Roasted sesame hulls improve broiler performance without affecting carcass characteristics

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Abstract

An experiment was conducted to evaluate the effect of using graded levels of roasted sesame hulls (RSH) on growth performance and meat quality characteristics in broiler chickens. A total of 360 day-old Lohmann chicks were randomly allocated into 24 floor pens and raised over 42 days. One of four dietary treatments was assigned to each group of six pens in a completely randomized fashion. The chicks in the control group were fed a corn-soybean based diet (RSH-0), while the chicks in treatments two, three, and four were fed graded levels of RSH at 4% (RSH-4), 8% (RSH-8), and 12% (RSH-12), respectively. Diets were formulated to meet broiler chickens’ requirements according to the National Research Council for both starter and finisher rations. The results showed that RSH inclusion increased (P<0.05) feed intake and final body weight without adversely affecting the feed conversion ratio. Broiler chicks fed RSH-12 had heavier (P<0.05) breast and leg cuts compared to the control-fed group with no change in their chemical composition. Water holding capacity (WHC), cooking loss (CL), and shear force (SF) reported similar results in all dietary groups. The chemical composition of both thigh and breast cuts was not affected by the RSH. After one day of thawing, color coordinates of breast cuts behaved similarly in all dietary groups. The results of this study suggest that the addition of RSH to broiler diets up to 12% improves their growth performance; nevertheless, carcass characteristics and meat quality showed no alterations compared to the control-fed group.

Introduction

Sesame (Sesamum indicum L.) is an herbaceous annual plant belonging to the Pedaliaceae family and one of the world’s most important and oldest oilseed crops known to man (Sonntag, 1981). The chemical composition of sesame seeds is 48.3% oil, 20.8% protein, 13.5%, and 5.3% for oil, protein, carbohydrates, and ash, respectively (Kahyaoglu and Kaya, 2006), which shows the importance of these seeds as source of nutrients for humans. Mechanical oil extractions of intact seeds by a screw-pressed expeller produce bitter meal with low digestibility due to the presence of fibrous husks, which can be useful only in livestock feeding. However, the quality of this meal can be greatly improved by seed de-hulling before the pressing process.

In Jordan, the imported quantity of sesame grew from around 16,000 tons in 2007 to about 25,000 tons in 2013 (Ministry of Agriculture, 2007, 2013). Most of this was processed to make sesame paste called tehineh, a popular food in the Middle East that is also used for the manufacture of halaweh (sweetened tehineh), as described by Abou-Garbia et al. (2000). Whole sesame seeds are hulled using peeling machines to separate the sesame hulls (SH) from the seed. Usually, small and broken seeds escape the peeling process and stay in the de-hulled portion, comprising 15-17% of the original weight. Elleuch et al. (2007) described the stages of the by-product elimination during the preparation of the sesame paste. After water soaking, the majority of the SH by-products are collected by sieving the de-hulled seeds, while the rest of the SH are removed after the roasting stage (RSH). The chemical composition of RSH shows that it is important source of crude protein (25.8%), oil (17.6%), and metabolizable energy (3.92 kcal/g) (Obeidat and Aloqaily, 2010). Great discrepancies exist between the hulls collected after soaking (SH) compared to those collected after roasting (RSH). The RSH is a remarkable source of calcium, phosphorus, zinc, and iron, and contains higher percentages of dry matter, protein, and oil compared to SH (Elleuch et al., 2007) and is rich in sulphur-containing amino acids (Kapadia et al., 2002).

Due to the great jump in costs for conventional feeds and the chemical composition of RSH, we believe that RSH can be incorporated in broiler rations. However, the literature cites a limited number of research studies using either SH or sesame meal (SM) on broiler or layer (Cheva-Isarakul and Tangtaweewipat, 1993; Mampuut and Buhr, 1995; Farran et al., 2000), sheep (Obeidat et al., 2009; Obeidat and Aloqaily, 2010), or goat feeding trials (Obeidat and Gharaybeh, 2011). Cheva-Isarakul and Tangtaweewipat (1993) demonstrated that SM can be used at 13% in layer rations without adversely changing egg production, feed intake, body weight gain, and egg weight. However, Mampuut and Buhr (1995) reported depressed egg production variables in hens fed a diet containing 18% SM. Additionally, they also showed that the performance of broiler chicks decreased when fed a dietary level of SM beyond 7.5%. Farran et al. (2000) recommended that SH be used at levels not exceeding 8% in broiler diets and 14% in layer diets without adversely affecting the production parameters. In this trial, we propose using the RSH for the first time in broiler rations and hypothesize that it can be included at higher levels without adversely affecting growth performance, carcass characteristics, and meat quality.

