1.74	1.74	1.74	1.74	1.74	1.58	1.58	1.58	1.58	1.58	1.25	1.25	1.25	1.25	1.25
Met + Cys	1.19	1.19	1.19	1.19	1.19	1.11	1.11	1.11	1.11	1.11	0.86	0.86	0.86	0.85	0.85
threonine	1.06	1.06	1.05	1.05	1.05	0.97	0.97	0.97	0.97	0.97	0.80	0.80	0.80	0.80	0.80
Ca	1.25	1.25	1.25	1.25	1.25	1.15	1.15	1.15	1.15	1.15	0.75	0.75	0.75	0.75	0.75
P	0.58	0.58	0.58	0.58	0.58	0.54	0.54	0.54	0.54	0.54	0.30	0.30	0.30	0.30	0.30
metabolizable energy, $MJ \cdot kg^{-1}$	11.28	11.28	11.28	11.28	11.28	11.8	11.8	11.8	11.8	11.8	12.54	12.54	12.54	12.54	12.54

C – cellulose, AP – apple pomace, BCP – blackcurrent pomace, SP – strawberry pomace, SSP – seedless strawberry pomace; [1] 0.5% of the Extramix provided per kg of diet: IU: all trans-retinol acetate 13.000, cholecalciferol 3.000; mg: all-rac-α-tocopheryl acetate 40, vit. K_3 2, vit. B_1 2, vit. B_2 8, vit. B_6 3.5, niacin 65, pantothenic acid 18, folic acid 1.5, biotin 0.2, choline chloride 400, Mn 100, Zn 80, Fe 50, Cu 8, I 0.8, Se 0.3

At the end of the trial, seven birds representing the average body weight of each group were selected, tagged and fasted for 8 h. After slaughter, the carcasses were scalded, plucked and eviscerated. The weights of the breast, thigh, drumstick, giblets (gizzard, liver and heart) and abdominal fat were calculated as relative (%) weight of the carcass. After 24 h of chilling the carcass, the pH and colour parameters of breast muscle were determined.

The pH of breast muscles was measured 24 h post mortem (Testo GmbH 206-pH2 meter). The Hunter L* (lightness, a lower value indicates a darker colour), a* (redness, a higher positive value indicates a higher contribution of redness) and b* (yellowness, a higher value indicates a higher contribution of yellowness) values were determined using a MiniScan XE Plus colour difference meter (Hunter Associates Laboratory, Inc., Reston, VA, USA). The average of three readings taken from a cross-section of a muscle free from colour defects, bruising and haemorrhages was recorded.

Chemical analyses

Fruit pomace samples were analysed in duplicate for dry matter (DM), crude protein (CP), fat, crude fibre, ash and dietary fibre using AOAC (2005) methods: 934.01, 976.05, 920.39, 978.10, 942.05 and 985.29, respectively. The samples were mineralized in a mixture (3:1) of nitric and perchloric acids (Merck, Germany) to determine the mineral composition of pomaces. Weighed samples were mineralized in a VELP DK 20 electric aluminium heating block with selectable temperatures (VELP Scientifica, Italy). The Ca, K, Mg and Na contents of mineralized samples were determined by flame atomic absorption spectrometry (acetylene-air flame). The analysis was performed using a Unicam 939 Solar atomic absorption spectrophotometer equipped with an Optimus data station, background correction system (deuterium lamp) and cathode lamps. The P content of mineralized samples was determined by colourimetry using ammonium molybdate, Na sulphate and hydroquinone. Absorbance was measured in a VIS 6000 spectrophotometer (Krüss–Optronic, Germany) at a wavelength of $\lambda = 610$ mm.

Amino acid concentrations were determined by post-column derivatization with ninhydrin in an AAA-400 Automatic Amino Acid Analyser (INGOS Ltd., Czech Republic). Before analysis, the samples were hydrolysed with 6 N hydrochloric acid for 24 h at 110°C (procedure 994.12; AOAC, 2005). Methionine and cysteine were determined as methionine sulphone and cysteic acid after cold performic acid oxidation before hydrolysis (procedure 994.12). Tryptophan was determined by hydrolysing the samples with barium hydroxide, carrying out a colour reaction with *p*-dimethylaminobenzaldehyde and spectrophotometrically measuring the absorbance of the product at 590 nm.

