Nutrients profile, protein quality and energy value of whole Prosopis pods meal as a feedstuff for poultry feeding

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ABSTRACT

The chemical composition, tannins level, mineral profile, fatty acids profile and amino acids profile of whole Prosopis pods meal (WPPM) were determined. In addition, apparent energy metabolisability (AEM) and true energy metabolisability (TEM) and apparent (AAAD) and true (TAAD) amino acids digestibility were determined via a precision-feeding assay. Protein quality was also determined via a total protein efficiency assay. The tannins content of WPPM was 42.8 mg/g dry matter. WPPM showed 15.2% crude protein, 2.61% ether extract, 18.58% crude fibre and 6.04% ash, with 5.44 and 7.57 MJ/kg AEM and TEM, respectively. The WPPM contained 0.66% Ca, 0.20% P, 764 ppm Fe, 69.4 ppm Zn, 33.9 ppm Mn, 61.1 ppm Cu, 21.7 ppm Cr, 7.4 ppm Cd, 9.8 ppm Ni and 28.2 ppm Pb. The WPPM showed 92.54% total fatty acids, of which 25.33% were saturated fatty acids and 67.21% unsaturated fatty acids; of the latter, 37.83% were monounsaturated and 29.37% polyunsaturated. Threonine, valine, methionine, isoleucine, leucine, phenylalanine, histidine, lysine, arginine and tryptophan levels were 0.47, 0.67, 0.12, 0.54, 1.03, 0.40, 0.20, 0.46, 0.67 and 0.44%, respectively. Therefore, WPPM can meet 1.08% of the total amino acids requirements of broiler chickens from 1 to 21 days of age. The AAAD and TAAD of the WPPM were 34.9 and 65.0%, respectively. The protein quality of WPPM was 23.4% lower than that of soybean meal. In conclusion, WPPM contains a considerable amount of energy and nutrients (protein, minerals, fatty acids and amino acids), but its protein quality is lower than that of soybean meal.

Keywords

Prosopis pods meal; chemical composition; fatty acids; amino acids; amino acids digestibility; energy metabolisability; protein quality; chickens

Introduction

The use of cereals and oilseeds for the production of biofuel has caused a significant increase in the price of traditional feed resources, such as corn and soybean meal, for poultry diets, with a consequent increase in feed prices. Therefore, finding alternative feed resources is crucial (Farrell, 2005; Al-saffar et al., 2013; Al-Harthi and Attia, 2015). *Prosopis juliflora* is a widely distributed plant in arid and semi-arid areas and tolerates harsh agronomic and environmental conditions, with a high resistance to diseases and pests (Choge et al., 2007; Tran, 2015a, 2015b) and adequate nutritional characteristics (Maikhuri et al., 1991; Girma et al., 2011a, 2011b; Girma et al., 2012; Odero-Waititu et al., 2016).

*Prosopis juliflora* has been investigated as a source of protein, carbohydrates and sugars for humans and livestock (Manhique et al., 2017), and as a fodder plant for livestock (Abdulrazak et al., 1997; Sawal et al., 2004; King’ori et al., 2011). In the literature, the nutritional content of whole Prosopis pods meal (WPPM) differs widely; for example, crude protein varied from 7.1 to 18.5%, ether extract from 0.4 to 7.3%, crude fibre from 12.3 to 30.8%, nitrogen-free extract from 46.3 to 71.1% and ash content from 1.4 to 7.15% (Sawal et al., 2004; Choge et al., 2007; King’ori et al., 2011). However, not much is known about the amino acids and fatty acids profiles as well as the metabolisability of WPPM energy. In addition, the nutritional profiles differ greatly, depending on the *Prosopis* species as well as the agronomic, geographic and environmental conditions (Heuze et al., 2015; Tran, 2015a, 2015b). Thus, this research was carried out to investigate the chemical composition, amino acids, fatty acids and minerals profiles of WPPM. Also, to test the efficiency of WPPM when used in diets of broiler chickens in terms of amino acids digestibility, energy metabolisability and protein efficiency through productive performance of the chickens.
Materials and methods

The study was performed in the Hada Al-Sham Research Station, Faculty of Meteorology, Environment and Arid Land Agriculture, King Abdulaziz University, Jeddah, Saudi Arabia. The methodology was approved by the department committee that regulates animal rights and welfare, subjected to the Government Law No. 9 in 24-8-2010.

