Original research article

Effects of derived meals from juncea (*Brassica juncea*), yellow and black seeded canola (*Brassica napus*) and multicarbohydrase enzymes supplementation on apparent metabolizable energy in broiler chickens

CrossMark

Balachandar Jayaraman [a, *], Janice MacIsaac [b], Derek Anderson [b]

[a] *Department of Animal Science, University of Manitoba, Winnipeg R3T 2N5, Canada*
[b] *Dalhousie University, Faculty of Agriculture, Truro B2N 5E3, Canada*

ARTICLE INFO

ABSTRACT

Two experiments were conducted to determine the nitrogen-corrected apparent metabolizable energy (AMEn) of differently processed meals from Juncea (*Brassica juncea*), yellow and black seeded canola (*Brassica napus*), with or without supplementation of multi-carbohydrase enzymes (Enz) in diets for broiler chickens. The first experiment was a $3 \times 2 \times 2$ factorial arrangement with the main factors being seed type (yellow [Yellow] or black [B1] canola seeds and Juncea seeds), processed at two temperatures (high temperature desolventized-toasted [HTDT] at $95°C$ or low temperature desolventized-toasted [LTDT] at $57°C$), with or without Enz. In Exp. 1, a total of 384 one-day-old male broiler chicks were randomly assigned to 64 battery cages, with 6 birds/cage. The second experiment was a $2 \times 2 \times 2$ factorial arrangement with the main factors being seed type (Yellow or black [B2]), seed source (Scott, Saskatchewan or Truro, Nova Scotia) and Enz (with or without) supplementation. A total of 264 one-day-old male broiler chicks were randomly assigned to 44 battery cages, with 6 birds per cage. In Exp. 1 and 2, all birds were fed a common starter diet from 1 to 14 days of age. From d 15 to 21, the birds were fed one of the test treatments, a basal grower diet or the basal grower diet replaced with 30% test ingredient with celite (0.8%) added as an inert marker. Excreta was collected on d 20 and 21. In Exp. 1, there were no interactions ($P > 0.05$) among seed type, processing temperature and Enz. Processing temperature and dietary Enz did not affect ($P > 0.05$) AMEn of different canola meals. The AMEn of prepress solvent extracted canola and juncea meals (PSEM) from Yellow (11.2 MJ/kg) was higher ($P < 0.05$) than B1 (10.2 MJ/kg) and Juncea (10.2 MJ/kg). In Exp. 2, there were no interactions ($P > 0.05$) among seed color, location and Enz. Supplementation of dietary Enz did not affect ($P > 0.05$) AMEn of different cold press canola meals. The AMEn of cold press canola meals (CPM) from Yellow (14.7 MJ/kg) was higher ($P < 0.05$) compared with B2 (12.2 MJ/kg). In conclusion, among the different processing methods of oil extraction, meals derived from yellow seeded canola had higher AMEn than B seeded canola and Juncea.

1. Introduction

In Canada, commercial canola meal (CM) is made from the mixtures of seeds of *Brassica napus* and *Brassica rapa* processed by expeller and solvent extraction processes (Canola Council of Canada, 2009). Canola meal is a good source of protein (35% to 38% crude protein on dry matter basis), and has a well-balanced amino acid composition (Newkirk et al., 2003). The most important anti-nutritional factors in CM are non-starch polysaccharides (NSP) and phytates (Simbaya et al., 1996). Currently, Canadian canola meal

* Corresponding author.
 E-mail address: balachandar.vet@gmail.com (B. Jayaraman).

contains very limited amounts of glucosinolates (4.2 μmol/g) (Canola meal feeding guide, 2015). Development of yellow-seeded canola was one of the major approaches to reduce the fiber content, increase the protein content and to enhance the overall nutritional characteristics of CM (Khajali and Slominski, 2012).

The processing of canola seed for separation of oil has a significant effect on oilseed meal quality (Mustafa et al., 2000; Newkirk et al., 1997, 2003). Commercial canola meal prepared by prepress solvent extraction process is exposed to 95 to 115°C during the toasting process which leads to losses in amino acid content and also reduced digestibility of amino acids (Anderson-Hafermann et al., 1993; Newkirk et al., 2003) and metabolizable energy content (Canola Council of Canada, 2009) when fed to poultry.