The polyphenol content was determined spectrophotometrically by the Folin-Ciocalteau method (FC polyphenols) based on the reducing capacity of phenolic compounds. The standard curve was developed with the use of gallic acid according to the method of Singleton and Rossi (1965).

Statistical analysis

The statistical analysis was performed using one-way analysis of variance (ANOVA), according to the GLM procedure for Statistica 8.0PL software (StatSoft Inc., 2007). Treatment effects were considered to be significant at $P \leq 0.05$. All data were expressed as mean values with a pooled standard error (SEM).

Results

The evaluated fruit pomaces differed in their proximate composition, including the content of total protein, crude fat and crude fibre (Table 2). In comparison with the remaining pomaces, AP was characterized by a lower content of crude protein and crude fat and relatively low concentrations of crude ash. In comparison with AP, crude fibre levels were lower in BCP and higher in SP and SSP. The analysed pomaces had similar dietary fibre levels that ranged from 56.5% in AP to more than 62% in BCP and SP. In comparison with the standard (SP), (SSP) contained less crude ash, more crude protein, less crude and dietary fibres.

Table 2. Chemical composition of dried fruit pomaces, %

Indices	AP	BCP	SP	SSP
Proximate composition				
dry matter	92.4	93.7	93.2	94.8
crude ash	1.10	3.89	8.01	5.86
crude protein	6.64	15.5	16.4	17.8
crude fat	2.63	13.8	10.4	9.64
Fibre fractions				
crude fibre (CF)	22.0	19.8	31.4	26.3
dietary fibre (DF)	56.5	62.4	62.97	59.6
Macroelements				
Ca	0.09	0.36	0.37	0.26
K	0.23	0.39	0.15	0.15
P	0.16	0.33	0.43	0.41
Mg	0.04	0.17	0.10	0.06
Na	<0.01	<0.01	<0.01	<0.01

AP, BCP, SP, SSP – see Table 1

Table 3. Amino acid profile of protein from dried fruit pomaces vs soyabean protein, % crude protein (CP)

Amino acid, % CP	Soyabean meal[1]	AP	BCP	SP	SSP
Met	1.32	0.76	1.27	1.13	1.30
Cys	1.45	1.01	1.71	1.11	1.16
Met + Cys	2.77	1.77	2.99	2.26	2.46
Lys	6.03	4.81	5.89	4.56	4.79
Thr	3.91	3.46	4.22	3.72	3.67
Trp	1.34	0.65	0.85	0.82	1.05
Arg	7.14	4.94	7.83	6.36	5.21
Ile	4.53	3.92	5.81	4.37	4.09
Leu	7.57	7.30	7.43	7.16	7.16
Val	4.77	4.78	4.41	5.02	5.11
His	2.60	2.77	2.97	2.74	2.23
Phe	5.03	3.89	4.63	3.88	4.18
Tyr	3.45	2.17	3.16	2.23	1.77
Phe + Tyr	8.48	6.06	7.79	6.11	5.95
Gly	4.21	4.84	6.35	5.03	5.48
Ser	4.98	4.62	4.78	4.51	4.60
Pro	5.00	3.88	4.11	3.65	3.86
Ala	4.35	4.90	4.87	4.85	4.37
Asp	11.37	11.0	10.9	9.87	10.1
Glu	18.0	14.5	18.9	15.0	18.0
EAAI[2]	100	78.6	93.4	85.6	84.9
First limiting AA, %	100	Trp (49)	Trp (63)	Trp (61)	Tyr (78)

AP, BCP, SP, SSP – see Table 1; [1] soyabeans analysed in a previous study (Zduńczyk et al., 2014); [2] the essential amino acid index (EAAI) and the first-limiting AA were determined using soyabean protein as a reference standard

AP was characterized by lower calcium and magnesium concentrations in comparison with the remaining pomaces. The highest potassium and magnesium levels were noted in BCP, but the observed differences were smaller than those noted between SP and SSP vs AP.