Materials and methods

Animal and experimental procedure

A total of 360 one day-old broiler chicks (Lohmann) were randomly assigned to 24 floor pens located in a commercial open-sided poultry house and raised over 42 days. One of four dietary treatments was assigned to each group of six pens in a completely randomized fashion. The chicks in treatment one were fed a corn-soybean basal diet with no RSH (RSH-0), while the chicks in treatments two, three, and four were fed graded levels of RSH at 4% (RSH-4), 8% (RSH-8), and 12% (RSH-12), respectively. The respected RSH were included in both starter and finisher diets (Table 1), which
were formulated to satisfy the recommendations of the National Research Council (NRC, 1994). The poultry house was illuminated 23 h a day. Feed and water were provided *ad libitum* throughout the experimental period. Feed consumption (FC) and refusal were recorded daily and body weight gain (BWG) was measured weekly. The feed conversion ratio (FCR) was calculated as the ratio between total FC to daily gain (BWG).

The feed and water were provided *ad libitum* throughout the experimental period. The feed consumption (FC) and refusal were recorded daily and body weight gain (BWG) was measured weekly. The feed conversion ratio (FCR) was calculated as the ratio between total FC to final BWG. The chicks in all of the experimental groups were vaccinated against Newcastle and Infectious Bronchitis diseases at six days of age, and against the Infectious Bursal Disease at 14 days of age. At 42 days of age, two birds were randomly selected from each replication of each treatment (n=12 samples per treatment) and then slaughtered for meat quality, meat color coordinates, and chemical composition. The contents of dry matter (DM), crude protein (CP), and ether extract (EE) for breast and thigh muscles were analysed as outlined by AOAC (1990).

The live body weight (BW) was recorded after the birds had fasted for eight hours. Slaughtering was done by manual exsanguinations by severing both the carotid arteries and at least one jugular vein with a knife; the bleeding was continued for 120 s and the head and shanks were removed. After bleeding, the birds were scalped at 60°C for 120 s followed by defeathering in a rotary drum picker for 40 s and manually eviscerated. Then, the carcasses were washed internally and externally, and chilled for 40 min at 4°C in clean water. The carcass, breast, leg, and fat pad weights were measured and the dressing percentage was calculated using the carcass weight.

Meat quality measurements were performed on the *pectoralis major* muscle of the broiler breast. Right and left *pectoralis major* muscles were harvested from each carcass after chilling according to the procedure described by Abdullah et al. (2010). Briefly, carcasses were aged for 5 h on crushed ice before hand deboning at 6 h post-mortem. *Pectoralis major* samples were then placed on trays wrapped with plastic sheets and refrigerated at 3-6°C. At 24 h post-mortem, the left *pectoralis major* muscles were used for the measurement of cooking loss (CL) and Warner-Bratzler shear force (SF) values of cooked meat. Whereas the right *pectoralis major* muscles were used for colour coordinates, pH, and water holding capacity (WHC) measurements.

### Cooking loss determination

The left *pectoralis* muscles were weighed (initial weight) then placed in labelled polyethylene bags. The bags were placed in a thermostatically-controlled water bath and cooked for 25 min at 85°C to achieve the maximum internal temperature of 80°C. After cooking, the bags were brought to room temperature (23-24°C) before opening to drain the liquid, and then the cooked samples were dried with paper towels to remove excess surface moisture and re-weighed. CL was reported as the weight lost during cooking divided by the fresh sample weight and expressed as a percentage (Abdullah and Matarneh, 2010).

#### Shear force (tenderness)

Tenderness was measured according to Abdullah and Matarneh (2010). Briefly, within three hours of cooking, the dried samples from each of the left *pectoralis major* muscle were cut to obtain four cores (20 x 13 x 13 mm) of similar size parallel to a line beginning at the humoral insertion and ending at the point adjacent to the keel, and included the complete depth of each cooked muscle sample. Each core was sheared perpendicular to the longitudinal orientation of the muscle fibre using a Warner-Bratzler shear blade with the triangular slot cutting edge mounted on a Salter model 235 (Warner-Bratzler meat shear, G-R manufacturing co. 1317 Collins LN, Manhattan, Kansas).