Another method of oil extraction is the cold press method, where, there is no pre-heating the seed and during extraction, there is not application of steam, which results in 50% to 70% oil extraction (Leming and Lember, 2005; Spragg and Mailer, 2007). Cold press cake is the main co-product of cold pressing extraction of oil which has high residual oil levels. Cold press cake is ground into a meal (CPM) prior to dietary addition. The residual oil in CPM ranges from 12% to 17% (Ferchau, 2000), which results in higher dietary energy (Seneviratne et al., 2010; Woyengo et al., 2010).

Dietary supplementation of cell wall degrading enzymes has proven to be beneficial for poultry in utilizing the polysaccharides in canola meal (Slominski and Campbell, 1990). The effect of different processing conditions and multicarbohydrase enzyme supplementation on apparent metabolizable energy (AMEn) in meals derived from yellow and black seeded canola and juncea in broiler chickens has not been adequately studied. This study was conducted to determine the AMEn in different prepress solvent extracted canola and juncea meals (PSEM) and CPM and evaluate the effects of multicarbohydrase supplementation to these meals on AMEn for broiler chickens.

2. Materials and methods

The experiments were conducted at Atlantic Poultry Research Centre, Nova Scotia (NS), Canada. The experimental protocol was reviewed and approved by the Animal Care and Use Committee of the Faculty of Agriculture, Dalhousie University. Birds were cared for according to the guidelines of Canadian Council of Animal Care (CCAC, 2009).

2.1. Preparation of prepress solvent extracted canola meals

Seeds from yellow seeded canola (line YN01-429) (Yellow) and commercial black canola (B1) grown near Scott, Saskatchewan (SK) and juncea seed grown in Saskatoon, SK, from the crop year 2007, were processed by prepress solvent extraction by the POS pilot plant, Saskatoon, SK. Canola and juncea meals were subjected to different temperatures during the desolventization-toasting stage of processing. The normal processing temperature (95°C) (HTDT) was relative to low temperature processing (57°C) (LTDT). All seeds were processed at the same location within the same week.

2.2. Preparation of cold press canola meals

Yellow (line YN01-429) and black canola seeds (line N89-53) (B2) from Scott, SK or Truro, NS were single pressed at temperature ≤50°C in an oil expeller (Komet press, type D85-1G OEKO TEC, IBG Monforts, Germany) by the Prince Edward Island Food Technology Centre. All seeds were processed during the same week. Press cakes produced were ground through a hammer mill, through a screen size 3 mm to produce CPM prior to incorporation into diets.

2.3. Experiment procedure

In Exp. 1, PSEM of Yellow and B1 canola and Juncea with or without dietary enzymes were tested using 384 one-day-old male Ross 508 broiler chickens. Birds were randomly distributed to 64 battery cages (5 replicate cages per test diet and 4 replicate cages per basal diet) with 6 birds per cage. Reduced replicates for the basal diet were due to limitation in cages on the battery caging system. In Exp. 2,264 one-day-old broiler chickens of the same strain used in Exp. 1 were used to evaluate CPM from Yellow or Black 2 canola seeds with or without dietary enzymes. Birds were randomly distributed to 44 battery cages (5 replicate cages per test diet and 4 cages per basal diet) with 6 birds per cage. In both experiments the multi-carbohydrase enzyme cocktail contained cellulase ($\geq$2,800 U/g), amylase ($\geq$2,500 U/g), mannanase ($\geq$400 U/g), galactonase ($\geq$50 U/g), xylanase ($\geq$1,000 U/g), gluconase ($\geq$600 U/g), and protease ($\geq$200 U/g) prepared and provided by the Department of Animal Sciences, University of Manitoba. The starter diet, formulated to contain 23% crude protein and 3,050 kcal/kg ME was fed from 1 to 14 days of age to all birds; a basal grower diet, formulated to contain 20% crude protein and 3,150 kcal/kg ME (Table 1). The starter and basal grower diets met or exceeded the nutritional requirements of broiler chickens (National Research Council (NRC), 1994). In the grower diet, celite (Hyflo Super Cell, food chemical codex grade) was added at 0.8% as an inert marker to determine digestibility using the indicator method (Leeson and Summers, 2001). From 15 to 21 days of age, the birds were fed either the basal grower diet or the test diet (basal grower diet replaced by 30% of one of the test ingredients). On d 20 and 21, a representative sample of excreta was collected from the trays underneath each cage

Table 1
Composition (as fed basis) and calculated nutrient content of the broiler starter diet and basal grower diet.

