Journal of Meat Science
Year 2026 (June), Volume-21, Issue-1

www.acspublisher.com

ISSN 0975-5209 (Print)
ISSN 2581-6616 (Online)

Effects of Feeding Differently Processed Karanj (*Pongamia pinnata*) Seed Meal on Digestibility and Carcass Characteristics of Broiler Chickens

Benisheikh Ali Adam[1], Mustapha Abdul[1, 3*], Igwebuike Joseph[2], Makinta Alhaji Ali[1], Marte Musa Ali[1], Sani Ibrahim[5], and Usman Muhammad Kolo[2].

[1]Department of Animal Production Technology, Ramat Polytechnic, Maiduguri, Borno State, Nigeria.
[2]Department of Animal Science, University of Maiduguri, Maiduguri, Borno State, Nigeria
[3]Halal Products Research Institute, Universiti Putra Malaysia, Putra Infoport, 43400 UPM, Serdang, Malaysia
[4]Laboratory of Sustainable Animal Production and Biodiversity, Institute of Tropical Agriculture and Food Security, Universiti Putra Malaysia (UPM), 43400 Serdang, Malaysia
[5]Department of Animal and Husbandry, Audu Bako College of Agriculture, Dambatta, Kano State, Nigeria

ARTICLE INFO

*Corresponding author:
*E-mailaddress: abdulmustapha2244@gmail.com

Received 2026-02-28; Accepted 2026-03-10

doi10.48165/jms.2026.21.01.8

ABSTRACT

The present study examined the effect of differently processed karanj (*Pongamia pinnata*) seed meal (KSM) on the digestibility and carcass characteristics of broiler chickens. Diets were formulated as T1 (0% KSM), T2 (5% of raw KSM), T3 (5% soaked KSM), T4 (5% KSM boiled for 30 minutes), T5 (5% KSM boiled for 60 minutes), and T6 (5% toasted KSM). A total of 240-day-old broiler chicks were allocated to the six treatments in groups (n=40) and fed on the formulated diets for 7 weeks. At the end of the experiment (7th week) Four birds from each treatment group were randomly selected and put into metabolism cages and served with the experimental diets. The carcass characteristics were recorded at the end of the experiment. The findings for nutrient digestibility indicate that the T2 group fed on raw KSM recorded the lowest values, whereas, apart from the control, T1 broilers fed on a diet without KSM, T6 recorded the highest digestibility values. The 60-minute boiling and toasting significantly improved the nutrient digestibility of KSM. The carcass characteristics revealed no significant (P>0.05) differences in bled weight, plucked weight, and dressed weight. The cut-up parts of broiler chickens fed KSM showed no significant (P>0.05) differences except for the drumstick, which significantly (P<0.05) differed from the other treatment groups. The findings of this study revealed that the processing methods used were effective in reducing the adverse effects of anti-nutritional factors in KSM.

Keywords: *Karanj seeds Meal (KSM), Pongamia pinnata, Broiler, Digestibility, Carcass characteristics*

INTRODUCTION

There has been a rapid increase in broiler production due to their wide acceptability across societies and cultures, desirable nutritive value, technological attributes of meat, feed conversion efficiency, all-in-all-out principle, and quick returns. (Kumar et al. 2012). Feed costs a major chunk of the overall production cost of broilers and may reach up to 60- 70% of the total cost, depending upon the production system, bird age, genetic makeup, environment, and other management factors. (Department of Statistics Malaysia, 2022; Mallick et al. 2020). Further, with the rapid outburst in the global population, there has been an increasing demand for poultry meat, consequently leading to a higher demand for feed for rearing birds. Food supply has been a serious problem in developing tropical countries and has resulted in competition for food between humans and animals.

With the challenges faced by the agriculture sector due to climate change and limited natural resources, it becomes quite challenging to ensure a regular supply of feed to poultry sustainably. The utilization of vast unconventional resources in animal feed could reduce pressure on crops (grains) that compete with humans and animals. (Alshelmani et al. 2021; Thirumalaisamy et al. 2016). With the escalating cost of feeds caused by the high cost of conventional feeds, it is imperative to look for alternatives to soya bean meal, one of the premium plant protein sources for poultry. Since soya bean meals are often expensive and in short supply, measures are often adapted to partially or completely replace them with alternative protein supplements to reduce the cost of production. (Kumar et al. 2023; Parrini et al. 2023). Thus, there is an urgent need to exploit some underutilized seeds that could replace the costly protein and energy feedstuffs. (Adegbenro et al. 2011). Therefore, the animal feed industry is searching for newer and alternative feed resources like karanj (*Pongamia pinata*) seed as animal feed.