AP was characterized by the lowest content of selected essential amino acids, including methionine, tryptophan and isoleucine, whereas the remaining pomaces had similar amino acid profiles (Table 3). The highest cysteine, lysine and arginine concentrations were found in BCP. In comparison with soyabean meal protein, BCP protein was characterized by the highest levels of essential amino acids, which were higher than in SP and SSP, and considerably higher than in AP. In comparison with soyabean protein, tryptophan limited the biological value of protein in the analysed fruit pomaces, excluding SSP.

The compared pomaces differed in their polyphenol contents (Table 4). Polyphenol concentrations were the lowest in AP, approximately 2-fold higher in BCP and SP, and almost 6-fold higher in SSP.

Table 4. Polyphenol concentrations in dried fruit pomaces and in the experimental diets, g · kg^{-1}

Polyphenol concentrations	C	AP	BCP	SP	SSP
Dried fruit pomace	–	5.75	12.43	11.51	32.81
Diets fed to turkeys in three consecutive phases, weeks:					
1–4	2.03	2.11	2.18	2.21	2.31
5–10	1.82	1.88	2.03	1.98	2.10
11–15	1.27	1.45	1.48	1.48	1.58

C, AP, BCP, SP, SSP – see Table 1

Table 5. The growth performance of turkeys from 1 to 105 days of age

Feeding phase, days	C	AP	BCP	SP	SSP	SEM	*P*
Daily feed intake, g							
1–28	49	49	49	49	50	0.358	0.943
1–70	163	159	160	165	163	0.948	0,515
1–105	254	250	250	250	252	1.366	0.903
Body weight, kg							
1	0.06	0.06	0.06	0.06	0.06	0.001	0.917
28	0.93	0.91	0.93	0.93	0.93	0.007	0.947
70	5.74	5.72	5.76	5.74	5.78	0.070	0.972
105	10.44	10.58	10.47	10.44	10.57	0.045	0.779
FCR, kg of feed/kg of BWG							
1–28	1.49	1.50	1.49	1.48	1.60	0.007	0.895
1–70	2.02	2.00	2.00	2.02	2.04	0.006	0.633
1–105	2.57	2.51	2.54	2.52	2.58	0.013	0.539
Mortality, %							
1–105	0.95	1.90	1.90	0.95	0.95	–	–

C, AP, BCP, SP, SSP – see Table 1; FCR – feed convertion ratio, BWG – body weight gain

In all feeding phases, the dietary inclusion of dried fruit pomaces with different polyphenol contents did not affect feed intake (Table 5). Daily feed intake in the analysed groups was determined within a narrow range of 250–254 g during the 105-day feeding trial. Dietary treatments did not influence the growth rate of young birds. Body weights determined on successive weighing days between the ages of 1 day to 105 days were similar in all experimental groups. The final body weights of female turkeys were within a very narrow range of 10.4–10.6 kg. In all groups, the feed conversion ratio was similar in each feeding phase and throughout the feeding trial. The mortality rates of turkeys were very low in all groups (below 2%).

No significant differences were found in such slaughter quality parameters as the yields of breast, thigh and drumstick meat, abdominal fat, or the pH and colour parameters of breast meat (Table 6).

