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The Effects of Canola or Mustard Biodiesel Press Cake on Nutrient Digestibility and Performance of Broiler Chickens

P. A. Thacker* **and D. Petri**
Department of Animal and Poultry Science, University of Saskatchewan, 51 Campus Drive,
Saskatoon, Saskatchewan, S7N 5A8, Canada

ABSTRACT : This study compared the nutritional value of canola (*B. napa*) and mustard (*B. hirta*) press cakes obtained from the biodiesel industry as ingredients for use in diets fed to broiler chickens. A total of 210, one-day old, male broiler chicks were randomly assigned to one of seven dietary treatments. The control diet was based on wheat and soybean meal and contained 15% canola meal. For the experimental diets, 5, 10 or 15% of the canola meal was replaced with an equal amount of either canola or mustard biodiesel press cake. Dry matter and neutral detergent fiber digestibility were significantly higher for birds fed diets containing either canola or mustard biodiesel press cake compared with canola meal. Dry matter and neutral detergent fiber digestibility of the canola biodiesel press cakes was higher than the mustard biodiesel press cakes. Ether extract digestibility and nitrogen retention were significantly higher for birds fed canola biodiesel press cake compared with canola meal and mustard biodiesel press cake. Body weight gain and feed intake did not differ between birds fed canola or mustard biodiesel press cake and canola meal. In addition, there was no significant difference in body weight gain or feed intake between birds fed diets containing canola or mustard biodiesel press cake. Feed conversion was significantly improved for birds fed either canola or mustard biodiesel press cake compared with canola meal. Mortality was unaffected by treatment. Since the performance of broilers fed canola biodiesel press cakes was essentially the same as that of broilers fed canola meal, it is difficult to justify a premium to be paid for canola biodiesel press cake over that paid for canola meal. In addition, there was no difference in the performance of broilers fed biodiesel press cake obtained from canola or mustard seed. As mustard seeds are generally available at a lower price than canola seed, there may be some incentive to use mustard rather than canola seed for producing biodiesel press cake for use in poultry production. (**Key Words :** Poultry, Mustard, Canola, Press Cakes, Biodiesel, Performance, Digestibility)

INTRODUCTION

Interest in biodiesel production is expanding rapidly (Hancock, 2005). For 2007, worldwide production of biodiesel was projected to reach 8.4 million tonnes and could be as high as 20 million tonnes by 2010 (Licht, 2007). Advantages of biodiesel compared to petroleum diesel include its renewable nature, higher cetane rating, higher fuel lubricity and lower production of greenhouse gases (Hancock, 2005).

Biodiesel can be produced from vegetable oils, animal fats and recycled restaurant grease (Natural Resources Canada, 2008). Canola seed is one of the most widely utilized feedstocks for biodiesel production (Koh, 2007). Some advantages of canola as a feedstock for biodiesel production include its high oil content which results in more oil per unit of seed, its low level of saturated fat which improves the fuel's cold weather performance as well as the oil's low iodine value which results in lower production of corrosive acids and deposits that cause increased engine wear (Anderson, 2007). However, since approximately 70-80% of the cost of producing biodiesel can be attributed to the price of the feedstock used, the production costs for biodiesel can be substantially reduced by using less expensive feedstocks (Beshada et al., 2008).

Mustard oil is one potential alternative to canola oil for use in biodiesel production (Tyson et al., 2000). Mustard is a high yielding oilseed with a reasonably high content of oil (Riley, 2004). This combination provides for high oil yield per acre, which is an important consideration in developing a biodiesel feedstock. In addition, in many countries, mustard oil is not considered suitable for human consumption (Tyson et al., 2000). Therefore, it is typically available at a lower cost than canola oil. Mustard also has agronomic advantages in that it is more tolerant to drought,

* Corresponding Author: P. A. Thacker. Tel: +1-306-966-4159, Fax: +1-306-966-4151, E-mail: phil.thacker@usask.ca
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Table 1. Chemical analysis of main ingredients used to determine the nutritive value of canola and mustard press cakes for broiler chickens

