**SHORT COMMUNICATION**

**Extrusion enhances metabolizable energy and ileal amino acids digestibility of canola meal for broiler chickens**

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**Abstract**

The aim of the current study was to determine the effect of extrusion process on apparent metabolizable energy (AME), crude protein (CP) and amino acid (AA) digestibility of canola meal (CM) in broiler chickens. A total of 36, 42-day-old broilers were randomly assigned into adaptation diets (no CM or 30% CM) with six replicates. After 4 days of adaptation period, on day 47, birds were allowed to consume the assay diets that contain CM or extruded canola meal (ECM) as the sole source of energy and protein. Following 4 h after feeding, the birds were killed and ileal contents were collected. The results showed that ECM had greater (P<0.001) AME (10.87 vs 9.39 MJ/kg) compared to CM. The extrusion also significantly enhanced apparent ileal digestibility of CP and some AA such as Asp, Glu, Ser, Thr and Trp. In conclusion, the extrusion treatment appeared to be a practical and effective approach in enhancing the digestibility of AME, CP and some AA of CM in broiler chickens.

**Materials and methods**

The canola meal (CM) samples assayed in the present study were obtained from a commercial feed mill in United Arab Emirates. The CM samples were extruded using a laboratory scale stand-alone single-screw extruder with a throughput of 5 kg/h (Brabender KE19; Brabender GmbH, Duisburg, Germany). The extruder had a barrel length and barrel diameter of 420 mm and 19 mm, respectively, with a length to diameter ratio of 22:1. A uniform pitch screw with a length to diameter ratio of 25 was used in the experiment. The maximum screw torque was 150 Nm and the compression ratio achieved inside the barrel was 3:1. The barrel zone was heated electrically with heating/cooling jacket. The barrel temperature profile was set at 60, 100, 120°C while the die temperature was set at 160°C. The moisture content was 20%. The extruder was operated at a preset feeder, screw and bladed cutter speed of 150 rpm. The die had a diameter of 3 mm and pressure of 8.0-10.0 MPa. Extrudates were oven-dried at 45°C for about 24 h.

Two experimental diets containing either CM (97%) or extruded CM (ECM) (97%) as a sole source of energy and protein were prepared (Jia et al., 2012) (Table 1). Both diets were balanced for minerals and vitamins to meet NRC (1994) requirements and contained titanium dioxide (0.5%) as digestibility marker. All experimental procedures were conducted in accordance with Universiti Putra Malaysia Research Policy on animal care. A total of 50 1-day-old male broiler chickens (Cobb 500) were obtained from a local hatchery and raised in groups of 5 in 10 battery cages with wire floors in a conventional open-sided house with cyclic temperatures (maximum 34°C and minimum 24°C). Chicks were fed commercial broiler starter in crumble form (12.14 MJ ME/kg; 21% CP) and grower in pellet form (12.77 MJ ME/kg; 19% CP) from day 1 to 21, and 22 onwards, respectively. Water was available at all times. On day 42, 36 chickens of uniform body weight (2000±45 g) were chosen. Groups of three birds were then randomly assigned to 12 cages. All birds were allowed a 4-day adaptation period where they were fed a corn-soybean based diet with 30% CM to eliminate the carry-over effects between the diets (Kadim et al., 2002; Soleimani et al., 2010). Following the adaptation period, the birds were fasted for 24 h to remove gastrointestinal con-
tent. On day 47, the birds were allowed to consume the assay diets for 1.5 h. Each diet was fed to six cages of birds. Following 4 h after feeding, the birds were killed by neck cut for collection of ileal content. The ileum was defined as the portion of the intestine from the yolk sac diverticulum to the ileocecal junction. Digesta sample from the birds within a cage were pooled and stored at -20°C immediately and subsequently freeze-dried. The dried ileal digesta were stored in airtight bags at -20°C until further analysis.

Samples of CM, ECM, diets and ileal digesta were finely ground using a coffee grinder (Panasonic, Petaling Jaya, Malaysia). Dry matter and crude protein were determined according to the procedures of AOAC (1990). Gross energy (GE) was measured with an adiabatic oxygen bomb calorimeter (Parr Adiabatic Calorimeter, Parr Instrument Co., Moline, IL, USA). Amino acid concentrations in the diet and ileal digesta were determined by HPLC according to procedures of Strydom and Cohen (1994) and following pre-column derivatisation with AQC reagent (6-aminoquinolyl-N-hydroxysuccinimidyl carbamate, Waters, Milford, MA, USA). Cys and Met were analysed as cysteic acid and methionine sulfone by oxidation with performic acid for 16 h at 0°C and neutralisation with hydrobromic acid before hydrolysis. Trp content was determined following alkaline hydrolysis of sample with 4.3 M NaOH for 16 h at 120°C and neutralization with 6 M HCl. Quantification of the other amino acids was done by hydrolysing the sample in 5 mL 6 M HCl for 22 h at 110°C. Titanium dioxide was determined according to procedures described by Short et al. (1996). Total glucosinolate was determined by spectrophotometry (Gallaher et al., 2012; Jezejek et al., 1999). Briefly, glucosinolates in samples were hydrolyzed under alkaline conditions to release 1-thioglucose by addition of 2 mL of freshly prepared 2 M NaOH. Samples were neutralized after 30 min with 310 L of concentrated HCl. The sinigrin standard curve was prepared and serially diluted (1-0.03125 mM) using freshly made 1 M NaOH as the diluent and neutralized with 7.2% of total final volume concentrated HCl. The reaction was initiated by addition of 1.5 mL of a solution of 2 mM potassium ferricyanide in 0.4 M PBS (pH 7.0) to 1.5 mL of the standard solution or sample extract. Absorbance was read at 420 nm at 2 min after addition of the ferricyanide solution.