Item	Starter	Grower
Ingredients, g/kg		
Corn	448	507
Soybean meal	380	301
Wheat	100	100
Poultry fat	33	46
Limestone, ground	16	18
Mono-dicalcium phosphate	9.0	8.0
Vitamin-mineral premix[1]	5.0	5.0
Celite[2]	0.0	8.0
Iodized salt	4.0	4.0
Methionine premix[3]	4.5	2.2
Coban[4]	0.5	0.5
Stafac 44[5]	0.25	0.25
Total	1,000	1,000
Calculated analyses, g/kg		
Metabolizable energy, MJ/kg	12.8	13.2
Crude protein	230	200
Ether extract	53	67
Crude fiber	26	25
Calcium	10	9.2
Available phosphorus	4.5	4.0
Lysine	11.1	11.1
Methionine + cystine	7.5	7.5

[1] Premix supplied the following per kilogram of diet: vitamin A 9,750 IU; vitamin D 32,000 IU; vitamin E 25 IU; vitamin K_3 3 mg; vitamin B 27.6 mg; calcium pantothenate 13.5 mg; vitamin B_1 20.0 mg; niacin 29.7 mg; folic acid 1 mg; choline chloride 800 mg; biotin 30 mg; vitamin B_6 4.95 mg; thiamin 3 mg; manganous oxide 70.2 mg; zinc oxide 80 mg; copper sulfate 25 mg; selenium premix 0.1485 mg; ethoxyquin 50 mg; wheat middlings 1.543 g; ground limestone 190 mg.
[2] Hyflo Super Cel, food chemical codex grade (Van Waters and Rogers Ltd. Richmond, BC, Canada).
[3] Supplied per kg premix: DL-methionine, 0.5 kg; wheat middlings, 0.5 kg.
[4] Monensin (coccidiostat) 200 g/kg (Pfizer Animal Health, London, ON, Canada).
[5] Virginiamycin (Antibiotic) 44 g/kg (Phibro Animal Health, Regina, SK, Canada).

and immediately frozen. Excreta samples were frozen at −20°C until analyzed. Feed samples were retained for subsequent analysis.

In both experiments, diet mixing was done using a paddle type Hobart mixer. All diets in mash form were fed *ad libitum* to birds from a trough attached to the front of the cage. Feed intake and body weights of the birds were recorded on d 0, 14 and 21 for both experiments. Water was provided *ad libitum* from nipple drinkers. Throughout the trials, mortality was recorded when it occurred and birds were examined post-mortem by a veterinary pathologist.

2.4. Chemical analyses

The dry matter (DM) content of feed and excreta was determined using method 935.29 (AOAC, 2005). Feed samples were weighed (approximately 30 g) in duplicate and placed in a standardized hot air oven at 52°C for 24 h and then weighed to calculate DM%. Frozen (−20°C) excreta samples were weighed (approximately 30 g) in duplicate, freeze-dried and then weighed to calculate DM%. Oven-dried feed and freeze-dried excreta samples were ground to pass through a 1 mm screen prior to conducting analysis. Gross energy (GE) was determined using a Parr adiabatic bomb calorimeter (Parr Instrument Company, Moline, Illinois). Nitrogen content of dried feed and excreta samples were determined in duplicate using a Leco Nitrogen analyzer (Leco corporation, St Joseph, MI) method 990.03 (Association of Official Analytical Chemists (AOAC), 2005). Acid detergent fiber (ADF) and neutral detergent fiber (NDF) of the test ingredients were determined using ANKOM analyzer (AOAC, 2005; Komarek, 1993). The ether extract (EE) was determined according to AOAC using petroleum ether as the solvent (2005). Acid insoluble ash (AIA) procedure was performed using 4 mol/L HCl method (McCarthy et al., 1974).

2.5. Calculation of apparent energy digestibility coefficient (AED) and AMEn

The apparent digestibility coefficients (ADC) of gross energy in the basal and test diets were calculated using the following equation, ADC = 100 − [100 × (% AIA in diet/% AIA in excreta) × (% GE in excreta/% GE in diet)]. The resulting ADC for gross energy in the diets was used to calculate ADC in the test ingredients, according to the formula of Sugiura et al. (1998).