	Wheat	Soybean meal	Canola meal	Canola press cake	Mustard press cake
Chemical composition (% as fed)					
Moisture	11.80	10.83	10.56	10.56	6.91
Crude protein	15.23	45.95	37.89	31.76	33.96
Ash	9.24	6.01	7.26	9.11	6.57
Ether extract	1.32	1.23	2.27	27.49	12.39
Neutral detergent fiber	12.05	5.45	25.84	26.32	29.61
Acid detergent fiber	4.27	4.23	17.88	20.42	18.15
Calcium	0.05	0.27	0.65	0.59	0.58
Phosphorus	0.34	0.65	1.14	1.01	1.01
Essential amino acids (% as fed)					
Arginine	0.72	3.58	2.41	1.91	1.78
Histidine	0.35	1.21	1.92	1.03	1.16
Isoleucine	0.55	2.41	1.49	1.19	1.23
Leucine	0.99	3.91	2.62	2.16	2.23
Lysine	0.41	3.16	2.06	1.78	1.62
Methionine and cystine	0.62	1.70	1.67	1.41	1.34
Phenylalanine	0.68	1.48	1.49	1.24	1.30
Threonine	0.43	1.93	1.77	1.33	1.34
Valine	0.72	2.44	2.62	1.54	1.57

[1] All chemical composition data are the results of a chemical analysis conducted in duplicate.

heat and frost than canola (Woods et al., 1991).

In order to make biodiesel, the oil must be removed from the oilseed (Abiola et al., 2007). In commercial processes, this occurs through the use of a combination of mechanical pressing and solvent extraction (Hickling, 2001). However, many farm scale biodiesel producers utilize only mechanical pressing to remove the oil from the oilseed and do not employ the solvent extraction process (Beshada et al., 2008). This results in the production of press cakes which have a much higher residual oil content than the meals produced from processes which employ both processes in tandem (i.e. canola meal). Since significant improvements in broiler performance have been reported as the lipid content of the diet increases (Latshaw, 2008), it might be anticipated that the higher residual oil of the biodiesel press cakes could increase their nutritional value over that of the commercially produced meals.

The nutritional value of mustard press cakes has been evaluated previously (Lodhi et al., 1974; Vaidya et al., 1975 and 1979; Prasad and Rao, 1982). However, most of these experiments were conducted in excess of 25 years ago and many improvements have been made in mustard varieties since that time. These include significant reductions in the levels of various antinutritional factors including glucosinolates (Love et al., 1990) and erucic acid (Getinet et al., 1994). Therefore, a re-examination of the nutritional value of mustard press cake for poultry seems warranted. The objective of this study was to compare the nutritional value of canola (*B. napa*) and mustard (*B. hirta*) press cakes obtained from the biodiesel industry as ingredients for use in diets fed to broiler chickens.

MATERIALS AND METHODS

Production of canola and mustard biodiesel press cakes

The canola biodiesel press cake was produced at the Olds College School of Innovation (Olds, Alberta) as part of their program to determine the technical and economic feasibility of on-farm biodiesel production (Abiola et al., 2007). The mustard biodiesel press cake was produced at Milligan Biotech (Foam Lake, Saskatchewan). Both production systems involved a cold-press system of oil extraction without the use of solvent extraction. A chemical analysis of the canola and mustard biodiesel press cakes, as well as the other major ingredients used in the experiment is presented in Table 1 while a glucosinolate analysis of the main ingredients is presented in Table 2.