### Table 1. Feed formulation and nutrient composition of roasted sesame hull experimental diets.

| Ingredients, g/kg | Starter ration 1 - 21 days | Finisher ration 22 - 42 days |
|-------------------|----------------------------|----------------------------|
|                   | RSH-0 | RSH-4 | RSH-8 | RSH-12 | RSH-0 | RSH-4 | RSH-8 | RSH-12 |
| Corn              | 589   | 576   | 579   | 561    | 658   | 639   | 641   | 627    |
| Soybean meal (44%)| 310   | 300   | 275   | 258    | 250   | 240   | 220   | 200    |
| Soybean oil       | 25    | 20    | 8     | 6      | 6     | 5     | 10    | 10     |
| Dicalcium phosphate| 11    | 11    | 11    | 11     | 7     | 7     | 7     | 8      |
| Limestone         | 14    | 8     | 2     | 0      | 14    | 8     | 2     | 0      |
| Fish meal         | 20    | 20    | 20    | 20     | 20    | 20    | 20    | 15     |
| Roasted sesame hulls| 0    | 40    | 80    | 120    | 0     | 40    | 80    | 120    |
| Poultry by-product meal | 25 | 20 | 20 | 20 | 20 | 20 | 15 | 15 |
| Methionine        | 0.5   | 0     | 0     | 0      | 0.5   | 0.5   | 0     | 0      |
| Lysine            | 0.5   | 0     | 0     | 0      | 0.5   | 0.5   | 0     | 0      |
| Mycofix®          | 1     | 1     | 1     | 1      | 1     | 1     | 1     | 1      |
| Mineral-vitamin®  | 1     | 1     | 1     | 1      | 1     | 1     | 1     | 1      |
| Salt              | 3     | 3     | 3     | 2      | 3     | 3     | 2.5   | 2.5    |

Chemical analysis

| ME, Kcal/kg | CP, % | Ca, % | Lysine, % | Meth. + Cys, % |
|-------------|-------|-------|-----------|---------------|
| 3050        | 21.5  | 0.44  | 1.08      | 0.72          |
| 3065        | 21.7  | 0.43  | 1.07      | 0.73          |
| 3025        | 21.8  | 0.43  | 1.08      | 0.78          |
| 3035        | 21.8  | 0.43  | 1.2       | 0.83          |
| 3125        | 19.4  | 0.35  | 0.96      | 0.67          |
| 3135        | 19.7  | 0.35  | 0.97      | 0.67          |
| 3140        | 19.6  | 0.33  | 0.96      | 0.72          |
| 3160        | 19.5  | 0.34  | 1.1       | 0.72          |

RSH, roasted sesame hull. RSH-0, -4, -8, and -12 refer to roasted sesame hulls at zero, 4%, 8%, and 12% respectively. **Provides per kg of diet: vitamin A acetate, 4500 U; DL-a-tocopherol acetate, 20 mg; riboflavin, 11.2 mg; Panthenolic acid, 14.5 mg; niacin, 25 mg; folic acid, 0.65 mg; vitamin B12, 0.15 mg; Ca, 140 mg; Cu, 40 mg; Fe, 82 mg; Mn, 215 mg; Se, 0.32 ppm; I, 5200 ppm; Zn, 144 mg. CP, crude protein: analysed. ME, metabolisable energy: calculated. AP, available phosphorus: calculated. Ca, calcium: calculated. Lysine: calculated. Meth + Cys, calculated.
Kansas, 66502, USA) to determine the peak force (kgf/cm²) when shearing the samples. SF was determined as the average of the maximum force of the four replicates from each pectoralis major muscle sample.

pH measurements

The pH values were determined in duplicate samples using the iodoacetate method as described by Jeacocke (1977) and Sams and Janky (1986). To measure pH values, 1-1.5 g of raw right muscles were put into a plastic test tube containing 10 ml of neutralized 5 mM iodoacetate reagent and 150 mM KCL, and homogenized using a homogenizer (Ultra-Turrax T8, IKA Labrotechnik, Janke & Kunkal GmbH & Co., Germany). The ultimate pH values of the homogenate were measured using a pH meter (pH paper, large screen, waterproof pH/temperature tester, double injection, model 35634-40, Eurotech Instruments, Malaysia).