Pongamia pinnata, popularly known as karanj or Indian beech, belongs to the family Leguminosae and is a medium-sized glabrous tree capable of growing under a wide range of agro-climatic conditions. Its seeds are a rich source of nutrients and functional ingredients. Its seeds are inefficiently used as manure for improving soil fertility, as a source of biofuel, and for the production of seedcakes. (Scott et al. 2008). However, its use in poultry feeding is limited due to the presence of antinutritional factors in it, such as karanjin (0.57-1.75%), trypsin inhibitors (790–1278 µg / g seed meal), and pongamol (0.25- 1.27%) (Kumar et al. 2011), which could limit feed intake, affect nutrient utilization, and growth performance (Woyengo et al. 2017).

These anti-nutritional factors, such as tannins and phytates, inhibit the activity of digestive enzymes, which consequently affect digestion and availability of nutrients, while some, such as tannins and phytates, bind to the nutrients and make them inaccessible to the digestive enzymes. (Soetan and Oyewole 2009). Various processing technologies, such as defatting (Kumar et al. 2011), fermentation, and hydrothermal processing (Zentek and Goodarzi Boroojeni 2020), soaking, milling, autoclaving, and germination (Samtiya et al. 2020) exerted a beneficial effect on nutrient digestibility by effectively reducing antinutritional factors.

Studies on the application of karanj seed meal prepared by different processing methods to reduce the antinutritional factors on growth performance and carcass characteristics in poultry are scarce. Thus, the present study was undertaken to evaluate the effect of karanj seed meal prepared by soaking, boiling, and roasting on the growth performance and carcass characteristics of broiler chickens.

MATERIALS AND METHODS

Animals and Experimental Design

The study was conducted at the Livestock Unit of the Teaching and Research Farm, Department of Animal Production Technology, Ramat Polytechnic, Maiduguri, Nigeria (latitude 11°5’ and 12^0 North, longitude 13°09’ and 14^0 East). The karanj seeds were obtained from *Pongamia pinnata* across the University of Maiduguri Campus. The seeds were divided into five batches as per Benisheikh et al. (2021). The first batch was left raw and untreated. The second batch was soaked in water for 24 h at room temperature, followed by decanting and sun drying for 3 days. The third and fourth batches of seeds were boiled for 30 and 60 min, respectively, followed by draining the water and sun drying. The fifth batch was toasted in a frying pan with ash until the development of the characteristic aroma of roasted beans.

A total of 240 day- old broiler chicks were purchased from Amo Hatchery, Jos, Nigeria, and brooded for two weeks on a commercial broiler starter diet and then fed the formulated/experimental starter diets from three to four weeks and experimental finisher diets from the fifth to the seventh week. The chicks were vaccinated against Gumboro disease at the second and fifth weeks of age and Newcastle disease at 3^{rd} week of age. Feeding and watering were given *ad libitum* throughout the experimental period. Experimental diets at the starter and finisher phases were formulated using locally procured feed ingredients to meet the recommended nutrients. (Benisheikh et al. 2021). Six starter and finisher diets were formulated with the same inclusion levels of 5% of karanj seed meal (KSM). The diets were designated as: T1 (control without KSM), T2 (5% raw KSM), T3 (5% KSM soaked in water for 24 h), T4 (5% KSM boiled for 30 min), T5 (5% KSM boiled for 60 min), and T6 (5% KSM toasted). The birds were allocated to the experimental diets in groups of 40 birds each in a completely randomized design (CRD).