Feedstuff and analysis

Whole Prosopis pods were collected from the Jeddah area in Saudi Arabia. The pods were ground into dry powder, sieved to a particle size of 0.5 mm and placed in bags until further evaluation. Total tannins were determined according to Burns (1971).

The proximate chemical composition of the WPPM was determined according to the AOAC procedure (AOAC 2004), using triplicate randomised samples to generate one mean value. We measured the following parameters: dry matter, method number 934.01; crude protein, method number 954.01; ether extract, method number 920.39; crude fibre, method number 954.18; and ash, method number 942.05. Neutral detergent fibre, acid detergent fibre and hemicellulose were measured according to Van Soest et al. (1991). Nitrogen-free extract (NFE) was calculated via the difference between dry matter and organic matter (protein, ether extract, crude fibre) and ash.

Macro- and micro-minerals were determined by atomic absorption (GBC Avanta Z), using a standard curve according to Jackson (1967); phosphorus was determined according to Dickman and Bray (1940).

A part of the extracted lipid of WPPM, performed according to Folch et al. (1957), was used for the determination of the fatty acids profile according to Radwan (1978), using chromatographic analysis. The fatty acids content was determined via a Shimadzu gas chromatograph GC-4CM (Shimadzu Corp., Kyoto, Japan) with a field-effect mobility (pFE) connected to a glass column (3 m x 3.1 mm ID; cat no. 221-14368-31, Shimadzu Corp., Kyoto, Japan), packed with 5% diethylene glycol succinate (DEGS) and equipped with a flame ionisation detector (FID). Two measurements were done for each analysis and the average was calculated.

Energy was measured using an IKA-adiabatic bomb calorimeter model C400 (IKA Analysentechnik GmbH, Gribheimer Weg 5, D79423, Heitersheim, Germany). The amino acids profile of WPPM was determined at the Novus International Research Centre, St. Charles, MO, according to AOAC (2004), using a Hitachi–L8900 amino acid analyser (Minato-ku, Tokyo, Japan). Tryptophan was determined as reported by Concon (1975) and modified by Ogunsua (1988). Also, the percentages of amino acids to crude protein content of WPPM were calculated; in addition, the ratio of the total amino acids of WPPM to the total amino acids required for broiler chickens from days 1 to 21 of age (NRC 1994) was calculated.

Bioassay of protein quality

The biological assay for protein quality determination (protein efficiency ratio) was carried out according to Woodham (1968). The growth experiment was run using 90 Ross-308 male broiler chickens from 14 to 28 d of age to evaluate diets containing ~180 g protein/kg (Table 1). There were two diets, a corn soybean meal diet and a corn soybean meal diet with WPPM. The tested material (WPPM) provides about one-third (32.6%) of the total protein provided by the main protein source (soybean meal) in the control diet (Table 1).
The diets were calculated based on the nutrients profile of the feedstuffs (NRC 1994), and the analysed chemical composition of WPPM. There were eight replicates per diet (treatment) and five chickens per replicate. Water and experimental diets were offered ad libitum. The broilers were reared using common husbandry and veterinary care practice for broilers. However, from 1 to 13 days of age, broilers were fed commercial broiler starter diets (23% CP and 12.96 MJ metabolisable energy, 1% Ca and 0.50% available phosphorus), broilers were kept at 23:1 light:dark cycle. Chicks were weighed based on replicates at 14 and 28 days of age and feed intake was calculated. Body weight gain, feed intake and protein intake were determined per chicken per day; subsequently, the protein efficiency ratio was calculated by dividing the protein intake by body weight gain.

### Statistical analyses

Data of protein quality experiment were analysed using the software package SAS (2002) with one-way variance analysis, using the GLM procedures of SAS. T-test was applied for comparing the significant differences at 0.05. Data were presented based on mean and SEM.