Colour measurements

Instrumental colour measurements of raw right pectoralis muscles were measured 24 h post-mortem using a colorimeter (12MM Aperture U 59730-30, Cole-parameter International, Accuracy Microsensors, Inc. Pittsford, New York, USA), and calibrated throughout the study using a standard white ceramic reference (CIE L* = 97.91, a* = -0.68, b* = 2.45). The samples were placed on a tray, covered with wax paper to avoid surface drying. Random readings were taken from each sample at three different locations on the muscle surface that were adjacent to the skin, and in areas that were free of any noticeable colour defects, such as bruises or broken blood vessels. The three location readings were averaged, and the colour for each sample was expressed in terms of CIELAB (Commission International de l’Eclairage, 1976) brightness (L*), redness (a*), and yellowness (b*).

Water holding capacity

The water holding capacity of the pectoralis major muscles were estimated by measuring the amount of water released from the muscle protein by the application of force (expressible juice) and by the ability of muscle protein to retain water present in excess and under the influence of internal force (WHC). The WHC was measured according to the method described by Graw and Hamm (1953) and modified by Sañudo et al. (1986). Briefly, approximately 5 g of raw meat samples were cut into small pieces (initial weight). Then the sample meat pieces were covered with two filter papers (qualitative, 185 mm φ circles, fine crystalline retention, Whatman International Ltd, England), and two thin plates of quartz material were then pressed with a weight of 2,500 gm for 5 min. The meat samples were then removed from the filter paper and their weight was recorded (final weight). The difference in weight divided by the initial sample weight was reported as the WHC of the pectoralis major muscles.

Statistical analysis

The means of the pens’ performance and meat quality variables were analyzed as a completely randomized design to examine the effect of including RSH in poultry rations. The statistical analysis was achieved using the general linear model procedure (PROC GLM) of SAS (SAS Institute, 1994) by applying the following model: $Y_{ij} = \mu + \alpha_i + \epsilon_{ij}$, where $\mu$ is overall mean, $\alpha_i$ is the effect of RSH, and $\epsilon_{ij}$ is the residual error. Treatment means were compared using the least squares means option in PROC GLM. The differences among the means were declared significant at a P<0.05.

Results and discussion

The statistical inference for FC and BWG were similar among experimental treatments (Table 2). The inclusion of RSH in broiler diets increased (P<0.05) both FC and BWG compared to the basal (RSH-0) diet with no change in FCR. Feeding RSH-4 diet lifted both FC and BWG upwards when compared with birds fed on RSH-0 diet, but did not reach a significant level. However, FC and BWG were greater (P<0.05) when the birds were fed on RSH-8 and RSH-12 diets compared to RSH-0 diet. The efficiency of feed conversion remained within normal ranges among all of the experimental groups. The differences in dressing percent-ages remained within the normal range for one group. However, the dietary inclusion of RSH at 4% and 8% resulted in numerically higher weights of breast and leg cuts, but at 12%, the increase in weight was significant (P<0.05) compared to the control-fed group. The proximate chemical composition for tissues sampled from breast and thigh muscles is summarized in Table 3. Our results point out that breast and thigh tissues of broilers fed on control or RSH diets had similar levels of DM, CP, and EE.

Carcass WHC, CL, and SF from basal-diet fed chickens and RSH-fed chickens were comparable (Table 4). Chicks fed a basal diet tended to have a higher WHC and a lower CL, but these changes remained within the normal variation of the collected data in this study. The changes in colour coordinates (L*, a*, b*) and pH values 24 h after thawing are also summarized in Table 4. The results presented in this study also indicate that the inclusion of dietary RSH did not alter colour coordinates and pH scores. Colour lightness (L*) ranged between 53.3 and 55.9 with no statistical differences due to RSH.