Growth trial

The birds used in this study were housed and managed according to the Canadian Council on Animal Care (1993) Guidelines. A total of 210, one-day old, male broiler chicks (Ross-308 line) were randomly assigned to one of seven dietary treatments. The control diet was based on wheat and soybean meal and contained 15% canola meal. For the experimental diets, 5, 10 or 15% of the canola meal was

Table 2. Glucosinolate analysis of main ingredients (μmol/g)

	Soybean meal	Canola meal	Canola press cake	Mustard press cake
Allyl	0.01	0.03	0.03	0.04
3-Butenyl	0.04	1.66	1.06	0.19
4-Pentenyl	0.01	0.15	0.18	0.03
2-OH-3-Butenyl	0.07	4.09	2.54	2.36
2-OH-4-Pentenyl	0.00	0.05	0.04	0.01
4-Methylthiobenyl	0.00	0.18	0.04	0.02
Phenyl	0.00	0.16	0.12	0.02
4-OH-Benzyl	0.02	0.47	0.04	80.62
3-Methylindolyl	0.00	0.36	0.34	0.22
4-OH-3-Methylindoyl	0.05	1.55	7.67	0.87
Total	0.21	8.78	12.67	84.38

replaced with an equal amount of either canola or mustard biodiesel press cake. Diets were formulated to contain 3000 kcal/kg ME, 0.95% calcium, 0.45% available phosphorus, 1.10% lysine, 0.9% methionine and cystine, and 0.80% threonine. Actual analyses of the diets are presented in Table 3. The experiment diets were provided in mash form (3 mm screen) and the experiment was conducted over a 21-day period.

The chicks were housed in raised-floor battery cages (Jamesway Manufacturing Company) with five birds per pen and six replicate pens per treatment. Feed and water were available *ad libitum* throughout the experiment. The battery brooder was maintained at a temperature of 35°C for the first week with the temperature gradually being reduced to 29°C by the end of second week. Incandescent lighting (23 h light, 1 h dark) was provided with an intensity of 10 lux. Broilers were weighed individually at the start (day 1) and weekly thereafter. Weighed amounts of feed were added as required with a weigh back at the conclusion of the experiment to allow for the calculation of feed consumption and feed conversion on a pen basis.

Digestibility determination

Chromic oxide (0.35%) was added to all diets as a digestibility marker and was fed throughout the experimental period. On days 20 and 21, clean excreta (free from feathers and feed) were collected at 9 am and 3 pm from plastic liners placed in the excreta collection trays

Table 3. Ingredient composition of diets used to determine the nutritive value of canola or mustard press cake fed to broiler chicks (0-21 days of age)

	Control	Canola press cake			Mustard press cake		
		5%	10%	15%	5%	10%	15%
Ingredient (% as fed)							
Wheat	56.79	56.79	56.79	56.79	56.79	56.79	56.79
Soybean meal	18.86	18.86	18.86	18.86	18.86	18.86	18.86
Canola meal	15.00	10.00	5.00	0.00	10.00	5.00	0.00
Canola press cake	0.00	5.00	10.00	15.00	0.00	0.00	0.00
Mustard press cake	0.00	0.00	0.00	0.00	5.00	10.00	15.00
Canola oil	4.84	4.84	4.84	4.84	4.84	4.84	4.84
Dicalcium phosphate	1.61	1.61	1.61	1.61	1.61	1.61	1.61
Limestone	1.12	1.12	1.12	1.12	1.12	1.12	1.12
Vitamin-mineral premix	0.50	0.50	0.50	0.50	0.50	0.50	0.50
Salt	0.50	0.50	0.50	0.50	0.50	0.50	0.50
Chromic oxide	0.35	0.35	0.35	0.35	0.35	0.35	0.35
Avizyme	0.10	0.10	0.10	0.10	0.10	0.10	0.10
Endofeed	0.10	0.10	0.10	0.10	0.10	0.10	0.10
Choline chloride	0.08	0.08	0.08	0.08	0.08	0.08	0.08
DL-methionine	0.12	0.12	0.12	0.12	0.12	0.12	0.12
L-lysine·HCl	0.03	0.03	0.03	0.03	0.03	0.03	0.03