### Results and discussion

#### Chemical composition

The proximate composition of WPPM is shown in Table 2. Crude protein, ether extract, crude fibre, NFE and ash contents were within the ranges cited by Sawal et al. (2004), Choge et al. (2007), Girma et al. (2011a) and King’ori et al. (2011), with some exceptions for protein, ether extract and fibre values as recorded by Girma et al. (2011b). However, WPPM showed substantial amounts of nutrients, suggesting that it is a valuable feedstuff for chicken nutrition (Odero-Waititu et al. 2016; Manhique et al. 2017). The CP concentration of whole Prosopis pods was similar to that of wheat bran (15.2 vs. 15.4%), but almost twice as high as that of corn (15.2 vs. 8.5%) and about 65.2% of that of undehulled sunflower meal (23.3% CP) (NRC 1994). This indicates that WPPM contains a reasonable amount of protein.

WPPM tannins content was 42.8 mg/g dry matter. The tannins value found herein is higher than those

### Table 1. The composition, calculated and determined values of the diets used in the total protein quality assay.

| Ingredients and composition | Corn–soybean meal diet | Whole prosopis pods |
|-----------------------------|------------------------|----------------------|
| Yellow Corn                 | 649                    | 364                  |
| Soybean meal (44%)          | 286                    | 270                  |
| Whole Prosopis pods meal    | 000                    | 245                  |
| Commercial oil blend        | 30.0                   | 90                   |
| Dicalcium phosphate         | 20.0                   | 20                   |
| Lime stone                  | 9.0                    | 5.0                  |
| Sodium chloride             | 3.0                    | 3.0                  |
| Premixa                     | 3.0                    | 3.0                  |
| Total                       | 1000                   | 1000                 |

#### Table 2. Proximate chemical composition of whole Prosopis pods meal as compared with the literature values.

| Proximate chemical composition, g/100 g | Prosopis pods | Prosopis pods | Prosopis pods | Prosopis pods | Prosopis pods |
|----------------------------------------|---------------|---------------|---------------|---------------|---------------|
| Dry matter                             | 91.4          | 91.81         | 82.0–94.0     | NR            | 82.0–92.6     |
| Moisture                               | 8.6           | 8.19          | 18.0–6.0      | NR            | 18.0–7.4      |
| Crude protein                          | 15.2          | 12.1          | 7.1–18.5      | 8.48–16.5     | 7.1–16.2      |
| Ether extract                          | 2.61          | 7.31          | 0.4–3.5       | 1.30–4.26     | 0.4–4.0       |
| Crude fibre                            | 18.58         | 14.4          | 12.3–28       | 16.9–30.77    | 12.3–28.0     |
| NDF                                    | 28.14         | NR            | 30.93–51.8    | NR            | 30.93–51.8    |
| ADF                                    | 20.04         | NR            | 16.99–36.2    | NR            | 16.99–36.2    |
| Hemicellulose                          | 8.1           | NR            | 13.94–15.6    | 14.03–21.03   | NR            |
| Nitrogen free extract                  | 48.97         | 52.2          | 46.3–65.3     | NR            | 46.3–71.1     |
| Ash                                    | 6.04          | 5.8           | 1.4–6.0       | 3.2–7.1       | 1.4–6.0       |
| Tannins, mg/g dry matter               | 42.8          | NR            | NR            | NR            | NR            |

### Notes

- Vit = Min mix. provides per kilogram of the diet: Vit. A, 12,000 U, vit. E (dl-α-tocopheryl acetate) 20 mg, menadione 2.3 mg, Vit. D3, 2200 ICU, riboflavin 5.5 mg, calcium pantothenate 12 mg, nicotinic acid 50 mg, Choline 250 mg, vit. B12 10 μg, vit. B6 3 mg, thiamine 3 mg, folic acid 1 mg, dl-biotin 0.05 mg. Trace mineral (mg/kg of diet): Mn 80, Zn 60, Cu 35, Fe 8 and Selenium 0.1 mg.
- ME: Metabolisable energy; CP: Crude protein; Ca: Calcium.
- aPresent sample of whole pods meal.
- bGirma et al. (2011b).
- cKing’ori et al. (2011).
- dSawal et al. (2004).
- eChoge et al. (2007).
- fOdero-Waititu et al. 2016; Manhique et al. 2017.
(25.5 and 26.7 mg/g dry matter), as previously recorded (Abdulrazak et al. 1997; King’ori, 2011), respectively. Tannins (1.5–1.9% on a dry matter) showed an adverse effect on chickens’ performance (Talpada et al. 1989), due to its negative influences on protein, amino acids and minerals availabilities (Attia et al. 1998).