Table 2. Means of cumulative performance and carcass parameters of chicken fed different levels of roasted sesame hulls inclusion through 42 days of life.

| Performance and carcass parameters | Roasted sesame hulls |
|-----------------------------------|---------------------|
|                                   | RSH-0              | RSH-4              | RSH-8              | RSH-12              | SEM    | P-Value |
| Cumulative feed consumption, g    | 3327a              | 3594a              | 3617a              | 3584a              | 79.8   | 0.006   |
| Body weight gain, g               | 1901b              | 1978b              | 2068a              | 2077a              | 50.8   | 0.001   |
| Feed conversion, %                | 1.75               | 1.77               | 1.75               | 1.73               | 0.03   | 0.141   |
| Dressing percentage, %            | 74.1               | 75.2               | 74.4               | 75.2               | 0.62   | 0.357   |
| Breast weight, g                  | 420a               | 456a               | 468a               | 485a               | 17.8   | 0.022   |
| Leg weight, g                     | 394a               | 422a               | 428a               | 436a               | 13.2   | 0.015   |
| Fat pad weight, g                 | 25                 | 26                 | 32                 | 31                 | 4.20   | 0.225   |

RSH, roasted sesame hull. RSH-0, -4, -8, and -12 refer to roasted sesame hulls at zero, 4%, 8%, and 12% respectively. a,b,cMeans with different superscripts within variable differ (P<0.05). Each value represents the mean of six replicates with two samples in each replicate.
inclusion. Similarly, the redness (a*) and yellowness (b*) of breast muscle were not altered due to RSH and registered values between 2.24 and 3.02 and 12.8 and 14.3; respectively. The pH values of breast muscles 24 h post-mortem also seemed not to be affected by RSH. The pH values of breast muscles collected from different dietary treatments ranged from 5.73 and 5.91.

The use of agro-industrial by-products has become a necessity in poultry feeding to cut down on production costs as major feed ingredient prices increase. In Jordan, a total of 3,750-4,500 tons of SH are produced annually, most of which is being drained into the sewer system and some is sold as a livestock feed (MOA, 2013). The high energy and protein levels in RSH maximize its added value in poultry rations. However, the high calcium content was a major constraint of setting the highest level of RSH in the starter and finisher rations; thus, broilers fed RSH-12 have no limestone added to the formulated diet (Table 1). In this study, we state that RSH scaled up FC and improved the BWG of broiler chickens without affecting the FCR. Both FC and BWG of the RSH-0 fed group and those fed on RSH-4 had similar results. However, when chickens were fed 8% and 12% RSH, their FC increased by 8.7% and 7.7%, respectively, which consequently improved BWG by 8.8%, and 9.3%, respectively. The dressing percentages of all dietary treatments were comparable to each other; however, birds fed RSH-12 reported an increase of 15%, and 11% in breast and leg cuts, respectively, compared to birds fed on the control diet. Although RSH positively altered growth performance and major carcass cuts, the chemical composition of both breast and leg muscles appeared not to be influenced by dietary RSH inclusion. Carcass composition was not significantly affected, in support of previous findings (Kamran et al., 2008) that show it is more difficult to modify carcass composition than to alter growth rate or efficiency. The mean pH of breast meat did not differ between broilers that were fed different levels of RSH and the control diet. In addition, no treatment had a significant incidence of pH values below 5.7. It has been found that pH is a potential indicator of meat exhibiting poor quality characteristics because rapid post-mortem pH decline can lead to protein denaturation, which may result in a pale colour and low WHC (Briskey and Wismer-Pedersen, 1961). According to Jones and Grey (1989) and Sams and Miles (1993), normal pH values at the end of the post-mortem process are between 5.60 and 5.80 and 5.78 to 5.86, respectively. Our data showed that at 24 h post-mortem, breast pH persisted within these values in broilers fed different dietary treatments. This indicates that there were no quality problems with the broiler meat independently of RSH inclusion. WHC, CL, and SF are quality parameters interrelated to meat tenderness, one of the most important sensory characteristics of meat, and were not altered by dietary RSH. SF values in conventional boned breast muscle were close to 6.0 kg/cm² (Papinaho and Fletcher, 1996; Souza et al., 2005). Considering these reference values, dietary

### Table 3. Effect of roasted sesame hulls inclusion on dry matter, crude protein, and ether extract percentages of broiler breast and thigh muscles at 42 days of age.