[1] Supplied per kilogram of diet: 11,000 IU vitamin A, 2,200 IU vitamin D_3, 30 IU vitamin E (dl-tocopherol acetate), 2.0 mg menadione, 1.5 mg thiamine, 6.0 mg riboflavin, 60 mg niacin, 4 mg pyridoxine, 0.02 mg vitamin B_{12}, 10.0 mg pantothenic acid, 6.0 mg folic acid, 0.15 mg biotin, 0.625 mg ethoxyquin, 500 mg $CaCO_3$, 80 mg Fe, 80 mg Zn, 80 mg Mn, 10 mg Cu, 0.8 mg I, 0.3 mg Se.

underneath each pen. The excreta samples from the four collections were pooled by placing the samples into an aluminium pan and stirring with a rubber spatula. The pooled samples were then frozen. Prior to analysis, the samples were dried in a forced oven dryer at 55°C for 72 h, followed by fine grinding using a centrifugal mill (Retzsch ZM 100, Retzsch GmbH, Haan Germany). Digestibility coefficients for dry matter, neutral detergent fiber, and ether extract as well as nitrogen retention were determined using the equations for the indicator method described by Schneider and Flatt (1975).

Chemical analysis

Samples of the main ingredients and the experimental diets were analyzed according to the methods of the Association of Official Analytical Chemists (2007). Analyses were conducted for moisture (AOAC method 930.15), crude protein (AOAC method 984.13), ash (AOAC method 942.05) calcium (AOAC method 927.02) neutral detergent fiber (AOAC method 2002.04) and ether extract (AOAC method 920.39). Amino acid analysis of the feed was determined by High Performance Liquid Chromatography (Hitachi L-8800 Amino Acid Analyzer, Tokyo, Japan). All samples were hydrolyzed for 24 h at 110°C with 6 N HCl prior to analysis. Sulphur-containing amino acids were analyzed after cold formic acid oxidation for 16 h before acid hydrolysis. For diets and excreta, the chromic oxide content was determined by the method of Fenton and Fenton (1979). Glucosinolates were determined using a Hewlett-Packard 5890 Gas Chromatograph following the method of Thies (1980).

Statistical analysis

The experimental data were subjected to one way analyses of variance using the PROC MIXED procedure of the Statistical Analysis System Institute (2004). Replicate was treated as a random effect. The significance of differences between means was assessed using Tukey's test. Treatment means were tested for linear, quadratic and cubic effects of graded levels of either canola or mustard biodiesel press cake. Single degree of freedom orthogonal contrasts were also used to test the effects of the control diet vs. the three canola biodiesel press cake diets; the control diet vs. the three mustard biodiesel press cake diets and finally the three canola biodiesel press cake diets vs. the three mustard biodiesel press cake diets. The pen was the experimental unit for all measurements. Differences were considered significant when $p<0.05$.

RESULTS AND DISCUSSION

The results of the chemical and amino acid analyses conducted on the major feed ingredients (Table 1) are within the range of those previously reported for wheat, canola meal and soybean meal in standard industry sources such as the National Research Council (1994), Feedstuffs (Dale and Batal, 2007) as well as the Raw Material Compendium (Novus, 1994).

With the exception of its ether extract content, the chemical analysis for the canola biodiesel press cake was similar to that previously reported by Keith and Bell (1991) and Schone et al. (1996) for canola press cake. Cake from expeller processed canola seed typically contains between 14 and 20% oil (Hickling, 2001). Therefore, the canola biodiesel press cake contained a higher residual oil (27.4%) content than typical canola press cakes. However, Keith and Bell (1991) obtained canola press cakes from seven different crushing plants and reported that one plant was producing a meal with a residual oil content of 26.7% which is not too different from the value obtained for the canola press cake utilized in the present experiment. The chemical analysis of the mustard biodiesel press cake is similar to previously reported values (Lodhi et al., 1974; Vaidya et al., 1979; Cheva-Isarakul et al., 2003). The amino acid content of the canola biodiesel press cake (Table 1) is intermediate to the values reported for canola seed and canola meal as reported by Keith and Bell (1991). Mustard biodiesel press cake would appear to be lower in lysine and the sulfur containing amino acids than canola biodiesel press cake.