Digestibility Trial

Four birds from each treatment group were randomly selected and put into metabolism cages and served with the experimental diets. Faecal samples were collected during this period, sun-dried, and stored for proximate analysis. During this time, the leftover feeds from each cage were collected and weighed daily to determine feed intake. The faecal and feed samples were subjected to chemical analysis using AOAC (2019) methods. The digestibility was calculated
as: Feed intake – Fecal output / Feed intake × 100

Carcass Analysis

Before the slaughter, the birds were fasted for 12 hours; only water was provided. The slaughter of the birds was conducted at the slaughter house of the farm. The birds were weighed and taken to the slaughtered house individually, held by the farm staff, and slaughtered by certified farm staff. The birds were slaughtered according to halal procedure by cutting both the jugular veins and the carotid artery with a sharp knife. Eight chickens from each treatment group were randomly selected and slaughtered. The slaughter weight, dressed carcass weight, dressing percentage, and weight of cut-up parts were weighed individually and expressed as a percentage (%) of the live weight, and were taken using a digital scale. The visceral organs, which include the gizzard, kidneys, lungs, heart, and liver, were weighed using a weighing balance (analytical), while the intestinal length was measured using the meter rule. The abdominal fat was also weighed.

Statistical Analysis

All data collected were subjected to the analysis of variance (ANOVA) using a completely randomized design. Significant differences between the treatment means were separated and compared using Duncan's Multiple Range Test. A computer package (Statistics 10.0) was used for the analysis.

RESULTS AND DISCUSSION

Nutrient digestibility KSM

The nutrient digestibility coefficients of broiler chickens fed differently processed karanj (*Pongamia pinnata)* seed meal are presented in Table 1. There were significant (P<0.05) differences in the dry matter (DM) digestibility among the treatment groups. The DM digestibility of the birds fed the control diet (0% KSM), 5% SKSM, 5 % B.30 M. KSM, and 5 % TKSM was significantly (P<0.05) superior to that of those fed 5 % RKSM and 5 % B.60 M. KSM.

With respect to crude protein (CP) and nitrogen-free extract (NFE) digestibility, birds fed 5 % RKSM and 5 % B. 60 M. KSM diets recorded the least values. Similarly, the crude fiber (CF) digestibility of the birds significantly (P<0.05) decreased in the RKSM and B. 60 M. KSM diet groups. The CF digestibility of the birds on control diets (0% KSM) and TKSM was superior to the other two groups (RKSM and B. 60 M KSM diets). The ether extract (EE) digestibility showed similar values in all the treatment groups except the birds fed the RKSM diet, which recorded the lowest value. The ash availability showed significant (P<0.05) differences among the treatment groups with birds fed control diet (0 % KSM), 5 % SKSM, and 5 % TKSM diets recording similar values. The least value is recorded in the 5 % RKSM group.

The digestibility of a feed determines the amount of the nutrient that is actually absorbed by an animal and, therefore, the availability of nutrients for growth and reproduction (Zewdie 2019). The detoxification methods did not affect the amino acid composition of KSM and improved the nutritive value of KSM (Vinay and Sindhu Kanya 2008). The above results indicate that the control diet (0% KSM) and 5 % TKSM recorded the highest digestibility values, while the lowest digestibility value was recorded in the RKSM diet. The poor digestibility of KSM prepared from raw seeds could be attributed to the effects of anti-nutritional substances such as tannins, protease inhibitors, phytates, trypsin inhibitors, and furano-flavonoids (glabrin and karanjin) in the RKSM diet (Vinay and Sindhu Kanya 2008; Kumar et al. 2011). These antinutritional factors inhibit the activities of enzymes and form insoluble complexes with proteins, thereby reducing their absorption in the body (Aguihe and Kehinde 2019). Improvement in the nutritive value of KSM was noticed upon various treatments such as water leaching, acid or alkali treatment, and defatting. Vinay and Sindhu Kanya (2008) observed a significant increase in the nutritive value of KSN by acid treatment due to a significant reduction in anti-nutritional factors, such as 81% reduction in phytate, 69% reduction in tannins, and 84% reduction in trypsin inhibitory activity.

Table 1. Nutrient digestibility of broiler chickens fed raw and differently processed karanj (*Pongamia pinnata*) seed meal