Table 6. Carcass characteristics of turkeys after 15 weeks of experimental feeding

Indices	C	AP	BCP	SP	SSP	SEM	*P*
Muscle, % of carcass							
breast	23.6	23.6	24.2	24.1	24.2	1.591	0.880
thigh	10.3	10.0	10.8	10.4	10.6	0.740	0.287
drumstick	7.9	7.2	8.2	8.1	8.00	0.582	0.617
total	41.8	41.3	43.2	42.6	42.8	1.914	0.278
Giblets[1], % of carcass	2.35	2.45	2.32	2.32	2.22	0.233	0.414
Abdominal fat, % of carcass	2.10	2.19	2.05	1.94	1.92	0.429	0.739
pH_{24h} of breast muscle	5.67	5.70	5.88	5.72	5.69	0.213	0.313
Meat colour paramaters[2]							
L*	51.6	52.6	52.8	52.4	52.7	2.141	0.838
a*	5.2	5.7	5.1	5.4	4.8	0.984	0.461
b*	10.5	11.0	11.2	10.8	10.6	0.960	0.574

C, AP, BCP, SP, SSP – see Table 1; [1] combined data for the gizzard, liver and heart; [2] L* – lightness, a*– redness, b* – yellowness

Discussion

Numerous authors have investigated the use of grape pomace (Goni et al., 2007) and apple pomace (Matoo et al., 2001; Figuerola et al., 2005) in animal nutrition. In our experiment, apple pomace was the least abundant in nutrients among the analysed dried fruit pomaces. The crude protein content and crude fat content of apple pomace was low (6.64% and 2.63%, respectively) and similar values were reported in other studies (Massini et al., 2013). The results of another experiment (Figuerola et al., 2005) indicate that the crude protein content of apple pomace can be lower than 5% of dry matter.

In one of the few experiments investigating the nutritive value of raspberry pomace for monogastric animals, its crude protein content was estimated at 10% (McDougall and Beames, 1994). The total protein content of strawberry pomace was found to be even higher at 19% (Jarosławska et al., 2011). In comparison with apple pomace, higher concentrations of crude protein in berry fruit pomaces could be attributed to their higher seed content, which was estimated at 40% in strawberry pomace (Sójka et al., 2013) but only at 2%–3% in apple pomace (Carson et al., 1994). In our study, however, the nearly complete removal of seeds from strawberry pomace did not decrease, but actually increased its total protein content.

The compared fruit pomaces, in particular apple pomace, contained small amounts of mineral macroelements: Ca, P, K, Mg and Na. In berry fruit pomaces, Ca levels were slightly higher, whereas P and K concentrations were considerably lower than those noted by Helbig et al. (2008) in whole blackcurrant seeds. The differences in the mineral content of plants can be attributed to numerous factors, including soil nutrient levels and fertilization rate (Mayer, 1997).

In the current experiment, considerable differences were observed in the amino acid profiles of the analysed pomaces. In comparison with soyabean meal, the value of the essential amino acid index (EAAI) was lower in apple pomace, distinctly higher in strawberry pomace and very high in blackcurrant pomace. The observed high biological value of protein in blackcurrant pomace is consistent with the results of Helbig et al. (2008) in whose study the EAAI of blackcurrant seeds was equivalent to 76% of the EAAI of whole eggs. In the cited experiment and in our study, the first limiting amino acid that decreased protein quality in fruit pomaces was tryptophan, which is generally present in sufficient quantities in poultry diets.

In our experiment, considerable differences in crude fibre content and relatively small differences in dietary fibre (DF) content were noted in the analysed dried fruit pomaces. This indicates that the compared pomaces differ in their content of soluble fibre fractions such as hemicellulose and lignin, a small portion of which was measured as crude fibre. In this study, the DF content ranged from 56.5% in apple pomace to 63.0% in standard strawberry pomace, and was similar to the values reported by other authors. In other experiments, DF concentrations in apple and strawberry pomaces ranged from 50% to 61% (Jarosławska et al., 2011; Dhillon et al., 2013).

Other studies indicate that the polyphenol content of apples, currants and strawberries varies in both fresh fruit (Vulic et al., 2011) and in dried fruit pomace (Suarez et al., 2010; Jarosławska et al., 2011). In this experiment, the total polyphenol content of apple pomace was below 6 $g \cdot kg^{-1}$ but it was more than twice as high in blackcurrant and strawberry pomaces that were dried in a rotary drum dryer. Polyphenol concentrations were several-fold higher in seedless strawberry pomace (32.8 $g \cdot kg^{-1}$). The above results suggest that strawberry flesh residues are more abundant in polyphenols than strawberry seeds.