The result of the glucosinolate analysis of the main ingredients is presented in Table 2. The total glucosinolate content of the canola meal used in the present study (8.78 μmol/g) was lower than the 16 μmol/g reported as typical for canola meal by the Canola Council of Canada (Hickling 2001). The principal glucosinolates in canola meal were 3-butenyl glucosinolate, 2-hydroxyl-3-butenyl glucosinolate, and 4-hydroxyl-3-methylindoyl glucosinolate. This agrees with the work of Blair et al. (1986) and Thacker and Newkirk (2004). The glucosinolate content of the canola biodiesel press cake (12.67 μmol/g) was higher than the glucosinolate content of the canola meal (8.78 μmol/g). This agrees with the work of Keith and Bell (1991). The major difference between canola meal and the canola biodiesel press cakes was a dramatically higher content of 4-hydroxyl-3-methylindoyl glucosinolate in the canola biodiesel press cake than in canola meal.

The total glucosinolate level of the mustard biodiesel press cake was approximately 7-fold higher than that of the canola biodiesel press cake (Table 2). The principle difference between the two types of biodiesel press cake was the higher level of 4-OH-benzyl glucosinolate in the mustard biodiesel press cake compared with canola biodiesel press cake. Unlike canola, mustard tends to have only one type of glucosinolate per species, with little or none of the other common types of glucosinolate being

Table 4. Chemical analysis of diets used to determine the nutritive value of canola or mustard press cake fed to broiler chicks (0-21 days of age)

	Control	Canola press cake			Mustard press cake		
		5%	10%	15%	5%	10%	15%
Chemical composition (% as fed)							
Moisture	9.96	10.16	9.33	9.74	9.28	9.78	9.59
Ash	5.87	5.79	5.89	5.92	5.92	5.84	5.90
Crude protein	22.20	21.53	22.08	21.92	23.00	22.34	22.24
Ether extract	6.08	8.40	9.33	10.32	7.74	7.88	8.45
Neutral detergent fibre	13.32	13.57	14.04	13.46	13.11	13.21	13.23
Acid detergent fibre	5.70	5.24	5.38	5.24	6.39	5.62	5.73
Calcium	0.96	0.95	0.95	0.97	0.96	0.95	0.95
Phosphorus	0.78	0.76	0.77	0.74	0.75	0.74	0.74
Amino acid content (% as fed)							
Arginine	1.33	1.37	1.41	1.32	1.36	1.37	1.33
Histidine	0.75	0.75	0.75	0.70	0.77	0.78	0.76
Isoleucine	0.90	0.91	0.93	0.91	0.94	0.94	0.91
Leucine	1.29	1.66	1.69	1.65	1.70	1.71	1.69
Lysine	1.17	1.20	1.23	1.16	1.22	1.21	1.17
Methionine+cystine	0.96	0.91	0.91	0.96	0.97	0.92	0.93
Phenylalanine	0.86	1.07	1.09	1.07	1.04	1.08	1.11
Threonine	0.85	0.84	0.86	0.83	0.88	0.87	0.86
Valine	1.04	1.07	1.09	1.06	1.10	1.10	1.06

[1] All chemical composition data are the results of a chemical analysis conducted in duplicate.

present (Bell, 1990). The presence of high levels of 4-OH-benzyl glucosinolate is consistent with the work of Bell et al. (1981) who reported that this was the predominant glucosinolate in *B. hirta* varieties of mustard.

The chemical analysis (Table 4) conducted on the broiler rations verified that the diets met the specifications called for in the diet formulation. The rations containing canola biodiesel press cake tended to have higher ether extract than rations containing mustard biodiesel press cake, reflecting the differences in the chemical composition of the two types of biodiesel press cake. Similarly, the glucosinolate content (Table 5) of the rations containing mustard biodiesel press cake were generally slightly higher than those containing canola biodiesel press cake, reflecting the higher glucosinolate content of the mustard biodiesel press cake compared with the canola biodiesel press cake.