Nutrients	T1(0% KSM)	T2 (5%RKSM)	T3 (SKSM)	T4 (M. KSM)	T5 (M. KSM)	T6 (TKSM)	SEM
Dry Matter Digestibility	72.40^{a}	58.10^{c}	69.84^{ab}	68.26^{ab}	61.13^{bc}	70.49^{a}	3.14^{*}
Crude Protein Digestibility	79.80^{a}	65.55^{c}	77.40^{ab}	75.27^{ab}	70.23^{bc}	77.87^{a}	2.43^{*}
Crude Fibre Digestibility	51.36^{a}	33.85^{c}	46.64^{ab}	45.70^{ab}	36.68^{bc}	47.13^{a}	3.50^{*}
Ether Extract Digestibility	88.53^{a}	87.56^{b}	88.07^{a}	88.09^{a}	88.14^{a}	88.47^{a}	0.16^{*}
Ash Availability	62.85^{a}	42.89^{c}	53.30^{ab}	50.39^{bc}	46.29^{bc}	56.59^{ab}	3.53^{*}
Nitrogen-Free Extract Digestibility	91.77^{a}	86.05^{c}	91.13^{a}	89.09^{ab}	87.86^{bc}	90.710^{ab}	0.99^{*}

* = Significant (P < 0.05): SEM = Standard Error of Mean, a, b, c = Means within the same row bearing different superscripts differ significantly (P < 0.05), RKSM = Raw karanj seed meal, SKSM = Karanj seed meal Soaked for 24 h., B.30 M. KSM = Karanj seed meal Boiled for 30 minutes, B.60 M. KSM = Karanj seed meal Boiled for 60 minutes, TKSM = Toasted karanj seed meal.

Carcass characteristics

The results of carcass characteristics and organ measurements of broiler chickens fed differently processed karanj (*Pongamia pinnata*) seed meal are presented in Table 2. The results revealed no significant (P>0.05) differences in bled weight, plucked weight, dressed weight, and dressing percentage in all treatment groups, but live weight showed significant (P<0.05) differences among the treatment groups. The dressing percentage obtained in this study ranged from 72.89 to 79.93 %. The chickens were fed 5 % RKSM, which recorded the lowest value for dressing percentage (73.20 %). It could be the poor nutrient utilization poorly utilized by T2 broilers, consequently affecting their plucked weight, dressed weight, and dressing percentage. The T2 group (5 % RKSM) had a higher density of anti-nutritional factors such as tannins, trypsin inhibitors, and karanjin in KSM. A lower feed intake of broiler fed on 5% raw KSM was also reported by Benisheikh et al. (2021).

Table 2. Carcass characteristics of broiler chickens fed raw and differently processed karanj (*Pongamia pinnata)* seed meal experimental diets

Parameter	T1 (0 % KSM)	T2 (5 % RKSM)	T3 (5 % SKSM)	T4 (5% B.30KSM)	T5 (5% B. 60 KSM)	T6 (5 % TKSM)	SEM
Live weight (g)	1918.60[a]	1631.60[b]	1876.50[ab]	1647.80[b]	1704.00[ab]	1836.70[ab]	128.74*
Bled weight (g)	1767.10	1534.00	1753.40	1502.00	1555.00	1692.40	131.74[NS]
Plucked weight (g)	1610.90	1483.30	1651.00	1386.20	1489.00	1492.90	128.73[NS]
Dressed weight (g)	1471.40	1255.10	1367.90	1214.90	1362.00	1372.30	147.95[NS]
Dressing percentage	76.69	76.90	72.89	73.73	79.93	74.72	5.35[NS]
Components and organs expressed as % of live weight							
Head	3.87	3.62	3.58	4.26	4.24	3.62	0.60[NS]
Shanks	5.25	5.22	6.07	6.22	5.95	5.96	0.74[NS]
Thigh	11.69	11.09	13.35	11.01	12.77	10.93	1.44[NS]
Drumstick	10.15[b]	9.90[b]	13.21[a]	11.25[ab]	11.52[ab]	10.84[ab]	1.30*
Wings	9.68	9.15	10.49	9.94	9.93	9.41	1.16[NS]
Breast	22.05	22.09	25.84	20.13	24.34	21.13	3.10[NS]
Back	16.09	15.36	20.17	17.75	15.35	16.37	2.54[NS]
Neck	5.05	4.57	5.73	4.96	5.04	4.96	0.72[NS]
Liver	3.09	3.43	2.94	3.60	3.12	3.08	0.33[NS]
Heart	0.56[b]	0.610[ab]	0.75[ab]	0.83[a]	0.65[ab]	0.68[ab]	0.09*
Gizzard	4.21[b]	3.83[a]	5.44[a]	4.55[a]	4.42[b]	4.12[b]	0.61*
Proventiculus	0.80[bc]	1.07[ab]	1.20[a]	1.02[abc]	1.02[abc]	0.79[c]	0.09*
Crop	1.39[ab]	1.25[ab]	1.29[ab]	2.43[a]	1.13[b]	1.14[b]	0.41*
Intestine	11.08[ab]	9.80[ab]	11.62[a]	10.56[ab]	9.92[ab]	8.73[b]	8.94*
Caeca	1.08	1.13	1.67	1.22	1.04	1.17	0.55[NS]
Abdominal fat	1.65	1.43	2.02	0.99	1.68	1.72	0.41[NS]