**Mineral profile**

The mineral profile of WPPM elucidated that they contain 0.66% Ca, 0.20% total P, 764 ppm Fe, 69.4 ppm Zn, 33.9 ppm Mn, 36.1 ppm Cu, 21.7 ppm Cr, 7.4 ppm Cd, 9.8 ppm Ni and 28.2 ppm Pb (Table 3). This leads us to infer that WPPM are a good source of macro- and micro-minerals. Our results are, to some extent, in agreement with those reported by Sawal et al. (2004) in their review. However, the results of Girma et al. (2011b) showed that WPPM contains 0.28% Ca and 0.14% total P. Heuzé et al. (2015) reported 0.45% Ca, 0.15% total P, 18.0 ppm Zn, 22.0 ppm Mn and 4 ppm Cu. These differences are most likely a result of the different agronomic and environmental conditions, the different Prosopis species as well as different methods of determination and instruments (Girma et al. 2011a; King’ori, 2011; Silvia et al. 2012; Heuzé et al. 2015; Tran, 2015a, 2015b).

**Fatty acids composition**

The fatty acids composition of WPPM is presented in Table 4. Our results indicate that WPPM is a rich source of unsaturated fatty acids (UFA, 67.21%), mono-unsaturated fatty acids (MUFA, 37.83%) and polyunsaturated fatty acids (PUFA, 29.37%), while the concentration of saturated fatty acids (SFA) was 25.33%, with an SFA/UFA of 0.377. Linoleic acid (27.9%), oleic acid (35.5%) and palmitic acid (10.8%)

### Table 3. Minerals composition of whole Prosopis pods meal as compared with the literature values and broiler chickens requirements.

| Minerals contents | Prosopis pods<sup>a</sup> | Prosopis pods<sup>b</sup> | Prosopis pods<sup>c</sup> | Prosopis pods<sup>d</sup> | Broiler chickens requirements between 0 and 3 weeks<sup>e</sup> |
|-------------------|--------------------------|--------------------------|--------------------------|--------------------------|----------------------------------------------------------|
| Ash, g/100 g      | 6.04                     | 5.80                     | 1.4–6.0                  | 3.8                      | NR                                                      |
| Minerals profile  |                          |                          |                          |                          |                                                          |
| Calcium, g/100 g  | 0.66                     | 0.28                     | 0.33–0.71                | 0.45                     | 1.0                                                     |
| Phosphorus, g/100 g | 0.20                   | 0.14                     | 0.08–0.20               | 0.15                     | 0.45                                                    |
| Iron, ppm         | 764                      | NR                       | 203.5–638.8             | NR                       | 80                                                      |
| Zinc, ppm         | 69.4                     | NR                       | 18.3–28.8               | 18.0                     | 40                                                      |
| Manganese, ppm    | 33.9                     | NR                       | 22.1–22.3               | 22.0                     | 60                                                      |
| Copper, ppm       | 36.1                     | NR                       | 12.5–15.5               | 4.0                      | 8                                                       |
| Chromium, ppm     | 21.7                     | NR                       | NR                      | NR                      | NR                                                      |
| Cadmium, ppm      | 7.4                      | NR                       | NR                      | NR                      | NR                                                      |
| Nickel, ppm       | 9.8                      | NR                       | NR                      | NR                      | NR                                                      |
| Lead, ppm         | 28.2                     | NR                       | NR                      | NR                      | NR                                                      |
| NR: not reported. |                          |                          |                          |                          |                                                          |

<sup>a</sup>Present sample of whole pods meal.  
<sup>b</sup>Girma et al. (2011b).  
<sup>c</sup>Sawal et al. (2004).  
<sup>d</sup>Heuzé et al. (2015).  
<sup>e</sup>NRC (1994).

