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Nutritional value of rapeseed expeller cake for broilers: effect of dry extrusion*

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ABSTRACT

The effect of extrusion, applied in the production of cold-pressed rapeseed cake on its nutritional value for broilers was evaluated. Two experiments were performed on 55 female broiler chickens, kept individually and allocated to 2 groups of 14 birds (growth trial) or to 3 groups of 9 chickens (digestibility trial). Rapeseed cakes pressed once (RC) or extruded and pressed again (RCE) were mixed in a 6:4 proportion with a basal diet and used in a balance trial with 3-week-old chickens. Furthermore, they were included into wheat-soyabean meal diets at a level of 100 or 150 g/kg and fed during 1-3 and 4-6 weeks of age, respectively, in a growth trial.

Due to extrusion and additional pressing, the amount of crude fat decreased from17.4% in RC to 10% in REC, fat digestibility increased from 83 to 91% ($P<0.01$), protein digestibility decreased from 79 to 76% ($P<0.01$), and the metabolizable energy value decreased from 13.8 to 11.4 MJ/kg DM ($P<0.01$). Broilers ate more of the REC diet compared with the RC diet and their final body weight gain was higher (2.61 vs 2.39 kg; $P<0.05$). This, as well as a lower relative mass of the liver ($P<0.05$) and kidneys ($P<0.01$) and a slightly lower mass of thyroids, indicates that extrusion resulted in partial inactivation of the antinutritional factors present in rape seeds.

KEY WORDS: rapeseed expeller cake, dry extrusion, metabolizable energy, broiler chickens, antinutritional factors

INTRODUCTION

The share of rapeseed expeller cake (RC) in Polish rapeseed products is growing because expelling technology is more cost-effective and more environmentally

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friendly than the prepressing/solvent extraction method yielding rapeseed meal as the final product. Rapeseed cakes seem to be more suitable components of broiler diets than solvent-extracted rapeseed meal as their metabolizable energy value is higher than that of rapeseed meal due to a higher residual oil content (Smulikowska et al., 1997, 2006). Moreover, the residual oil has a lower n-6/n-3 PUFA ratio than most of the fats used in broiler diets. Nguyen et al. (2003) showed that broilers fed diets with rapeseed oil deposited fat with a low n-6/n-3 PUFA ratio in edible parts of the carcass, which can be considered beneficial for consumer health.

A number of technologies have been developed to improve oil yield by expelling, but so far their effect on the digestibility of fat and protein from RC is poorly understood. Rapeseed contains considerable proportions of non-protein components, primarily fibre. Fibre encapsulates fat and protein, hinders pressing out oil during expelling and impedes digestion of RC fat and protein in monogastric species. As a result, there is a potential for RC to derive additional value from partial disruption of fibre structures due to extrusion or the ammonia fibre explosion process (Newkirk and Classen, 2003). Apart from oil yield, additional treatments may affect myrosinase activity and glucosinolate toxicity, as well as protein digestibility and lysine availability in the final product (Smulikowska et al., 1997, 2006).

The aim of this study was to evaluate the effect of dry extrusion on the digestibility of RC nutrients, and on the performance and thyroid status in broiler chickens.

MATERIAL AND METHODS

Materials

Rapeseed press cakes were produced in a small rural mill (Kamex, Sulechów, Poland) from seeds harvested in the year 2003. Rape seeds were heated to 50°C and pressed on a screw press expeller (02PVO Bispomasz, Bydgoszcz, Poland), producing sample RC, or immediately extruded (120-130°C for 20 sec) on an FE 1000 dry extruder (Farmet, Czech Republic) and pressed again on the same press, producing sample RCE (Table 1). Finally both samples were formed into flakes and were ground prior to inclusion into the experimental diets.

Diets and animals

The composition of the basal diet (B) used in the digestibility trial is given in Table 2. Two test diets were composed of diet B mixed with RC or RCE in a 6:4

Table 1. Chemical composition of rapeseed expeller cakes (g/kg DM), glucosinolate contents (μmol/g air-dry matter) and protein solubility, %

Item	RC[1]	RCE[2]
Component		
DM, g/kg	915	927
gross energy, MJ/kg DM	25.2	23.2
crude protein	311	358
crude fat[3]	174	101
crude ash	55	63
crude fibre	125	144
N-free extractives	335	334
NDF	274	281
NDIN (NDF-bound protein),% total	7.5	7.0
total P	9.1	10.6
phytate P	4.9	4.6
lysine available, g/16 g N	5.09	5.07
alkenyl-glucosinolates	18.1	21.1
total glucosinolates	23.3	26.8
Protein solubility, %		
in 0.5% KOH (NSI)	94.3[A]	86.4[B]
in borate	91.9[A]	53.9[B]
Protein dispersibility index (PDI)	40.1[A]	25.3[B]

