Effect of *Jatropha curcas* seed meal inclusions in the diet of Lohmann Brown Layers on egg production and its quality

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Abstract: *Most of the protein source feedstuffs for poultry like soybean and soybean meal are expensive. Thus alternative and cheaper non-conventional feedstuffs should be assessed in order to broaden sources of ingredients. Jatropha curcas seed meal is one of the non-conventional feed ingredients that can be used for poultry feed. Therefore, the objectives of this study were to investigate the effect of dietary inclusion of treated and untreated Jatropha seed meal on feed intake, feed conversion ratio, egg production and egg quality traits. A feeding trial was carried out for eight weeks at Hawassa University, with 250 Lohmann Brown commercial layers (42 weeks old). Chicken were allotted to five treatment diets replicated five times with 10 hens per replication in a completely randomized design. The control treatment (T1) represents the standard poultry feed that contained 42% white maize, 15% wheat bran, 7% noug cake, 25% soybean, 4% bone and meat meal, 4% limestone, 2.5% Premix and 0.5% salt. In the treatments T2 to T5, 5% of soybean seed in T1 was replaced by 1.25% untreated and treated Jatropha seed meal where T2, T3, T4 and T5 contained untreated, heat-treated, NaOH-treated and T5 yeast treated Jatropha seed meal, respectively. There were significant variations in daily feed intake, food conversion rate, hen-day egg production, hen-housed egg production and mortality among treatment groups. Chicken receiving T2 had reduced daily feed intake compared to hens that were fed on all other diets ($p<0.05$). Chickens reared under T1 had lower values of food conversion rate and mortality than chickens kept on all other diets ($p<0.05$). There was no significant differences among all treatment groups in egg shape index, egg weight and shell thickness. Substituting 5% soybean with untreated jatropha seed meal influences most of the tested parameters in the present study. On the other hand, the replacement of 5% quantity of soybean with treated jatropha seed meal had no effects on hen-daily egg production, hen-house egg production, Egg shape index, Egg weight, Shell thickness, Albumin height, Yolk height, Yolk weight and Haugh Unit compared to the standard poultry diet (T1). Accordingly, 1.25% heat, NaOH and yeast-treated jatropha seed meal could be used to replace 5% of the soybean seed in the Lohmann Brown layers diet.*

Keywords: Dietary feed intake, Egg production, Egg quality, Jatropha seed meal

1. Introduction

Feed ingredients used in poultry production in Ethiopia are cereal grains, protein-rich oil seed cake (meal) and meat & bone meal. Most of the protein source feedstuffs like soybean and soybean meal are expensive. Thus, alternative and cheaper feedstuffs should be assessed in order to broaden sources of ingredients for the poultry feed industry (Annongu *et al*., 2010). Jatropha curcas seed meal is one of the non-conventional feed ingredients that may have the potential for both nutritional and medicinal uses (Goel *et al*., 2007).

Jatropha curcas, commonly known as physic nut, belongs to the euphorbiaceous family and is cultivated primarily for bio-fuel production (Barros *et al*., 2015). It grows quickly and survives in poor stony soil, is resistant to drought and disease, and can be grown on marginal agricultural land where no irrigation facility is available. Jatropha curcas seed meal is produced after the shells have been removed and has high nutritive value. The protein content of detoxified jatropha kernel meal 665g/kg was better than soybean meal 471g/kg and has a great potential to complement and substitute soybean meal as a protein source in livestock diets as it was reported by (Kumar *et al*., 2010).

However, Jatropha seed meal contains anti-nutritive compounds, such as lectin, trypsin inhibitor (anti-trypsin), saponin, phytate, and phorbol esters (Makkar and Becker, 1998). Of all

the compounds, phorbol ester is considered as the most toxic compound. Anti-nutritional factors are harmful to humans and animals and limit the nutrient availability. Therefore, inactivation of such ingredients may be necessary to avoid damages.

The removal of phorbol esters would transform the Jatropha meal into a highly nutritious and high-value feed ingredient for monogastric, fish, and ruminants (Hass and Mittelbach, 2000). According to Martinez-Herrera *et al*. (2006) the meal could be detoxified and the residual protein-rich seed cake or meal, remaining after extraction of the oil, could form a protein-rich ingredient in feeds for poultry, pigs, cattle and even fish.

The nutrient compositions of ingredients in the ration of poultry affect the egg production performances and internal and external egg qualities. When nutrients are in excess and deficient in the ratio it affects and interferes with the absorption of other nutrients and causes deficiency disease. Calcium deficiency will lead to a weaker eggshell with a decrease in eggshell weight and eggshell strength (Bar *et al*., 2002). Eggs are one of the most important sources of animal proteins. Eggs are used in various food industries to produce different products, cosmetics and vaccines (Oluyemi and Roberts, 2007).

As egg is used for various purposes including for consumption in human diets quality means different for many people. Egg quality is a general term that refers to several standards, which define both internal and external qualities. Kramer (1951) defined quality as "the sum of characteristics of a given food item which influence the acceptability or preference for that food by the consumer". Evaluation of the internal and external qualities of a chicken egg is an important index in commercial egg production (Parmer *et al*., 2006).

Consumers are concerned about its quality, especially the yolk color. The quality of egg could be affected by many factors such as dietary nutrients, environmental factors, and diseases. Dietary nutrients like vitamin A and minerals influence both internal and external egg quality.

Earlier work shows that jatropha seed meal treated with 4% sodium hydroxide and heat achieved the best-reduced percentage of phytic acid and there was no reduction in body weight gain in comparison to the control groups of rats (Nabil *et al.*, 2011). The heat treatment in combination with the chemical treatment of sodium hydroxide and sodium hypochlorite has also been reported to decrease the phorbol ester level in Jatropha seed meal to 75% (Goel *et al*., 2007).