The apparent metabolizable energy of diets was determined using the following formula on a DM basis (Driver et al., 2006):

\[
\text{AME (MJ/kg diet)} = \text{GE diet} - \left[ \text{GE digesta} \times \left( \frac{\text{TiO}_2}{\text{TiO}_2 \text{ digesta}} \right) \right]
\]

\[
\text{Digestibility} \% = 100 - \left[ \left( \frac{\text{TiO}_2 \text{ digesta}}{\text{TiO}_2 \text{ diet}} \right) \times \left( \frac{\text{Nutrient digesta}}{\text{Nutrient diet}} \right) \times 100 \right].
\]

The amino acids output (related to ingestion of 1 g of DM; the units are mg/kg) and digestibility was calculated using the following equation (Kadim and Moughan, 1997):

\[
\text{AA output (mg/kg DM intake)} = \frac{\text{AA digesta} \times (\text{TiO}_2 \text{ digesta} \times \text{Nutrient digesta})}{\text{TiO}_2 \text{ diet} \times \text{Nutrient diet} \times 100}.
\]

Apparent AA digestibility (%) = \text{AA diet} - \text{(AA output / AA diet)} \times 100.

All statistical analyses were carried out with the Student’s t-test using TTEST procedure of SAS (2002).

**Results and discussion**

The analyzed compositions of CM and ECM are presented in Table 2. Both CM and ECM had similar percentages of DM (93.21\% vs 92.13\%), CP (39.96\% vs 39.36\%, on DM basis), and ether extract (3.03\% vs 3.11\%, on DM basis). Similarly, there were no difference in AA and glucosinolate contents of CM and ECM. However, the ECM had higher gross energy (18.97\% vs 18.47\% MJ/kg, on DM basis) and lower crude fibre (9.82\% vs 12.42\%, on DM basis) than CM. These nutrients changes resulted in the greater digestibility values for ME, GE, CP and DM in ECM compared to CM (P<0.05) (Table 3). Among the various AA, the enhancement in ECM AA digestibility was observed only in Asp, Glu, Ser, Thr and Trp. The observed improvement in ME, GE and CP digestibility may be attributed to the lower fibre content in ECM. This finding is supported by the reports of Siregar et al. (1982) and Brenes et al. (2002) that increase in dietary fibre or oligosaccharides reduced ME in duck and chicken. Fibre has been recognized as one of the main factors contributing to the low energy content of CM in poultry diets. Previous studies suggested that although boiling and pressure-cooking cause small changes in total NSP content, some redistribution from insoluble to soluble components take place (Sagum and Arcot, 2000; Anguita et al., 2006). Marmsen et al. (1997) reported that extrusion considerably improved digestibility of the fibre fraction of soybean meal in poultry (4-16 % units). Anguita et al. (2006) reported that the expander and extrusion processing are best in feedstuffs that contain complex arabinoxylans. Therefore, CM is a suitable feedstuff for extrusion process as its NSP portion consists of 33% arabinose and 13% xylose. Thermal processes can break weak bonds between polysaccharides and glycosides linkages within the polysaccharides (de Vries et al., 2012). Heating particularly under moist condition causes starch gelatinization, which may result in swelling and breaking of the cell. Therefore, hydrothermal processes that include high

| Table 1. Feed composition of experimental diets. |
|------------------------------------------------|
| **Basal diet** | **CM** | **ECM** |
| **Ingredients, %** | | | |
| Corn | 54.97 | - | - |
| Soybean meal (44%) | 4.10 | - | - |
| Palm oil | 5.00 | - | - |
| Corn gluten | 1.00 | - | - |
| DCP | 2.50 | 0.60 | 0.60 |
| Calcium carbonate | 0.50 | 0.60 | 0.60 |
| Premix | 1.00 | 1.00 | 1.00 |
| Salt | 0.30 | 0.30 | 0.30 |
| L-lysine | 0.30 | - | - |
| Choline chloride | 0.08 | - | - |
| Sodium bicarbonate | 0.05 | - | - |
| DL-methionine | 0.20 | - | - |
| Canola meal | 30.00 | 97.00 | 97.00 |
| Titanium dioxide | - | 0.50 | 0.50 |