The AMEn of the test diets and test ingredients were calculated using the substitution method described by Leeson and Summers (2001). Nitrogen correction was calculated by using the correction factor of 8.22. The equation used to calculate AME and AMEn are as follows:

$$AME = GE_{Diet} − (GE_{Excreta} × AIA_{Diet}/AIA_{Excreta}),$$
$$AMEn = GE_{Diet} − (GE_{Excreta} × AIA_{Diet}/AIA_{Excreta}) − 8.22 × N_{Retained},$$

where GE diet and GE excreta (kcal/kg) equal to the GE of the diet and excreta, respectively; AIA diet and AIA excreta (%) equal to acid insoluble ash in the diet and excreta, respectively; 8.22 is energy value (kcal/kg) of uric acid; and N retained (g/kg) is the N retained by the broilers per kilogram of diet consumed. The retained nitrogen was calculated as follows:

$$N_{Retained} = N_{Diet} − (N_{Excreta} × AIA_{Diet}/AIA_{Excreta}),$$

where N_{Diet} and $N_{Excreta}$ (%) equal to N contents of the diet and excreta, respectively.

The AMEn of the test ingredient was calculated as follows:

$$AMEn \text{ of the test ingredient} = AMEn \text{ of the basal diet} − [(AMEn \text{ of the basal diet} − AMEn \text{ of the test diet})/0.3].$$

2.6. Statistical analysis

The two experiments were analyzed by ANOVA using the mixed model procedure of SAS (SAS/STAT Version 9.3, SAS Institute Inc., Cary, NC). For Exp. 1, ANOVA determined the differences among seeds (S), processing (P) and enzyme (Enz) supplementation and interactions among them. For Exp. 2, ANOVA determined the differences among seeds, seed source (Location) and Enz supplementation and interactions among them. If significant main effects or interactions were found, the Tukey–Kramer test was used to compare differences among the least square means at α = 0.05 (Montgomery, 2005). The results presented are least square means and standard error of mean (SEM).

3. Results

3.1. Chemical composition of different meals derived from juncea, yellow and black seeded canola

Dry matter and chemical composition of meals derived from pre-press solvent extraction and cold-press extraction methods (Table 2) indicated meals derived from yellow seeded (Yellow) *B. napus* contained more CP and less NDF than meals derived from black seeded canola. The EE of all PSEM were less than 20 g/kg. Neutral detergent fiber and ADF of Yellow canola meals were less than B1 canola and juncea meals. The CP content of CPM varied from 347 to 380 g/kg, on DM basis. The EE of Yellow meals (264 and 233 g/kg from seeds grown at Scott and Truro, respectively) were higher than Black 2 meals from seeds grown at Scott (181 g/kg) and Truro (180 g/kg). The NDF and ADF content of yellow meals were 37% and 45%, respectively, lower than Black 2 meals.

In both experiments, all diets were well received by the birds. No differences in feed intake occurred among diets fed containing the different test ingredients.

3.2. Experiment 1

In Exp. 1, there were no interactions (P > 0.05) among seed type, processing and multicarbohydrase supplementation on AED, AME and AMEn (Table 3). The AED, AME and AMEn of PSEM from Yellow were higher (P < 0.05) than those from B1 canola and Juncea. In PSEM, method of processing (HTDT and LTDT) and enzyme supplementation did not affect (P > 0.05) AED, AME and AMEn of the meals.

3.3. Experiment 2

In Exp. 2, there were no interactions (P > 0.05) among seed type, seed source and multicarbohydrase supplementation on AED, AME and AMEn (Table 4). The AED, AME and AMEn of CPM from Yellow canola were higher (P < 0.05) than those from Black 2. There was no difference in AMEn between CPM derived from seeds grown at Scott (SK) and Truro (NS) (Table 4). Enzyme supplementation did not affect (P > 0.05) AMEn of CPM.

4. Discussion

In both, pre-press solvent extraction and cold press processing methods, meals derived from yellow *B. napus* contained more

Table 2
Chemical composition of different meals derived from yellow and black seeded canola and juncea (on DM basis).