### Table 4. Fatty acids profile of whole Prosopis pods meal in the present study compared with the literature values.

| Fatty acids profile | g/100 g of FA<sup>a</sup> | g/100 g of FA<sup>b</sup> | g/100 g of FA<sup>c</sup> | g/100 g of FA seeds oil<sup>d</sup> |
|---------------------|--------------------------|--------------------------|--------------------------|-----------------------------------|
| C6:0                | 0.596                    | NR                       | NR                       | NR                                |
| C8:0                | 3.14                     | NR                       | NR                       | NR                                |
| C10:0               | 0.649                    | NR                       | NR                       | NR                                |
| C12:0               | 1.31                     | NR                       | NR                       | NR                                |
| C13:0               | 2.08                     | NR                       | NR                       | NR                                |
| C14:0               | 1.08                     | NR                       | NR                       | NR                                |
| C14:1               | 0.151                    | NR                       | NR                       | NR                                |
| C15:0               | 0.944                    | NR                       | NR                       | NR                                |
| C15:1               | 0.777                    | NR                       | NR                       | NR                                |
| C16:1               | 0.308                    | NR                       | NR                       | NR                                |
| C16:0               | 10.8                     | NR                       | 13.19                    | 14.43–15.32                      |
| C17:0               | 0.153                    | NR                       | NR                       | NR                                |
| C18:3               | 0.00                     | NR                       | NR                       | NR                                |
| C18:2c              | 27.9                     | NR                       | 50.92                    | 35.22–36.29                      |
| C18:1c              | 35.5                     | NR                       | 22.74                    | 37.21–39.45                      |
| C18:0               | 5.39                     | NR                       | 4.75                     | 5.43–6.54                        |
| C20:2               | 0.304                    | NR                       | NR                       | NR                                |
| C20:0               | 0.281                    | NR                       | NR                       | 0.80–1.41                        |
| C22:0               | NR                       | NR                       | 1.29                     | 0.47–1.37                        |
| C22:2               | NR                       | NR                       | 0.31                     | NR                                |
| C24:0               | NR                       | NR                       | 0.75                     | NR                                |
| DHA C22:6           | 1.17                     | NR                       | NR                       | NR                                |
| TFA                 | 92.54                    | 92.45                    | 94.11                    | 94.46                             |
| SFA                 | 25.33                    | 26.42                    | 20.14                    | 21.13                             |
| UFA                 | 67.21                    | 66.03                    | 73.97                    | 73.33                             |
| MUFA                | 37.83                    | 18.86                    | 23.05                    | 38.11                             |
| PUFA                | 29.37                    | 17.17                    | 50.92                    | 35.22                             |
| SFA/PUFA ratio      | 0.377                    | 0.400                    | 0.272                    | 0.288                             |

<sup>a</sup>Present study.  
<sup>b</sup>Choge et al. (2007).  
<sup>c</sup>Marangoni and Alli (1988).  
<sup>d</sup>Kathirvel and Kumudha (2011).

DHA: docosahexaenoic acid; MUFA: monounsaturated fatty acids, NR: not reported; PUFA: polyunsaturated fatty acids; SFA: saturated fatty acids; TFA: total fatty acids; UFA: Unsaturated fatty acids.
were the dominant fatty acids of PUFA, MUFA and SFA, respectively. Studies on the fatty acids profile of WPPM are scarce; however, a few fatty acids values in the present study are comparable to those previously reported for Prosopis pods (Marangoni and Alli 1988; Choge et al. 2007) and for seed oil (Kathirvel and Kumudha 2011). The differences in specific fatty acids concentration among the literature reports could be attributed to the oil extraction processes, the type of the products (pods vs. seeds) and, as mentioned before, the agronomic and environmental conditions (Marangoni and Alli 1988; Choge et al. 2007; Kathirvel and Kumudha 2011).

**Amino acids profile**

The amino acids profile of WPPM is displayed in Table 5. The results demonstrate that the protein content of WPPM contains a reasonable quantity of essential amino acids. Of these, valine, leucine and arginine were the most abundant ones. Furthermore, the values of threonine, valine and isoleucine are comparable to those cited by Heuzé et al. (2015). In addition, our findings for methionine + cysteine (0.29 vs. 0.35%), phenylalanine + tyrosine (0.60 vs. 0.52%) and lysine (0.46 vs. 0.43%) where comparable to those of Marangoni and Alli (1988). However, the values found in the present study were lower than those reported by Baião (1987) for Prosopis pod flour. These differences might be due to differences in crude protein (15.2 vs. 59%) and to the nature of the two products, whole pods vs. flour without hulls and fibre.