The effects of feeding canola or mustard biodiesel press cake on nutrient digestibility and nitrogen retention of broilers are shown in Table 6. Dry matter and neutral detergent fiber digestibility were significantly higher for

Table 5. Glucosinolate content (μmol/g) of diets used to determine the nutritive value of canola or mustard press cake fed to broiler chicks (0-21 days of age)

	Control	Canola press cake			Mustard press cake		
		5%	10%	15%	5%	10%	15%
Allyl	0.04	0.04	0.04	0.05	0.03	0.03	0.03
3-Butenyl	0.29	0.16	0.18	0.17	0.16	0.16	0.04
4-Pentenyl	0.00	0.02	0.09	0.08	0.02	0.05	0.01
2-OH-3-Butenyl	0.50	0.41	0.32	0.40	0.51	0.51	0.36
2-OH-4-Pentenyl	0.01	0.00	0.02	0.00	0.00	0.01	0.00
4-Methylthiobutyl	0.07	0.00	0.00	0.00	0.00	0.00	0.00
Phenyl	0.03	0.02	0.02	0.02	0.02	0.02	0.00
4-OH-Benzyl	0.06	0.07	0.12	0.12	3.97	9.55	12.01
3-Methylindoyl	0.06	0.05	0.05	0.04	0.04	0.04	0.03
4-OH-3-Methylindoyl	0.18	0.28	0.49	0.81	0.12	0.14	0.08
Total	1.27	1.06	1.35	1.72	4.88	10.55	12.58

Table 6. The effect of feeding canola (CPC) or mustard (MPC) canola press cake on apparent fecal digestibility and nitrogen retention of broilers

		Inclusion level of press cake (%)						p values		
		0.0	5.0	10.0	15.0	Average	SEM	Linear	Quad	Cubic
Dry matter (%) [x,y,z]	CPC	63.2[a]	67.1[b]	67.1[b]	67.6[b]	67.2	0.31	<0.01	<0.01	<0.01
	MPC	63.2[a]	64.9[b]	66.4[c]	65.0[bc]	65.4	0.37	<0.01	<0.01	0.12
Neutral detergent fibre (%)[x,y,z]	CPC	22.6[a]	30.7[b]	31.7[b]	31.8[b]	31.4	0.84	<0.01	<0.01	0.10
	MPC	22.6[a]	20.0[a]	29.8[b]	32.9[b]	27.6	1.35	<0.01	0.05	<0.01
Ether extract (%)[x,z]	CPC	77.8[a]	81.0[ab]	82.2[ab]	83.7[b]	82.3	1.20	<0.01	0.50	0.66
	MPC	77.8	77.8	80.9	77.3	78.6	1.39	0.80	0.21	0.14
Nitrogen retention (%)[x,z]	CPC	54.3[a]	58.3[b]	59.4[b]	59.8[b]	59.1	0.90	<0.01	0.07	0.55
	MPC	54.3[a]	57.7[b]	55.7[ab]	54.3[a]	55.9	0.79	0.59	<0.01	0.11

[x] Orthogonal contrast for control diet vs. canola biodiesel press cake diets significant at p<0.05.
[y] Orthogonal contrast for control diet vs. mustard biodiesel press cakes significant at p<0.05.
[z] Orthogonal contrast for canola biodiesel press cakes vs. mustard biodiesel press cakes significant at p<0.05.

birds fed diets containing either canola or mustard biodiesel press cake ($p<0.05$) compared with canola meal (Table 6). Dry matter and neutral detergent fiber digestibility of the canola biodiesel press cakes was higher than the mustard biodiesel press cakes ($p<0.05$). There were significant linear ($p<0.05$) and quadratic ($p<0.05$) effects on dry matter and neutral detergent fiber digestibility as the level of either canola or mustard biodiesel press cake in the diet increased.