Item	Crude protein, g/kg	Gross energy, MJ/kg	Ether extract, g/kg	Neutral detergent fiber, g/kg	Acid detergent fiber, g/kg	Ash, g/kg
Prepress solvent extracted canola and juncea meals						
High temperature (95°C) desolventized-toasted						
Yellow seeded canola[1]	445	18.1	19.6	150	120	60
Black seeded canola[2]	422	18.2	18.1	205	174	64
Juncea	454	17.8	14.9	176	135	64
Low temperature (57°C) desolventized-toasted						
Yellow seeded canola[1]	456	18.2	13.3	173	124	61
Black seeded canola[2]	421	17.8	17.4	211	186	64
Juncea	449	18.0	19.0	195	139	63
Cold press canola meals						
Yellow seeded canola[1]	355	24.5	264	92	74	47
Black seeded canola[3]	380	23.1	181	150	120	47
Yellow seeded canola[4]	347	23.3	233	120	92	58
Black seeded canola[4]	364	22.6	180	198	171	56

[1] Seed source: yellow *Brassica napus* (line YN01-429) grown in Scott, SK, Canada.
[2] Seed source: black *B. napus* (line N89-53) grown in Saskatoon, SK, Canada.
[3] Seed source: black *B. napus* (line unknown) grown in Scott, SK, Canada.
[4] Seed source: yellow *B. napus* (line YN01-429) and black *Brassica napus* (N89-53) grown in Truro, NS, Canada.

Table 3
Apparent energy digestibility coefficient (AED), apparent metabolizable energy (AME, MJ/kg) and apparent metabolizable energy (AMEn, MJ/kg) of meals derived from juncea (*Brassica juncea*), yellow and black seeded canola (*Brassica napus*) processed at different temperatures during desolventizing-toasting process.

Item	Seeded canola (S)			SEM[4]	P-value	Processing (P)		SEM	P-value	Enzyme (E)[5]		SEM	P-value	P-value S × P × E
	Yellow[1]	Black[2]	Juncea[3]			HTDT	LTDT			+	−			
AED	0.71	0.64	0.62	1.35	<0.001	0.66	0.66	1.00	0.986	0.66	0.65	1.09	0.552	0.855
AME, MJ/kg	12.7	11.6	11.5	0.24	0.001	12.0	11.8	0.20	0.451	12.0	11.8	0.20	0.426	0.563
AMEn, MJ/kg	11.2	10.2	10.2	0.21	0.002	10.6	10.4	0.20	0.376	10.7	10.4	0.22	0.240	0.537

HTDT = high temperature (95°C) desolventized-toasted; LTDT = low temperature (57°C) desolventized-toasted.
[1] Prepress solvent extracted meals (PSEM) derived from yellow *Brassica napus* (line YN01-429) grown in Scott, SK, Canada.
[2] PSEM derived from Black *B. napus* (line N89-53) (source: unknown).
[3] PSEM derived from Juncea *B. juncea* grown in Saskatoon, SK, Canada.
[4] Standard error of mean that applies to the statistical model.
[5] + and − indicate diets supplemented with and without multicarbohydrase enzymes, respectively.

Table 4
Apparent energy digestibility coefficient (AED), apparent metabolizable energy (AME, MJ/kg) and apparent metabolizable energy (AMEn, MJ/kg) of meals derived from yellow and black seeded canola (*Brassica napus*) from different locations processed by cold press oil extraction.

Item	Seeded canola (S)		SEM[3]	P-value	Seed source (L)		SEM	P-value	Enzyme (E)[6]		SEM	P-value	P-value S × L × E
	Yellow[1]	Black[2]			Scott[4]	Truro[5]			+	−			
AED	0.67	0.61	1.88	0.032	0.65	0.63	1.88	0.597	0.65	0.63	1.88	0.390	0.929
AME, MJ/kg	15.6	13.5	0.44	0.002	14.9	14.1	0.44	0.179	14.8	14.2	0.44	0.378	0.931
AMEn, MJ/kg	14.7	12.2	0.39	<0.001	13.7	13.1	0.39	0.241	13.7	13.2	0.39	0.307	0.819