|                      | RSH-0 | RSH-4 | RSH-8 | RSH-12 | SEM  | P-Value |
|----------------------|-------|-------|-------|--------|------|---------|
| **Breast**           |       |       |       |        |      |         |
| Dry matter, %        | 24.6  | 24.9  | 24.6  | 24.6   | 0.11 | 0.163   |
| Crude protein, %     | 21.8  | 22.2  | 21.9  | 21.7   | 0.17 | 0.319   |
| Ether extract, %     | 0.70  | 0.86  | 0.91  | 0.72   | 0.08 | 0.201   |
| **Leg**              |       |       |       |        |      |         |
| Dry matter, %        | 24.6  | 24.6  | 24.6  | 24.5   | 0.34 | 0.601   |
| Crude protein, %     | 18.7  | 18.9  | 18.7  | 18.9   | 0.27 | 0.142   |
| Ether extract, %     | 4.1   | 5.2   | 4.0   | 4.0    | 0.56 | 0.425   |

RSH, roasted sesame hull. RSH-0, -4, -8, and -12 refer to roasted sesame hulls at zero, 4%, 8%, and 12% respectively. Each value represents the mean of six replicates with two samples in each replicate.

### Table 4. Effect of roasted sesame hulls inclusion on meat quality parameters and colour coordinates of broiler breast muscle at 42 days of age.

|                      | RSH-0 | RSH-4 | RSH-8 | RSH-12 | SEM  | P-Value |
|----------------------|-------|-------|-------|--------|------|---------|
| **Meat quality parameters** |       |       |       |        |      |         |
| WHC, %               | 22.80 | 22.05 | 20.54 | 23.05  | 2.01 | 0.820   |
| CL, %                | 24.14 | 36.57 | 26.03 | 23.58  | 6.63 | 0.362   |
| SF, kg/cm²           | 2.54  | 2.41  | 2.33  | 3.33   | 0.63 | 0.679   |
| pH                   | 5.76  | 5.91  | 5.73  | 5.84   | 0.05 | 0.297   |
| **Colour coordinates** |       |       |       |        |      |         |
| Lightness (L*)       | 53.3  | 54.5  | 55.9  | 53.8   | 1.70 | 0.489   |
| Redness (a*)         | 2.26  | 2.55  | 2.24  | 3.02   | 0.42 | 0.412   |
| Yellowness (b*)      | 14.3  | 12.8  | 13.9  | 14.24  | 0.30 | 0.584   |

WHC, water holding capacity; CL, cooking loss; SF, shear force; RSH, roasted sesame hull. RSH-0, -4, -8, and -12 refer to roasted sesame hulls at zero, 4%, 8%, and 12% respectively. Each value represents the mean of six replicates with two samples in each replicate.
RSH did not affect meat tenderness in the present study, since SF values were between 2.33 to 3.33 kg/cm². Meat colour alteration is closely related to meat quality and can be identified by objective colorimetric measurements from the CIELAB system, which determines the parameters L*, a*, and b* (lightness, redness, and yellowness) as described by Barbut (1993). The results presented in this study revealed that dietary inclusion of RSH did not cause alteration to any of the color coordinates. Previous studies have used L* as a measure to estimate the importance of the pale, pastel, and muddy color of broiler meat (Barbut, 1998; van Laack et al., 2000). Van Laack et al. (2000) reported that broiler meat appearing to be normal had L* values of 55 and those appearing to be pale had CIE L* values of 60, and stated that high L* values and low pH were indicative of broiler meat that was pale in colour with low WHC. The L* and mean pH values for control and other RSH fed groups after 24 hours of thawing in the current study were similar to values that have been reported by previous researchers as characteristics of normal broiler meat at 24 hours post-mortem (Barbut, 1998; Woeielf et al., 2002).

As no studies interrelated to the use of RSH in monogastric feeding trials could be found in the available literature, the current results will be compared to SH or SM. The results reported in our study are not in harmony with the related literature of SH and SM researches. The general trend in the previous SH and SM studies revealed that layer hens tolerated higher levels of SH (Farran et al., 2000) and SM (Cheva-Isarakul and Tangtaweewipat, 1993; Mamputu and Buhr, 1995), without adversely deviating from their control groups counterparts. However, broiler birds fed SH at a 6-12% dietary level showed depressed weight gain and increased FC (Farran et al., 2000). Other studies reported that SM incorporation above 7.5% in the broiler diet reduced feed intake, BWG, and feed conversion during the first three weeks of age. In a recent study, broiler starter, grower, and finisher diets were formulated with increasing levels of SM, and yet a lower body weight and feed conversion efficiency were recorded (Rahimian et al., 2013). The effect of SM on growth performance and the histological intestinal alteration of layer chickens was evaluated by Yamauchi et al. (2006). They concluded that SM would have no detrimental effect on the growth performance with up to 20% dietary SM, nor on the intestinal villi with up to 30% dietary SM, but hypertrophy was observed in the epithelial cells of birds fed up to 20% dietary SM. They concluded that up to 20% SM could be incorporated into diets of male birds fed under commercial conditions of laying strains in the developer period.