Ether extract digestibility and nitrogen retention were significantly higher ($p<0.05$) for birds fed canola biodiesel press cake compared with canola meal. Ether extract digestibility and nitrogen retention did not differ ($p>0.05$) for birds fed mustard biodiesel press cake compared with canola meal. Ether extract digestibility was significantly higher for birds fed canola biodiesel press cake compared with mustard biodiesel press cake ($p<0.05$). There was a significant linear effect ($p<0.05$) on ether extract digestibility and nitrogen retention as the level of canola biodiesel press cake in the diet increased. Mustard biodiesel press cake did not produce this response.

The effects of feeding canola or mustard biodiesel press cakes on broiler performance are presented in Table 7. Body weight gain did not differ ($p>0.05$) between birds fed diets containing canola or mustard biodiesel press cake and canola meal (Table 7). In addition, there was no significant difference ($p>0.05$) in body weight gain between birds fed diets containing canola or mustard biodiesel press cake.

Early studies on the nutritive value of mustard press cake reported significant reductions in the weight gain of broilers as the inclusion level of mustard press cake in the diet increased (Vaidya et al., 1975; Rao, 1977; Prasad and Rao, 1982). Prasad and Rao (1982) attributed the reduction in weight gain to the presence of high levels of erucic acid in the mustard. However, the erucic acid content of the more recently developed cultivars of mustard has been dramatically reduced (Getinet et al., 1994) and it would appear that erucic acid is no longer a factor limiting the performance of broilers fed mustard press cake.

Another factor which might have been expected to limit the weight gain of the broilers fed mustard press cake was its high content of glucosinolates as the total glucosinolate content of the mustard press cake was approximately ten times higher than the total glucosinolate content of canola meal (Table 2). However, over 95% of the glucosinolates in

Table 7. Performance of broiler chicks fed diets containing canola (CPC) or mustard (MPC) press cake (0-21 days)

		Inclusion level of press cake (%)						p values		
		0.0	5.0	10.0	15.0	Average	SEM	Linear	Quad	Cubic
Body weight gain (g)	CPC	852	807	841	863	837	20.1	0.46	0.11	0.32
	MPC	852	828	874	845	849	21.5	0.79	0.89	0.14
Feed intake (g)	CPC	1,194	1,121	1,129	1,149	1,133	27.1	0.30	0.10	0.58
	MPC	1,194	1,136	1,200	1,159	1,165	28.9	0.77	0.77	0.11
Feed conversion[x,y]	CPC	1.40[a]	1.39[ab]	1.34[bc]	1.33[c]	1.35	0.01	<0.01	0.95	0.25
	MPC	1.40	1.36	1.37	1.37	1.37	0.01	0.07	0.11	0.22
Mortality (%)	CPC	0.00	0.00	3.33	0.00	1.11	1.67	0.66	0.33	0.19
	MPC	0.00	3.33	3.33	3.33	3.33	2.88	0.44	0.57	0.79

[x] Orthogonal contrast for control diet vs. regular press cake diets significant at p<0.05.
[y] Orthogonal contrast for control diet vs. green biodiesel press cakes significant at p<0.05.
[z] Orthogonal contrast for regular biodiesel press cakes vs. green biodiesel press cakes significant at p<0.05.

the mustard press cake were in the form of 4-OH-benzyl glucosinolates and these glucosinolates have been reported to be much less deleterious to chicks than other types of glucosinolates provided that sufficient iodine is present in the ration (Lodhi et al., 1974).

Feed intake did not differ ($p>0.05$) for birds fed canola or mustard biodiesel press cake and canola meal. In addition, there was no difference ($p>0.05$) in feed intake between birds fed canola or mustard biodiesel press cake. Early research on mustard press cakes reported reduced palatability of diets containing mustard press cake (Rao, 1977; Prasad and Rao, 1982). Factors suggested to reduce the palatability of mustard press cake include sinapine (Ravindran and Blair, 19992), erucic acid (Prasad and Rao, 1982) and tannins (Vaidya et al., 1979). In the current experiment, feed intake was not significantly affected by inclusion of mustard press cake suggesting that these factors are no longer a problem in newer cultivars of mustard.