[1] Cold press meal (CPM) derived from yellow *Brassica napus* (line YN01-429).
[2] CPM derived from Black *B. napus*.
[3] Standard error of mean that applies to the statistical model.
[4] Seed source: Scott, SK, Canada.
[5] Seed source: Truro, NS, Canada.
[6] + and − indicate diets supplemented with and without multicarbohydrase enzymes, respectively.

protein and less fiber than black canolas, which is in agreement with the previous studies (Montoya and Leterme, 2009; Simbaya et al., 1995; Slominski et al., 1994, 2011). The fiber content of Yellow (NDF 150 g/kg; ADF 120 g/kg) were found to be less than B1 (NDF 205 g/kg; ADF 174 g/kg) and Juncea meals (NDF 176 g/kg; ADF 135 g/kg). This agrees with the previous work (Bell and Shires, 1982; Montoya and Leterme, 2009; Simbaya et al., 1995; Slominski et al., 2011) stating that yellow rapeseed canola meal contained lower fiber content than B canola. The lower fiber content of yellow *B. napus* meals could be due to thinner hulls in seeds compared to those used to produce black *B. napus* meals (Simbaya et al., 1995).

The fiber content (NDF and ADF) of yellow CPM was lower than black CPM. The fat content in B2 was comparable to Australian CPM (181 versus 197 g/kg) reported by Geier (2004). The fat content in Yellow were 28% higher than B2 meals. The level of residual oil measured as EE ranging from 180 to 264 g/kg were higher than expected. A residual oil of this magnitude would reduce the saleable low temperature oil available for the crusher, using cold pressing. The higher residual oil in the CPM is due in part to the lack of added heat during processing. Leaving more oil in the meals would result in increased energy value of the press cakes but could contribute to more difficult handling and stability.

The AED of PSEM from Yellow was higher than B1 and Juncea, which is in consistent with previous studies (Simbaya et al., 1995; Slominski et al., 1999). High fiber content interferes with digestibility and lowers ME value of the CM in broiler chickens (Slominski and Campbell, 1990). The AME and AMEn contents of PSEM derived from Yellow canola (11.2 MJ/kg) were higher than

Black 1 canola (10.2 MJ/kg) and Juncea (10.2 MJ/kg) meals. The AME and AMEn of PSEM from Yellow and B1 canola meals was found to be higher than previous reports (8.8 MJ/kg), Emamzadeh et al. (2008); (8.3 MJ/kg), Lee et al. (1995) (8.9 MJ/kg), Newkirk et al. (2003). Slominski et al. (2011) reported that the AMEn of Juncea, yellow and black canola were 1,736 kcal/kg (7.3 MJ/kg), 2,190 kcal/kg (9.2 MJ/kg) and 1,904 kcal/kg (8.0 MJ/kg), respectively. The differences in AMEn of CM in broiler chickens could be due to the nutritive composition of oilseed meals, especially the amount of residual oil left in the meal.

Reduction of desolventizer—toaster temperature from HTDT to LTDT did not affect AMEn of meals. Toasting canola meals remove remnants of hexane and inactivate some of the anti-nutritional factors after processing (Newkirk and Classen, 2002), while excessive toasting would lead to browning of CM, which is an indication of Maillard reaction, perhaps denaturing the protein. During the prepress solvent extraction process of oil extraction, the cooking phase temperature was the same ($60 \pm 5°C$ in the top tray and $90 \pm 5°C$ in the bottom tray) for both HTDT and LTDT meals. During desolventization and toasting process, the temperature in HTDT meal processing was $95 \pm 5°C$ (both top and bottom trays) and the temperature in LTDT meal processing was $57 \pm 5°C$ (both trays). By altering the processing conditions, the meal quality can be either increased or decreased (Anderson-Hafermann et al., 1993). A minimum amount of heat ($90°C$) is applied to deactivate myrosinase enzyme, to avoid break down of glucosinolates to aglucones, toxic metabolite for animals. Thirty to seventy percent of Glucosinolates are thermally degraded during canola crushing process (Khajali and Slominski, 2012). High temperature during oil extraction process, could result in losses in content and digestibility of amino acids, particularly lysine (Khajali and Slominski, 2012). In this study, different processing conditions did not affect AMEn of canola meals. Changes in the desolventizer—toaster temperatures may not have been large enough to decrease the AMEn of the meal.