* = Significant (P < 0.05): SEM = Standard Error of Means, a, b, c, d = Means within the same row bearing different superscripts differ significantly, RKSM = Raw karanj seed meal, SKSM = karanj seed meal Soaked for 24 h., B.30 M. KSM = Karanj seed meal Boiled for 30 minutes, B.60 M. KSM = Karanj seed meal Boiled for 60 minutes, TKSM = Toasted karanj seed meal, NS= not Significant (P > 0.05)

The cut-up parts of broiler chickens fed KSM showed no significant (P>0.05) differences except for the drumstick, which significantly (P<0.05) differed from the other treatment diets. Birds on the processed (SKSM) recorded higher values than the 0 % KSM and 5 % RKSM. The values of 10.93 – 13.35 % for thighs and 9.90 – 13.21 % for drumsticks in the present study are similar to the values of 10.10 – 12.04 % and 9.43 – 10.62 %, respectively, reported by Kwari et al. (2019) for thighs and drumsticks of broilers fed differently processed *Senna obtusifolia* seed meal, an alternative protein source. However, the back weight (15.35 – 20.17 %) recorded from this study is lower than the values (24.01 – 25.05 %) recorded in broilers fed on tiger nut meal as a dietary supplement (Agbabiaka et al. 2012).

Broiler chickens fed 5 % SKSM had the highest breast, back, neck, thighs, wings, and drumsticks, while broiler chickens fed 5 % RKSM recorded the lowest values of cut-up parts. This is in line with the lower weight and carcass yield of the group. The relative breast weight (20.13 – 25.84 %) was not significantly (P>0.05) different among all treatment groups. The values in this study are comparable to those of other workers (Agbabiaka et al. 2012).

The results of the organ weights showed significant ($P<0.05$) differences among treatment groups except for liver, which showed no significant ($P>0.05$) differences among the treatments. Broiler chickens fed (0% KSM) recorded the lowest heart weight, while the group fed T4 (B. 30 M KSM) recorded the highest value. The gizzard values (3.83 – 5.44%) obtained from this study were superior to the findings of Agbabiaka et al. (2012), who reported 2.92 – 2.94%. The gizzard weight increased significantly in the differently processed KSM. These findings are similar to the findings of Panda et al. (2008) who revealed that the gizzard weight also increased significantly due to the incorporation of karanj seed cake (KSC). The results of intestinal weight showed a significant ($P<0.05$) difference among the treatment groups. Broiler chickens fed KSM recorded similar intestinal weight, except 5 % TKSM, which recorded the lowest intestinal weight. The intestinal weight value (9.80 – 11.62%) obtained from the study was higher than the 6.00 – 7.70 % reported by Agbabiaka et al. (2012).

The impact of the dietary treatment on abdominal fat content (0.99 – 2.02 %) of the broiler chickens was similar in all treatments. The values recorded here, however, are lower than the 4.65 – 5.45 % reported by Kwari et al. (2019) for broiler chickens fed differently processed *Senna obtusifolia* seed meal in the same environment. This is an advantage since high abdominal fat is undesirable in finished broiler chickens.

CONCLUSION

The findings of this study indicated that the inclusion of 5 % toasted KSM has no adverse effects on the carcass characteristics of broiler chickens. Therefore, Poultry farmers are encouraged to use karanj seeds as an alternative source after processing them, especially by toasting, and incorporating them at levels not exceeding 5 % in poultry diets to reduce the cost of feeding broiler chickens.

COMPETING INTERESTS

The authors do not have any competing interests among themselves or others related to this research work.

ETHICS STATEMENT

All studies were conducted in accordance with the highest ethical standards of animal welfare, adhering strictly to national, or international animal care guidelines.