*The basal diet was fed to all birds for 4 d before introduction of the assay diet. CM, canola meal; ECM, extruded canola meal. Premix provided the following (per kilogram of diet): vitamin A, 2300 U; vitamin D3, 400 U; vitamin E, 1.8 mg; vitamin B12, 3.5 mg; riboflavin, 1.4 mg; pantothenic acid, 2 mg; nicotinic acid, 7 mg; peroxidase, 0.25 mg; folate acid, 0.15 mg; menadione, 0.3 mg; thiamin, 0.15 mg; manganese oxide, 35 mg; ferrous sulfate 35 mg; zinc oxide, 38 mg; copper sulfate, 60 mg; cobalt carbonate, 5 mg; potassium iodide, 0.6 mg; selenium vanadate, 0.09 mg.*
Table 2. Analyzed composition (DM basis) of canola meal and extruded canola meal.  

| Analyzed composition       | CM          | ECM          |
|----------------------------|-------------|--------------|
| Dry matter, %              | 93.21       | 92.13        |
| Gross energy, MJ/kg DM     | 18.47       | 18.97        |
| Ash, % DM                  | 6.58        | 6.24         |
| Crude protein, % DM        | 39.96       | 39.36        |
| Crude fibre, % DM          | 12.42       | 9.82         |
| Ether extract, % DM        | 3.03        | 3.11         |
| Glucosinolate, μmol/g DM   | 23.28       | 22.68        |

Amino acids, % DM

| Amino acids                  | CM          | ECM          |
|------------------------------|-------------|--------------|
| Aspartic acid                | 2.66        | 3.00         |
| Serine                       | 1.69        | 1.84         |
| Glutamic acid                | 6.36        | 7.12         |
| Glycine                      | 2.04        | 2.02         |
| Histidine                    | 1.01        | 1.22         |
| Arginine                     | 2.18        | 2.26         |
| Threonine                    | 1.67        | 1.82         |
| Alanine                      | 1.61        | 1.78         |
| Proline                      | 2.31        | 2.55         |
| Cysteine                     | 0.94        | 0.95         |
| Tyrosine                     | 0.90        | 0.91         |
| Valine                       | 1.98        | 2.20         |
| Methionine                   | 0.68        | 0.70         |
| Lysine                       | 2.04        | 2.19         |
| Isoleucine                   | 1.46        | 1.70         |
| Leucine                      | 2.70        | 3.01         |
| Phenylalanine                | 1.58        | 1.73         |
| Tryptophan                   | 0.47        | 0.47         |

CM, canola meal; ECM, extruded canola meal.

Table 3. Apparent ileal digestibility of nutrients and amino acids of canola meal and extruded canola meal for broiler chickens.  

| Analyzed composition     | CM          | ECM          | SEM  | P    |
|--------------------------|-------------|--------------|------|------|
| AME, MJ/kg DM            | 9.39        | 10.87        | 0.17 | <0.001|
| GE, MJ/kg DM             | 65.9        | 73.4         | 0.4  | <0.0001|
| DM, %                    | 62.2        | 71.1         | 0.1  | <0.0001|
| CP, % DM                 | 69.3        | 75.3         | 1.7  | 0.027 |
| Amino acids, % DM        |             |              |      |      |
| Aspartic acid            | 69.6        | 79.1         | 1.3  | 0.001 |
| Serine                   | 67.9        | 78.3         | 3.1  | 0.027 |
| Glutamic acid            | 73.8        | 84.5         | 2.6  | 0.013 |
| Glycine                  | 69.7        | 73.5         | 7.5  | 0.644 |
| Histidine                | 72.3        | 61.3         | 2.4  | 0.066 |
| Arginine                 | 69.5        | 75.6         | 6.1  | 0.376 |
| Threonine                | 56.9        | 70.6         | 3.1  | 0.012 |
| Alanine                  | 69.1        | 75.6         | 4.2  | 0.198 |
| Proline                  | 73.0        | 78.4         | 7.6  | 0.516 |
| Cysteine                 | 64.3        | 73.8         | 3.7  | 0.060 |
| Tyrosine                 | 73.0        | 85.3         | 5.2  | 0.136 |
| Valine                   | 63.7        | 72.4         | 6.0  | 0.218 |
| Methionine               | 86.6        | 88.1         | 1.6  | 0.440 |
| Lysine                   | 71.3        | 79.4         | 3.4  | 0.070 |
| Isoleucine               | 65.4        | 71.3         | 7.3  | 0.461 |
| Leucine                  | 73.5        | 78.3         | 6.0  | 0.474 |
| Phenylalanine            | 73.9        | 80.1         | 4.6  | 0.255 |
| Tryptophan               | 61.0        | 71.7         | 2.7  | 0.015 |

CM, canola meal; ECM, extruded canola meal; AME, apparent metabolizable energy; GE, gross energy; DM, dry matter; CP, crude protein.

Conclusions

The results of the current study showed that extrusion may enhance the crude protein, amino acids, gross energy and metabolizable energy apparent digestibility of canola meal along with the reduction in crude fibre content.

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