In this study, supplementation of multicarbohydrase did not influence AMEn of PSEM or CPM. These findings agree with other studies, where the addition of multicarbohydrase enzyme to the diet did not affect ME content in CM based diets (Simbaya et al., 1996; Mushtaq et al., 2007). Similarly, Meng and Slominski (2005) reported that multi-carbohydrase supplementation in corn CM-based diets was not always beneficial in increasing AMEn. On the contrary, some studies reported that pre-treatment of canola with enzyme increased AME for broiler chickens (Campbell et al., 2001; Kocher et al., 2000). The effect of multicarbohydrase on non-starch polysaccharide digestibility could be more pronounced, when used with full-fat canola seeds compared to CM in the broiler diets (Khajali and Slominski, 2012). This variation in effects of enzyme addition reinforces the need for a data base of AMEn that encompasses the range of AMEn content of canola meals derived from different processes and seed types.

5. Conclusions

The low-fiber Yellow solvent extracted canola meal (11.2 MJ/kg) had higher AMEn than Black 1 CM (10.2 MJ/kg) and Juncea (10.2 MJ/kg) meals for broiler chickens. The AMEn content of cold press meals derived from yellow seeded canola (14.7 MJ/kg) was higher than black seeded canola (12.2 MJ/kg). Supplementation of multi-carbohydrases did not increase AMEn of different canola and juncea meals. Meals derived from yellow seeded canola had higher AMEn than corresponding meals from B1 or B2 canola and juncea seeds. Seed source did not result in different AMEn between Scott, SK and Truro, NS. The AMEn values for CM processed by PSEM and CPM are useful in ration formulation for broiler chickens.

References

Anderson-Hafermann JC, Zhang Y, Parsons CM. Effects of processing on the nutritional quality of canola meal. Poult Sci 1993;72:326—33.

Association of Official Analytical Chemists. Official methods of analysis of official analytical chemists. 18th ed. Arlington, Virginia: AOAC; 2005.

Bell JM, Shires A. Composition and digestibility by pigs of hull fractions from rapeseed cultivars with yellow or brown seed coats. Can J Anim Sci 1982;62: 557.

Campbell LD, Slominski BA, Liang D, Guenter W. Nutritive value of enzyme pretreated canola meal. In: International symposium on rapeseed science. The People's Republic of China; 2001. p. 334—42.

Canadian Council of Animal Care. Guide to the care and use of experimental animals. 2nd ed. Ottawa, ON: CCAC; 2009.

Canola Council of Canada. Canola feed industry guide. Winnipeg, MB. Canola Council of Canada; 2009. p. 35.

Canola meal feeding guide. Feed industry guide. Canola Council of Canada; 2015. p. 5.

Emamzadeh AN, Yagobdar A, Sadeghi AA, Mirhadi AA, Chamani M. Determination of metabolizable energy in soybean, sunflower and canola meals using caectomised and intact broilers. J Anim Vet Adv 2008;7:235—8.

Ferchau E. Equipment for decentralized cold pressing of oil seeds. 2000. p. 7. http://www.folkcenter.net/mediafiles/folkcenter/pdf/dk/efcposef.pdf.

Geier H. Canola quality in Alaska (2001 harvest). Research progress report, 42. Alaska Agricultural and Forestry Experiment Station Publications; 2004. p. 1—4.

Khajali F, Slominski BA. Factors that affect the nutritive value of canola meal for poultry. Poult Sci 2012;91(10):2564—75.

Kocher A, Choct M, Morrisroe L, Broz J. Effects of enzyme supplementation on the replacement value of canola meal for soybean meal in broiler diets. Aust J Agric Res 2000;52:447—52.

Komarek AR. An improved filtering technique for the analysis of neutral detergent fiber and acid detergent fiber utilizing the filter bag technique. ANKOM Co.; 1993. Publication 101.

Lee KH, Qi GH, Sim JS. Metabolizable energy and amino acid availability of full fat seeds, meals and oils of flax and canola. Poult Sci 1995;74:1341—8.

Leeson S, Summers JD. Scott's nutrition of the chicken. 4th ed. Guelph, ON: University Books; 2001. p. 1—33.

Leming R, Lember A. Chemical composition of expeller-extracted and cold-pressed canola meal. Agraarteadus 2005;16:103—9.