[1] rapeseed cake pressed once; [2] rapeseed cake extended and pressed again; [3] after acid hydrolysis
[A,B] means in rows with different superscripts are significantly different at $P<0.001$

proportion on DM basis. The composition of the diets used in the growth trial is also given in Table 2. The cakes were included at the level of 100 and 150 g/kg diets fed during days 1-21 and 22-42 of age, respectively. Diet B used in the balance trial and the diets used in the growth trial were supplemented with 1g/kg of the enzyme preparation Avizyme 1300 (Finnfeeds, Danisco Cultor, containing 2500 U endo-1,4-beta-xylanase and 800 U subtilisin (protease) per gram, according to the producer's declaration). All diets were cold pelleted on a CL-2 CPM Laboratory Pellet Mill.

Two experiments were performed. The digestibility trial comprised 3 groups of three-week-old broilers, 9 birds per group. The birds were housed individually in balance cages. In the balance trial, they were given 90 g/bird/day of the respective diets, in three meals. After two days of preliminary feeding the birds were fasted for 14 h, then given the same diets for 3 days and again fasted for 14 h. Feed intake was recorded daily, while during the last 86 h of the experiment excreta were quantitatively collected, frozen and kept at -18°C for further analysis. The chickens were then offered the same diets *ad libitum* and on the next day they were sacrificed, the abdominal cavity was opened and the contents of the jejunum, ileum and caeca were collected. Digesta from 2 birds were pooled for pH and viscosity measurement.

In the growth trial, two groups of one-day-old broiler females, 14 birds per group, were used. For the first week the chickens were kept in pens, on day 8 they were weighed and placed in individual cages. From the first day of life the birds were given the experimental diets *ad libitum* (Table 2). Body weight and feed intake were measured in weekly intervals after 4 h food deprivation. At the end of experiment the birds were killed by cervical dislocation, the abdominal cavity was opened and the liver, thyroid glands, kidneys and abdominal fat were excised and weighed.

Table 2. Ingredients and nutrient composition of diets, g/kg

Item	Basal diet in balance trial	Diets used in growth trial					
		1-21 d of age		22-35 d of age		36-42 d of age	
		RC[3]	RCE[4]	RC	RCE	RC	RCE
Components							
rapeseed cake	-	100.0	-	150.0	-	150.0	-
rapeseed cake extruded	-	-	100.0	-	150.0	-	150.0
wheat	352.8	311.7	317.8	347.2	356.4	371.2	380.1
soyabean meal	380.6	317.3	304.6	240.7	221.7	211.3	192.5
maize	200.0	200.0	200.0	200.0	200.0	200.0	200.0
limestone	3.4	3.6	3.6	4.5	4.5	2.3	2.2
dicalcium phosphate	18.0	17.0	17.0	14.7	14.7	14.5	14.5
lard	30.0	35.4	42.0	28.0	37.8	35.8	45.8
L-lysine (78%)	1.0	1.0	1.0	0.9	0.9	0.9	0.9
DL-methionine (98%)	0.2	-	-	-	-	-	-
NaCl	3.0	3.0	3.0	3.0	3.0	3.0	3.0
Avizyme 1300	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Premix[1,2]	10.0[1]	10.0[1]	10.0[1]	10.0[1]	10.0[1]	10.0[2]	10.0[2]
Calculated							
crude protein	222.7	220.0	220.0	205.0	205.0	195.0	195.0
crude fat	50.0	70.0	70.0	70.2	70.3	78.0	78.0

[1,2] mineral-vitamin premix supplied per kg diet: [1]vit. A 12000 IU; vit. D_3 2500 IU; mg: vit. E 40; vit. B_1 2; vit. B_2 7; biotin 0.06; vit. B_6 4; vit. B_{12} 0.02; vit. K 3; niacine 30; folic acid 1; Ca pantothenate 12; choline 300; Mn 70; Zn 50; Co 0.32; Se 0.1; Cu 15; Fe 40; I 0.5; Maxus (Semduramycin) 25; Avilamycin 8, g: DL-methionine 1 and Ca 2.85; [2] vit. A 9000 IU; vit. D_3 1500 IU; mg: vit. E 40; vit. B_1 1; vit. B_2 3; biotin 0.06; vit. B_6 2; vit. B_{12} 0.02; vit. K 1.4; niacine 20; folic acid 0.5; Ca pantothenate 10; choline 200; Mn 45; Zn 30; Se 0.2; Cu 10; Fe 15; I 0.3; g: DL-methionine 1 and Ca 3.44

[3,4] see Table 1

Both experiments were conducted in compliance with the European Union regulations concerning the protection of experimental animals. The Local Ethics Committee approved the study protocol.