However, as mentioned previously, the differences could also be a result of the varying agronomic and environmental conditions and the types of product used (seeds, pods, flour).

The differences in the amino acids profile of WPPM (Table 6) compared with that of other feedstuffs could be attributed to the different plant species, agronomic and environmental conditions, preparation methods as well as protein content and product type (seeds, pods, flour) (Attia et al. 1998, 2003; King’ori et al. 2011; Silvia et al. 2012). However, it should be noted that the crude protein of WPPM or the ratio of total essential amino acids to total essential amino acids required by broilers from 1 to 21 d of age (NRC 1994), which, converted as a percentage of protein, ranked third after undeilded sunflower meal and wheat bran, due to the similar nature of the ingredients. Nevertheless, that the amounts of total amino acids in WPPM exceeded the requirements of broiler chickens (52.96 vs. 49.16%).

**Amino acids digestibility**

So far, there are no studies on the amino acids digestibility from WPPM. The AAAD of WPPM ranged from −14.3% for glycine to 70.8% for proline, with an average of 34.9% (Table 7). The corresponding values for TAAD were 35.2 for glycine and 83.9% for proline, with an average of 65.0%. These results indicate that the correction of endogenous amino acids losses (34.9 vs 65%) resulted in an increase of up to 86.2% in TAAD (65−34.9 = 30.1/34.9 = 86.2%).

### Table 5. Amino acids profile of whole Prosopis pods meal in the present study compared with the literature values.

| Crude protein and amino acids profile, g/100 g | Whole Prosopis pods meal<sup>a</sup> | Prosopis pods<sup>b</sup> | Prosopis pods<sup>c</sup> | Prosopis pods<sup>d</sup> | Prosopis pods flour<sup>e</sup> |
|----------------------------------------------|-------------------------------------|-------------------------|-------------------------|-------------------------|---------------------------------|
| Crude protein                                | 15.2                                | 20.2                    | 10.5                    | 10.1                    | 59.0                            |
| Threonine                                    | 0.47                                | 0.485                   | 0.326                   | 0.17                    | 1.40                            |
| Valine                                       | 0.67                                | 0.707                   | NR                      | 0.25                    | 2.05                            |
| Methionine                                    | 0.12                                | 0.202                   | NR                      | 0.35                    | 1.26                            |
| Methionine + cystine                          | 0.29                                | 0.444                   | NR                      | 0.26                    | 1.60                            |
| Isoleucine                                    | 0.54                                | 0.545                   | NR                      | 0.26                    | 1.60                            |
| Leucine                                       | 1.03                                | 1.333                   | 0.693                   | 0.42                    | 3.88                            |
| Phenylalanine                                 | 0.40                                | 0.707                   | NR                      | 0.32                    | 3.42                            |
| Phenylalanine + tyrosine                      | 0.60                                | 1.172                   | NR                      | 0.32                    | 3.42                            |
| Histidine                                    | 0.20                                | 0.545                   | NR                      | 0.11                    | 1.58                            |
| Lysine                                        | 0.46                                | 0.808                   | 0.347                   | 0.43                    | 2.34                            |
| Arginine                                      | 0.67                                | 2.687                   | NR                      | 0.34                    | 7.83                            |
| Tryptophan                                    | 0.44                                | 0.222                   | 0.084                   | NR                      | 0.631                           |
| Glycine + serine                              | 1.04                                | 0.895                   | NR                      | 0.54                    | 4.98                            |
| Proline                                       | 1.11                                | NR                      | NR                      | 0.40                    | 3.38                            |
| Aspartic acid                                 | 1.76                                | NR                      | NR                      | 0.76                    | 4.45                            |
| Glutamic acid                                 | 1.28                                | NR                      | NR                      | 1.05                    | 10.58                           |

NR: not reported.

<sup>a</sup>Present sample.

<sup>b</sup>Heuzé et al. (2015).

<sup>c</sup>Tran (2015a).

<sup>d</sup>Marangoni and Alli (1988).

<sup>e</sup>Baião (1987).

Glycine only.
The digestibility of essential amino acids was found for arginine (88.6%), followed by leucine (79.9%) and lysine (72.4%). A similar range (21.1 to 62.8%) of amino acids digestibility has been reported by Mitaru et al. (1985).