McCarthy JF, Aherne FX, Okai DB. Use of HCl insoluble ash as an index material for determining apparent digestibility with pigs. Can J Anim Sci 1974;54:107.

Meng X, Slominski BA. Nutritive values of corn, soybean meal, canola meal and peas for broiler chickens as affected by a multicarbohydrase enzymes and their effect on nutrient utilization and broiler chicken performance. Poult Sci 2005;84: 1242—51.

Montgomery DC. Design and analysis of experiments. 6th ed. Hoboken, NJ: John Wiley & Sons, Inc; 2005.

Montoya CA, Leterme P. Determination of the digestible energy and prediction of the net energy of toasted and non-toasted canola meals from Brassica juncea and Brassica napus in growing pigs by the total faecal collection and the indigestible marker methods. Can J Anim Sci 2009:481—7.

Mustafa AF, Christensen DA, McKinnon JJ, Newkirk R. Effects of stage of processing of canola seed on chemical composition and in vitro protein degradability of canola meal and intermediate products. Can J Anim Sci 2000;80:211—4.

Mushtaq T, Sarwar M, Ahmad G, Mirza MA, Nawaz HM, Mushtaq H, et al. Influence of canola meal-based diets supplemented with exogenous enzyme and digestible lysine on performance, digestibility, carcass, and immunity responses of broilers. Poult Sci 2007;86:2144—51.

National Research Council. Nutrient requirements of poultry. 9th rev. ed. Washington: National Research Council; 1994.

Newkirk RW, Classen HL. The effects of toasting canola meal on body weight, feed conversion efficiency, and mortality in broiler chickens. Poult Sci 2002;85: 815—25.

Newkirk RW, Classen HL, Edney MJ. Effects of prepress-solvent extraction on the nutritional value of canola meal for broiler chickens. Anim Feed Sci Technol 2003;104:111—9.

Newkirk RW, Classen HL, Tyler RL. Nutritional evaluation of low glucosinolate mustard meals (Brassica juncea) in broiler diets. Poult Sci 1997;76:1272—7.

Seneviratne RW, Young MG, Beltranena E, Goonewardene LA, Newkirk RW, Zijlstra RT. The nutritional value of expeller-pressed canola meal for grower-finisher pigs. J Anim Sci 2010;88:2073–83.

Simbaya J, Slominski BA, Guenter WAM, Campbell LD. The effects of protease and carbohydrase supplementation on the nutritive value of canola meal for poultry: *in vitro* and *in vivo* studies. Anim Feed Sci Technol 1996;61:219–34.

Simbaya J, Slominski BA, Rakow G, Campbell LD, Downey RK, Bell JM. Quality characteristics of yellow-seeded *Brassica* seed meals: protein, carbohydrates, and dietary fiber components. J Agric Food Chem 1995;43:2062–6.

Slominski BA, Campbell LD. Non-starch polysaccharides of canola meal: quantification, digestibility in poultry and potential benefit of dietary enzyme supplementation. J Sci Food Agric 1990;53:175–84.

Slominski BA, Campbell LD, Guenter W. Oligosaccharides in canola meal and their effect on nonstarch polysaccharide digestibility and true metabolizable energy in poultry. Poult Sci 1994;73:156–62.

Slominski BA, Simbaya J, Campbell LG, Rakow G, Guenter W. Nutritive value for broilers of meals derived from newly developed varieties of yellow seeded canola. Anim Feed Sci Technol 1999;78:249–62.

Slominski BA, Jia W, Mikulski D, Rogiewicz A, Jankowski J, Rakow G, et al. Chemical composition and nutritive value of low-fiber yellow-seeded *B. napus* and *B. juncea* canola for poultry. In: Proc. 16th int. rapeseed congress, Prague; 2011. p. 443–5.

Spragg J, Mailer R. Canola meal value chain quality improvement. A final report prepared for AOF and Pork CRC. Berwick, Victoria, Australia: JCS Solutions Pty Ltd.; 2007.

Sugiura SH, Dong FM, Rathbone CK, Hardy RW. Apparent protein digestibility and mineral availabilities in various feed ingredients for salmonid feeds. Aquaculture 1998;159:177–202.

Woyengo TA, Kiarie E, Nyachoti CM. Energy and amino acid utilization in expeller-extracted canola fed to growing pigs. J Anim Sci 2010;88:1433–41.