Analysis and calculations

The glucosinolate content in press cakes was measured according to ISO 9167-1 (1992). Protein solubility was determined in 0.5% KOH (NSI) and in borate. Protein dispersibility in water (PDI) and the available lysine content in cakes were measured, and the contents of crude fat, N total, N faecal and gross energy in cakes, diets and excreta were determined as described by Smulikowska et al. (2006). Caecal contents were mixed with deionised water (1:1 w/w) and their pH was immediately measured using a digital pH-meter (WTW pH/340, Germany) against a pH standard WTW D-82362 Weilheim (model STP4) at room temperature. Jejunal and ileal digesta and diluted caecal contents were centrifuged at 10.000×*g* for 10 min using a Beckman centrifuge (model J2-21 with J-20 rotor) at 4°C and the viscosity of the supernatant (0.5 mL aliquot) was immediately measured with the use of a Brookfield Digital cone/plate viscometer (model LVDV II+, Brookfield Engineering Laboratories, Stoughton, MA, USA). Readings were expressed in centipoise (1cP=1MPa·s).

The apparent protein and fat digestibility and metabolizable energy value of press cakes were calculated by the difference method as described by Smulikowska et al. (2006). The results were subjected to one-way analysis of variance (ANOVA) generated by Statgraphics ® ver. 5.1 (1994-2001).

RESULTS

Due to extrusion and additional pressing, the crude fat content decreased, while the concentration of the remaining components in RCE increased in comparison with RC (Table 1). The glucosinolate content in RCE was also higher than in RC, so the respective diets used in the growth trial contained 1.8 or 2.1 µmol/g of aliphatic glucosinolates during the first 3 weeks and 2.7 or 3.2 µmol/g in the later period (Table 2). The protein solubility indexes were significantly lower in RCE than in RC ($P<0.001$), whereas the NDF-bound protein content in RCE, slightly decreased (Table 1).

The apparent protein digestibility, N retention, organic matter retention, apparent metabolizable energy value and energy metabolizability were lower ($P<0.01$), while fat digestibility was higher ($P<0.01$) in RCE than in RC (Table 3). In the balance trial, the viscosity of digesta in group RC did not differ from

Table 3. Effect of extrusion on apparent protein and fat digestibility, N and organic matter retention and metabolizable energy value of non-extruded (RC) and extruded (RCE) rapeseed cakes (balance trial)

Treatment	Apparent protein digestibility %	Apparent fat digestibility %	N retention %	Organic matter retention %	AME_N, MJ/kg DM	AME_N/GE %
RC	78.7^A	82.9^A	44.7^A	53.0^A	13.86^A	55.1^A
RCE	75.9^B	90.9^B	36.6^B	45.1^B	11.39^B	48.7^B
SEM	0.35	0.90	1.21	0.83	0.15	0.6

^{A,B} means in columns with different superscripts were significantly different at P<0.01

the group fed the basal diet, but in the RCE group the viscosity of jejunal digesta was significantly lower (P<0.01), while the ileal digesta viscosity was numerically lower than in the other groups. Viscosity of the caecal digesta was most variable and was numerically higher in the RCE group (Table 4). In both groups fed diets with rapeseed cakes, the pH of the caecal digesta was lower (P<0.01) than in the group fed the basal diet (Table 4).

Table 4. Viscosity of digesta and pH in caecal contents in chickens fed diets used in the balance trial

Dietary treatment	Viscosity of digesta, mPa·s			pH of caecal contents[1]
	jejunum	ileum	caeca[1]	
Basal	1.27^A	1.76	1.47	6.81^A
RC	1.29^A	1.95	1.56	5.95^B
RCE	1.09^B	1.62	2.61	5.82^B
SEM	0.03	0.12	0.47	0.16

[1] caecal contents were diluted with deionised water 1:1 (w/w)
^{A,B} means in the same column with different superscripts are significantly different at P<0.01

In the growth trial, broilers fed the RCE diet ate more than broilers fed the RC diet (P<0.01) and the body weight gain was significantly (P<0.05) higher in the RCE group during the first 3 weeks of life and during the whole period (Table 5). In RCE birds there was tendency towards the weight of the thyroid to decrease, whereas the liver weight was significantly (P<0.05) lower and the kidney weight, highly significantly (P<0.01) lower than in RC birds (Table 6). The abdominal fat weight was higher (P<0.01) in group RCE than in RC.