It appears that the nutritional efficacy of sesame seed by-products depends on its anti-nutritional factors such as phytate, oxalate, and tannins. The phytate level may have contributed to the lower performance reports in SH and SM researches. The level of phytate was estimated to be 5.18% in SM (Mega et al., 1982) and 1.12% in SH (Farren et al., 2000). It has been reported that a high level of phytates depressed feed and protein conversion in salmon (Richardson et al., 1985), decreased protein digestibility in common carp (Hossain and Jauncey, 1989), and increased the calcium requirement of broiler chicks (Farkvam et al., 1989). Furthermore, phytate decreases the bioavailability of proteins and essential elements such as Ca, Mg, Zn, Fe, and P by forming insoluble complexes, which are not readily absorbed by the gastrointestinal tract (Akande et al., 2010; Agbaire and Emoyan, 2012). The high content of oxalate (13%) in SH, as reported by Farren et al. (2000), may have contributed to the poor performance reported in broilers and layers by reducing Ca bioavailability (Ward et al., 1982). Oxalates interfere with magnesium metabolism and react with proteins to form complexes, which have an inhibitory effect in peptic digestion (Akande et al., 2010). Jacob et al. (1996) reported that SM contains 2.15% of tannins, which may also contribute to the poor performance reported in the literature, since tannins interfere with nutrient digestion by binding the protein in feed. Tannins are water-soluble phenolic compounds that chelate Fe and Zn and limit the absorption of these nutrients (Akande et al., 2010), which may precipitate proteins from an aqueous solution by inhibiting digestive enzymes. They have been found to interfere with digestion by displaying anti-trypsin and anti-amylase activity (Soetan and Oyewole, 2009). We believe the discrepancy between the performance results of our study and those in the related literature stems from the differences between SH and SM versus RSH. The chemical composition, functional properties, antioxidant activity, and the physicochemical characteristics of RSH might explain the reported improvement in broiler performance. Chang et al. (2002) reported that SH has significantly higher antioxidant components compared to sesame seed. Also, the industrial processing effect on physicochemical characteristics of sesame seed and its by-products were extensively researched by Elleuch et al. (2007), who found that roasting considerably improves SH physicochemical characteristics without changing its fatty acid composition. It also increases the total phenolic content, radical scavenging activity, reducing power, and antioxidant activity of SH (Elleuch et al., 2007); for example, the polyphenol content of RSH (260 mg/100 g) was higher than that of raw seed (87 mg/100 g). This can be explained by the fact that polyphenols are compounds associated with dietary fibre (Larrauri et al., 1996). Sesamol is a potent phenolic antioxidant (Yoshida and Takagi, 1997), increasing from 8 mg/kg in raw sesame seed to 22 mg/kg in SH; however, the RSH content jumped to 54 mg/kg (Elleuch et al., 2007). The abrupt increase in sesamol is explained by the conversion of sesamolin to sesamol, which occurs during roasting (Yoshida and Takagi, 1997). They also reported that sesamol is an effective stabilizing substrate for oil and has a synergistic action with tocopherol.

Conclusions

The presence of anti-nutritional factors in SH affects some nutrient bioavailability and may limit its usefulness as a feed ingredient. We believe that roasting was effective in degrading much of these anti-nutritional factors (Udousoro et al., 2013), and thus made SH a more valuable feed ingredient. Also, RSH is a good source of CP and fat with increased functional properties, as clearly illustrated in the searched literature that the antioxidant properties of RSH are considerably higher in polyphenolic compounds than antioxidant activity compared to raw SH. Therefore, it should be safe to conclude that RSH can improve broiler performance without altering meat composition or quality.

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