The low apparent and true digestibility of WPPM glycine found in this study could be attributed to the involvement of glycine in uric acid synthesis and in different metabolic functions in poultry. Moreover, glycine represented 95% of amino nitrogen in biliary salts (Corring and Jung 1972; Sturkie 1986; Corzo et al. 2004). However, the negative effects of antinutritional factors, that found in WPPM, on diet utilisation cannot be ignored, which will be discussed below.

The negative effect of tannins on the nutritional values of feedstuffs for monogastric and ruminate animals was reported previously (Tan et al. 1983; Mitaru et al. 1985; Ortiz et al. 1993; Frutos et al. 2004).

### Table 6. Amino acids profile (as g/100 g) of crude protein as fed basis) of whole Prosopis pods meal as well as some feedstuffs as compared to broiler chickens requirements.

| Crude protein/amino acids profile, g/100 g | Whole Prosopis pods meal<sup>a</sup> | Wheat Bran<sup>b</sup> | Undehulled sunflower meal<sup>c</sup> | Broiler chickens requirements between 0 and 3 weeks<sup>ab</sup> |
|-------------------------------------------|-----------------------------------|------------------|---------------------------------|----------------------------------|
| Crude protein content                      | 15.2                              | 15.4             | 23.3                            | 23.0                             |
| Threonine                                  | 3.09                              | 3.25             | 4.51                            | 3.48                             |
| Valine                                     | 4.41                              | 4.55             | 6.87                            | 3.91                             |
| Methionine                                 | 0.79                              | 1.49             | 2.15                            | 2.17                             |
| Methionine + cystine                       | 1.97                              | 3.57             | 4.29                            | 3.91                             |
| Isoleucine                                 | 3.55                              | 3.05             | 4.29                            | 3.48                             |
| Leucine                                    | 6.78                              | 6.23             | 6.87                            | 5.22                             |
| Phenylalanine                              | 2.63                              | 3.96             | 4.94                            | 3.13                             |
| Phenylalanine + tyrosine                   | 3.95                              | 6.95             | NR                              | 5.83                             |
| Histidine                                  | 1.32                              | 2.99             | 2.36                            | 1.52                             |
| Lysine                                     | 3.03                              | 3.96             | 4.29                            | 4.78                             |
| Arginine                                   | 4.41                              | 6.62             | 9.87                            | 5.43                             |
| Tryptophan                                 | 2.89                              | 1.49             | 1.93                            | 0.87                             |
| Glycine + serine                           | 6.84                              | 9.61             | 4.30<sup>d</sup>               | 5.43                             |
| Proline                                    | 7.30                              | NR               | 4.51                            | 2.61                             |
| Total amino acids                          | 52.96                             | 57.72            | 61.18                           | 49.16                            |
| TAAF:TAAR ratio<sup>e</sup>                | 1.08                              | 1.17             | 1.24                            | 1.00                             |

NR: not reported.
<sup>a</sup>Present sample.
<sup>b</sup>NRC (1994), but all values of amino acids are presented as a ratio of protein. e.g. threonine and protein of WPPM (Table 5) are 0.47% and 15.2% respectively, (0.47/15.2 × 100 = 3.09).
<sup>c</sup>Serine only.
<sup>d</sup>TAA:TAAR: total amino acids in different feedstuffs to the total amino acids required for broiler chickens, and calculated by total amino acids of whole Prosopis pods divided by total amino acids of broiler requirements = 52.96/49.16 = 1.08.

### Table 7. Apparent and true amino acids digestibility, and apparent and true energy metabolisability of whole Prosopis pods meal.