REFERENCES

Adegbenro M, Onibi GE, Agbede JO, Aletor VA, Aro SO and Adeyeye SA (2011). Evaluation of the nutrients and anti-nutritional factors in some under-utilized seeds. Proceedings of 16th Annual Conference of Animal Science Association of Nigeria: 96–98.

Agbabiaka LA, Madubuike FN and Esonu BO (2012). Performance, carcass, and organ weights of broiler finishers fed varying levels of tigernut (Cyperus esculentus L.) meal. British Journal of Poultry Science, 1(2): 11–17.

Aguihe PC and Kehinde AS (2019). Performance, haematology, and serum biochemistry of broiler chickens fed processed shea butter cake meal. Nigerian Journal of Animal Science, 21(2): 231–239.

Alshelmani MI, Abdalla EA, Kaka U and Basit MA (2021). Non-traditional feedstuffs as an alternative in poultry feed. Advances in Poultry Nutrition Research. IntechOpen.

AOAC (2019). Official methods of analysis, 21st edition. Association of Official Analytical Chemists, Washington DC.

Benisheikh AA, Marte AM, Jibrin TA and Mustapha A (2021). Performance of broiler chicks fed karanj seed (Pongamia pinnata). International Journal of Agricultural Science and Technology, 9(1): 1–7.

Department of Statistics Malaysia (2022). Report of special study on production cost of chicken and egg. Department of Statistics Malaysia.

Dinesh Kumar D, Rao SBN, Jash S, Elangovan AV and Hemalatha S (2011). Chemical composition and anti-nutritional factors in karanja (Pongamia pinnata) seed kernels and its in vitro evaluation. Indian Journal of Animal Sciences, 81(5): 478–483.

Kumar P, Sharma M, Abubakar AA, Hayat MN, Ahmed MA, Kaka U and Sazili AQ (2023). Soybean sustainability issues. Reference Module in Food Science. Elsevier.

Kumar S, Bhat ZF, Kumar P and Singh PK (2012). Effect of sex on carcass quality parameters of Vanaraja chicken. Indian Journal of Poultry Science, 47(3): 377–381.

Kwari ID, Medugu CI, Maisakala AA, Yoksa GA and Saleh B (2019). Growth performance and carcass characteristics of broiler chickens fed processed sickle pod seed meal. Nigerian Journal of Animal Science, 21(2): 272–281.

Mallick P, Muduli K, Biswal JN and Pumwa J (2020). Broiler poultry feed cost optimization using linear programming technique. Journal of Operations and Strategic Planning, 3(1): 31–57.

Panda AK, Sastry VRB and Mandal AB (2008). Growth and carcass characteristics in broiler chickens fed processed karanj cake. Journal of Poultry Science, 45(3): 199–205.

Parrini S, Aquilani C, Pugliese C, Bozzi R and Sirtori F (2023). Soybean replacement by alternative protein sources in pig nutrition and its effect on meat quality. Animals, 13(3): 494.

Samtiya M, Aluko RE and Dhewa T (2020). Plant food anti-nutritional factors and their reduction strategies. Food Production, Processing and Nutrition, 2(1): 6.

Scott PT, Pregelj L, Chen N, Hadler JS, Djordjevic MA and Gresshoff PM (2008). Pongamia pinnata: An untapped resource for the biofuels industry. BioEnergy Research, 1(1): 2–11.

Soetan KO and Oyewole OE (2009). Processing methods to reduce anti-nutritional factors in plant foods. African Journal of Food Science, 3(9): 223–232.

Thirumalaisamy G, Muralidharan J, Senthilkumar S, Hema Sayee R and Priyadharsini M (2016). Cost-effective feeding of poultry. International Journal of Science, Environment and Technology, 5(6): 3997–4005.

Vinay BJ and Sindhu Kanya TC (2008). Effect of detoxification on functional and nutritional quality of karanja seed meal. Food Chemistry, 106(1): 77–84.

Woyengo TA, Beltranena E and Zijlstra RT (2017). Effect of anti-nutritional factors of oilseed co-products on feed intake of pigs and poultry. Animal Feed Science and Technology, 233: 76–86.

Zentek J and Goodarzi Boroojeni F (2020). Biotechnological processing of poultry and pig feed and its impact. Animal Feed Science and Technology, 268: 114576.

Zewdie AK (2019). Methods of measuring feed digestibility: A review. EC Nutrition, 14(1): 68–74.