In comparison with the control diet, the inclusion of fruit pomaces in diets fed to turkeys at the age of 1–4, 5–10 and 11–15 weeks increased polyphenol concentrations by 0.08–0.28, 0.06–0.28, and 0.18–0.31 $g \cdot kg^{-1}$, respectively. The highest increase in polyphenol concentrations was noted in diets supplemented with strawberry pomace, and the lowest – in diets containing apple pomace. The above differences resulted from variations in the polyphenol content of pomaces incorporated into turkey diets. In the second and third feeding phases, clearly lower polyphenol concentrations in all diets resulted from lower soyabean meal levels. Soyabean and soyabean products are rich in polyphenols, in particular isoflavones (Malencic et al., 2012). The polyphenol content of wheat, whose share in turkey diets increased in the last feeding phase, is several times lower compared with fruit pomace (Perez-Jimenez et al., 2010).

The differences in the composition of experimental diets, including the increase in their total polyphenol content, did not affect feed intake, the growth rate of turkeys or feed conversion. In the study of Chamorro et al. (2013), the intestinal digestibility of protein and the growth rate of chickens were reduced only when dietary supplementation with grape polyphenol extract exceeded 2.5 g · kg^{-1}. In our experiment, the maximum polyphenol content of diets given in the first feeding phase (weeks 1–4) and containing strawberry pomace (2.31 g · kg^{-1}, in SSP) was lower than that reported by Chamorro et al. (2013). The above could explain why polyphenols from the fruit pomaces applied in our study did not negatively affect feed intake, feed conversion, or body weight gains of turkeys. In other experiments, the growth performance of chickens was not impaired when their diets were supplemented with apple pomace (Matoo et al., 2001) or grape pomace with a higher polyphenol content (Goni et al., 2007).

In earlier experiments performed on young hogs (McDougall and Beames, 1994), raspberry protein was characterized by a relatively high biological value (BV = 79.3%), but very low digestibility (14.7%). Consequently, only 1.5% of the 10% total crude protein content was digested. Low digestibility of pomace ingredients can exert a minor influence on the nutritive value of a diet due to the low content of fruit pomace. In our experiment, the use of seedless strawberry pomace contributed to the highest fruit protein content (0.9%) of the diet, which accounted for 4.2% of total dietary protein in the third feeding phase. This dilution of soyabean protein and wheat protein with fruit pomace protein had no effect on nutrient utilization or the growth performance of turkeys. In another experiment (Jankowski et al., 2012), moderate dilution of standard turkey diets with pelleted or whole wheat (18% on average, between weeks 5 and 18) decreased protein concentrations by 5.8% in comparison with the control diet. The above dilution had no effect on the final body weights or muscle yield of birds, but it improved feed efficiency. Fruit pomaces contained in turkey diets did not deteriorate bird performance for a similar reason, namely low digestibility of crude protein.

The results of few experiments indicate that the supplementation of poultry diets with purified flavonoids can modulate meat quality parameters such as colour and pH (Jiang et al., 2007) or fatty acid composition (Kamboh and Zhu, 2013). In the current experiment, fruit pomaces with differing polyphenol contents had no effect on the yields of major muscles or on the pH and colour parameters of breast meat.

Conclusions

The results of this study indicate that blackcurrant and strawberry pomaces contain more crude protein with a more desirable amino acid profile and more polyphenols than apple pomace. The differences in the chemical composition of fruit pomaces, including considerable differences in their polyphenol content, did not influence feed intake or feed conversion in the experimental birds. Dietary supplementation with 5% fruit pomace in three successive feeding phases is not a factor that negatively affects growth rate, feed conversion or slaughter quality parameters in female turkeys poults.

Acknowledgements

This research was carried out as part of the research project BIOFOOD – ‘Innovative, Functional Products of Animal Origin’ No. POIG.01.01.02-014-090/09 co-financed by the European Union from the European Regional Development Fund within the Innovative Economy Operational Programme 2007–2013.

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