| Items                          | Amino acids digestibility, % | Energy metabolisability (MJ/kg ±SD) |
|-------------------------------|------------------------------|-------------------------------------|
|                              | Apparent                     | True                               |
| Amino acids profile           |                              |                                     |
| Threonine                     | 26.1                         | 63.0                               |
| Valine                        | 40.1                         | 67.7                               |
| Methionine                    | 22.8                         | 60.1                               |
| Cystine                       | 5.6                          | 52.3                               |
| Isoleucine                    | 17.1                         | 58.6                               |
| Leucine                       | 56.5                         | 79.9                               |
| Phenylalanine                 | 30.5                         | 65.5                               |
| Tyrosine                      | 22.8                         | 41.0                               |
| Histidine                     | 34.4                         | 65.2                               |
| Lysine                        | 32.9                         | 72.4                               |
| Arginine                      | 67.7                         | 88.6                               |
| Tryptophan                    | 52.6                         | 57.7                               |
| Glycine                       | −14.3                        | 35.2                               |
| Serine                        | 30.2                         | 64.7                               |
| Proline                       | 70.8                         | 83.9                               |
| Aspartic acid                 | 68.9                         | 84.0                               |
| Glutamic acid                 | 44.5                         | 73.4                               |
| Alanine                       | 19.0                         | 55.9                               |
| Average                       | 34.9                         | 65.0                               |
| Energy metabolisability (MJ/kg ±SD) | 5.44 ± 0.234                 | 7.58 ± 0.179                       |

SD: stander deviation.

The involvement of glycine in uric acid synthesis and in different metabolic functions in poultry. Moreover, glycine represented 95% of amino nitrogen in biliary salts of pigs (Corring and Jung 1972; Sturkie 1986; Corzo et al. 2004). However, the negative effects of antinutritional factors, that found in WPPM, on diet utilisation cannot be ignored, which will be discussed below.

The negative effect of tannins on the nutritional values of feedstuffs for monogastric and ruminate animals was reported previously (Tan et al. 1983; Mitaru et al. 1985; Ortiz et al. 1993; Frutos et al. 2004).

### Energy metabolisability

Table 7 shows the values of apparent (AEM) and true (TEM) energy metabolisability of WPPM, i.e. 5.44 and 7.57 MJ/kg, respectively. These results indicate that the determined values of AEM and TEM represented 33.8 and 47.1% of WPPM gross energy (16.07 MJ/kg). In the literature, the gross energy of Prosopis pods for different species ranged from 10.52 to 19.35 MJ/kg (Marangoni and Alli 1988; Heuzé et al. 2015; Tran 2015a, 2015b). Of course, the higher value of TEM compared to that of AEM is resulted from the correction of endogenous losses.

So far, to the best of our knowledge, precise AEM and TEM values for WPPM have not been reported in the literature. However, it was clear that the energy metabolisability of WPPM is relatively low (5.44 MJ/kg) compared to that of other feedstuffs such as corn,
Table 8. Total protein efficiency of whole Prosopis pods meal.

| Measurements/chicken/day | Control     | WPPM        | SEM  | p value |
|--------------------------|-------------|-------------|------|---------|
| Body weight gain, g      | 79.5 a      | 67.5 b      | 3.95 | .01     |
| Feed intake, g           | 82.2        | 87.0        | 6.12 | .63     |
| Protein intake, g        | 14.9        | 15.6        | 1.1  | .66     |
| Total protein efficiency | 0.188 b     | 0.232 a     | 0.093| .001    |

a,bMeans within row not sharing a common superscript are significantly different (p > .05). SEM: standard error of mean, p value: probability level.

Protein quality

The protein quality assay clarified that the quality of WPPM protein is significantly lower (23.4%) than that of soybean meal (Table 8). These results confirmed the results of the amino acids digestibility (Table 7) and might be explained, as previously discussed, by the negative effects of high fibre (133.7%) and tannins (42.8 mg/g) in WPPM. Dietary fibres and their combination substances contain anti-nutritional substances, such as, lignin, pectin, mucilage, gum, phytic acid and tannins which are all adversely affect the utilisation of diet nutrients through two ways. Firstly, by binding with minerals, amino acids, protein and fat in the diet caused less absorption of these nutrients. Secondly, by increasing viscosity which prevents digestive tract enzymes action and, also, might reduce secretions of these enzymes. This, finally, leads to pass nutrients out with excreta (Mitaru et al. 1985; Talpada et al. 1989; Ortiz et al. 1993; NRC 1994; Almirall et al. 1995; Smits et al. 1998; AACC 2001; Choct 2006; Dida 2016).

Conclusions

The WPPM contains considerable amounts of energy and nutrients (protein, minerals, fatty acids and amino acids), although the protein quality was lower than that of soybean meal, and could be used as an alternative feedstuff for poultry production, specially, in tropical and sub-tropical regions where feed resources are generally limited.

Disclosure statement

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