Feed conversion was significantly improved for birds fed either canola ($p<0.05$) or mustard ($p<0.05$) biodiesel press cake compared with canola meal. Feed conversion did not differ ($p>0.05$) between birds fed canola or mustard canola biodiesel press cake. Feed conversion improved linearly ($p<0.05$) with increasing levels of canola biodiesel press cake while no such effect was observed for mustard biodiesel press cake ($p>0.05$).

Mortality did not differ ($p>0.05$) between birds fed either canola or mustard biodiesel press cake and canola meal. Mortality appeared to be higher for birds fed the mustard biodiesel press cake compared with canola biodiesel press cake but the difference was not statistically significant. Linear and quadratic effects were not observed for broiler mortality.

Canola meal is produced in a process that typically involves prepress expellers followed by solvent extraction of the biodiesel press cake and the meal has a residual oil content of approximately 2-3% (includes gums and acidulated soap stocks). The biodiesel press cakes used in the present study was processed using a cold press resulting in a residual oil content of 27.4% for the canola biodiesel press cake and 12.3% for the mustard biodiesel press cake. Since significant improvements in broiler performance have been reported as the lipid content of the diet increased (Latshaw, 2008), it was anticipated that the higher residual oil of the biodiesel press cakes would increase their nutritional value over that of canola meal. However, the results of the current study indicate that the performance of birds fed either canola or mustard biodiesel press cake did not differ appreciably from those of birds fed canola meal. There was no improvement in body weight gain while feed conversion was only modestly improved as a result of inclusion of either canola or mustard biodiesel press cake.

We are unaware of previous studies in which canola biodiesel press cake has been fed to poultry. However, Schone et al. (1996, 1997) similarly failed to improve the growth rate of pigs when canola press cake was included at levels as high as 15% of the diet. It would therefore appear that lipid which is resistant to removal by cold pressing is also resistant to use by poultry. In a previous study conducted in our laboratory, it was observed that pigs did not use the oil in canola seed as effectively as they used free canola oil (Thacker, 1998). Similarly, Leeson et al. (1978) and Summers et al. (1982) reported that poultry did not use the lipid in canola seed as effectively as they used the lipid in an animal-vegetable fat blend and reported no improvements in poultry performance from the inclusion of canola seed at levels as high as 35% of the diet.

Aldrich et al. (1997) reported that whole canola seed was resistant to digestion in both the rumen and intestine of cattle and suggested that the resistance of canola seed to microbial and enzymatic digestion was due to the high concentration of lignin in the canola seed hull. Therefore, one explanation for the failure of the inclusion of high-oil containing biodiesel press cakes to have a greater impact on broiler performance could be the fact that a significant proportion of the oil in the biodiesel press cakes is still encapsulated in the seed hull and the immature digestive system of the young broilers could have had difficulty in accessing the oil for digestion and absorption. This theory was put forward by Vieira et al. (1997) to explain why the oil in high oil corn was poorly utilized by young broiler chickens.

To the author's knowledge, this study is the first to compare the nutritional value of canola and mustard biodiesel press cakes processed using a micro-scale production process and fed to broiler chickens. Our results indicate that although nutrient digestibility and nitrogen retention were higher for birds fed canola and mustard press cakes compared with canola meal, these improvements did not translate into improvements in broiler performance. Since the performance of broilers fed canola biodiesel press cakes was essentially the same as that of broilers fed canola meal, it is difficult to justify a premium to be paid for canola biodiesel press cake over that paid for canola meal. In addition, there was no difference in the performance of broilers fed biodiesel press cake obtained from canola or mustard seed. As mustard seeds are generally available at a lower price than canola seed, there may be some incentive to use mustard rather than canola seed for producing biodiesel and biodiesel press cake for use in poultry production.

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