Table 5. Effect of extrusion on performance of chickens (growth trial)

Treatment	Feed intake, g			Body weight gain, g			FCR, g feed/g BWG		
	1-21 d	22-42 d	1-42 d	1-21 d	22-42 d	1-42 d	1-21 d	22-42 d	1-42 d
RC	1011^A	1802^A	3951^A	765^a	1083	2386^a	1.32^a	1.67	1.66
RCE	1130^B	1991^B	4399^B	833^b	1163	2612^b	1.36^b	1.72	1.68
SEM	21	44	90	18	31	59	0.01	0.02	0.02

^{a,b,A,B} means in the same column with different superscripts are significantly different at:
^{a,b} P<0.05; ^{A,B} P<0.01

Table 6. Effect of extrusion on the weight of organs and abdominal fat in 42-day-old chickens (growth trial)

Treatment	Weight of organs per 100 g live body weight			
	thyroids, mg	liver, g	kidneys, mg	abdominal fat, g
RC	17.9	2.41[a]	886[A]	1.14[A]
RCE	16.8	2.18[b]	690[B]	1.44[B]
SEM	1.22	0.07	16	0.07

[a,b,A,B] means in the same column with different superscripts are significantly different at:
[a,b] $P<0.05$; [A,B] $P<0.01$

DISCUSSION

Due to extrusion and additional pressing, more oil was removed from rapeseed and therefore the RCE contained more protein and less GE than RC.

The protein solubility indexes used in the study have been shown to be a good indicator of protein quality in soyabean meals (Batal et al., 2000) as well as in rapeseed meals that were overprocessed during toasting (Pastuszewska et al., 1998). In the present study, dry heat applied for a short time during extrusion substantially lowered the protein solubility indexes determined *in vitro* (by 8, 37 and 41%). This was not connected, however, with protein damage as the available lysine content was on the same level before and after extrusion. Most probably, extrusion promoted creation of insoluble complexes from protein and dietary fibre components. Nguyen et al. (2003) reported that the jejunal digesta from chickens fed rapeseed or soyabean-based diets were of similar viscosity, which was confirmed in this study. The viscosity of jejunal digesta was significantly lower, however, in the RCE group in comparison with the RC group. This supports the hypothesis on insolubilization of part of the soluble dietary fibre components due to extrusion.

The difference between the effect of extrusion on apparent total tract protein digestibility (3.6% lower in RCE) and on N retention (18% lower in the RCE group in comparison with the RC group) indicated that protein associated with dietary fibre was hydrolysed more distally by the microflora, whereby the degradation products were not utilized by the birds.

The lower protein digestibility and lower nitrogen retention from RCE resulted in a worse feed conversion ratio, especially during the first 3 weeks. Finally, the RCE chickens deposited more adipose tissue in the body in comparison with the RC group.

Similarly as in our previous study with broilers (Smulikowska et al., 2006) and in the study by Keith and Bell (1991) on pigs, there were no apparent palatability problems associated with the feeding of both types of rapeseed cake. Broilers fed the RCE diet consumed more feed than those fed the RC diet, which resulted in a higher final body weight. Part of the improvement may probably be related to the deactivation of myrosinase in the cake. In intact rape seeds myrosinase and glucosinolates are located in separate cellular compartments (Maheshwari et al., 1981) and crushing the seeds brings them into contact. Myrosinase hydrolyses glucosinolates, and the generated degradation products such as thiocyanates, 5-vinyl-oxazolidine-2-thione, 1-cyano-2-hydroxy-3-butene, isothiocyanates or nitriles have adverse effects on the physiological status of the thyroid, liver and kidneys and on growth performance. Inactivation of myrosinase by heat treatment prior to processing is advised (Bell, 1993). Shires et al. (1983) cited by Newkirk and Classen (2002) reported that heating canola meal to 100^{o}C improved feed intake and growth rate in broilers. The smaller thyroids as well as the significantly lower weight of the liver and kidneys in the RCE group in comparison with the RC group indicated that extrusion inactivated the myrosinase in the cake.

Newkirk and Classen (2003) reported that the ammonia fibre explosion technology (extrusion connected with injecting ammonia) has a great potential for improving the utilization of rapeseed by poultry. From a practical point of view, it is important to know if extrusion improves the digestibility of nutrients in RC. The fat digestibility in RCE was 8 percentage points higher than in RC, which indicates that part of the oil in RC was encapsulated by fibre and therefore indigestible. Partial disruption of fibre structures due to extrusion increased residual fat utilization, however, it was accompanied by a 2.8 percentage point reduction in protein digestibility. As a result, the metabolizable energy value of RCE as well as energy metabolizability were lower than in RC, mainly due to less oil remaining in the cake. The AME_N values of RC and RCE were much higher than in solvent-extracted rapeseed meal (8.25 MJ/kg DM) and higher than in rapeseed meal expeller double zero (10.25 MJ/kg DM) given in European Tables (1989). In practice, both types of cakes may be used to replace part of the soyabean meal in broiler diets, reducing the need for supplemental fat. Complete replacement of soyabean meal by rapeseed cake is not advised, as it may impair performance.

CONCLUSIONS

It may be concluded that pressing and extrusion of rapeseed reduced the antinutritional effect of glucosinolates. This resulted in an improved feed intake and body weight gain, however, the metabolizable energy of extruded cakes decreased in comparison with pressed cake.

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