However, there is little information regarding the effect of feeding jatropha seed meal on egg production performance and egg quality traits in layer hens in Ethiopia. Therefore, the aim of this research was to investigate the effect of Jatropha seed meal on egg production performance and internal and external egg quality of the Lohmann Brown chicken breed.

2. Materials and Methods

2.1. Description of the study area

The study was carried out at the poultry farm of the School of Animal and Range Sciences, Hawassa University, Hawassa, Ethiopia, which lies between 7° 5′ N latitude and 38°29′ E longitude. Hawassa lies at an altitude of 1650 m above sea level having an average rainfall ranging from 700 mm to 1200 mm. The mean minimum and maximum temperatures in the area are 13.5 °C and 27.6 °C, respectively (NMA, 2013).

2.2. Feeding trial

2.2.1. *Experimental treatments and design*

The diet was prepared out of white maize, wheat bran, soybean (roasted), noug cake (*Guizotia abyssinica*) meal, bone & meat meal, and from untreated, physically treated, chemically treated and biologically (Baker's yeast) treated jatropha seed meal (JSM), limestone, salt, and vitamin/mineral premixes.

Five treatments, which contain different feed mixes, were used in the present study (Table 1). The first feed mix (T1 = control) was the standard diet in the poultry farm of the School of Animal and Range Sciences at Hawassa University In the second, third, fourth and fifth diets 5% of soybean in the treatment one (T1) was replaced by 1.25% of untreated, heat treated, sodium hydroxide treated and Baker's yeast treated (24 hours fermented) JSM. The treatments were replicated five times and ten hens were randomly assigned to each treatment in a completely randomized design. The diets used in the present experiment were prepared at Hawassa University, College of Agriculture feed processing unit and formulated using FeedWin

InterActive vo. 24 computer software packages from Holland.

2.2.2. *Experimental animals and feeding management*

The experiment was conducted for eight weeks using 250 hens from Lohmann brown commercial layers, which were purchased from Debre Zeit Alema poultry farm (Ethiopia). The hens were reared in a deep-litter house system for eight months by feeding them with the standard feed (T1) in Hawassa University College's poultry farm.

The pullets were fed commercial grower diets in the company before they were brought to the university farm. After the 8th month of age (three months after they started laying eggs) the chicken was shifted to the experimental pens. They were allotted into five treatment diets, in which 5% of soybean in the control diet was replaced by 1.25% untreated, heat, NaOH and yeast (Baker's yeast) treated jatropha seed meal in treatments 2, 3, 4, and 5, respectively (Table 1). Chicken were fed ad-libtum daily at a refusal rate of not less than 10%. Feed was offered twice a day at 8:00 AM and 4:00 PM. The refusal was collected daily in the morning before the feed was offered. Feed offered and refusals were recorded daily.

Table 1: Proportion of the experimental diets used in the study

Ingredients (%)	Treatment diets				
	T1	T2	T3	T4	T5
White maize	42	42	42	42	42
Wheat bran	15	15	15	15	15
Noug cake	7	7	7	7	7
Soy bean (roasted)	25	23.75	23.75	23.75	23.75
Bone & meat meal	4	4	4	4	4
JSM	------	1.25	1.25	1.25	1.25
Limestone	4	4	4	4	4
*Premix	2.5	2.5	2.5	2.5	2.5
Salt	0.5	0.5	0.5	0.5	0.5
	100	100	100	100	100
Calculated nutritional composition					
Crude protein	18.7	18.75	18.7	18.6	18.7
Crude fiber	5.22	5.45	5.5	5.56	5.57
Crude fat	7.97	7.86	7.85	7.76	7.85
ME(kcal/kg DM)	3202.6	3177.94	3173.53	3164.63	3166.12
Calcium	2.37	2.37	2.37	2.37	2.37
Available phosphorous	0.64	0.64	0.64	0.64	0.64

DM= Dry matter, ME= metabolizable energy, T1 = control (42% white maize + 15% wheat bran + 7% noug cake + 25% soybean + 4% bone and meat meal + 4% limestone +2.5% Premix+ 0.5% salt), 5% of soybean seed in T1 was replaced by 1.25% untreated (T2), heat treated (T3), NaOH treated (T4) and yeast treated (T5) Jatropha seed meal

2.3. Data on feed consumption

The chicken feed consumption and feed conversion ratio was computed. Feed intake was determined by subtracting the weight of feed refused from that of feed offered for each replication and the average was taken for the group. The feed conversion ratio was determined as the ratio of the amount of feed consumed per kg of an egg. Mortality was recorded as it occurred. Chickens were offered tap water free of choice and water was changed daily. Chickens were reared in deep litter pens placed in ventilated and aerated rooms. A laying box was provided in each replication in which one box was for seven layers.

2.4. Egg production performance

Eggs were collected daily at 1400 h and 1600 h. Broken eggs were recorded in each replication. The cumulative average egg production percentage was calculated every week for eight weeks of

production starting from the 21th week of production until the 28th week's production period (42 weeks to 49 weeks of age).

The laying percentage of the hens was estimated as hen-day egg production (HDEP) and hen-housed egg production (HHEP) using the formulas below as indicated by North (1984.

$$HDEP\ (\%) = \left(\frac{\text{Total egg laid}}{\text{No. alive birds x No. days in laying period}}\right) x\ 100 \quad [1]$$

$$HHEP\ (\%) = \left(\frac{\text{Total egg laid}}{\text{No. birds initialy housed x No. days in laying period}}\right) x\ 100 \quad [2]$$

$$FCR = \frac{\text{Amount of feed consumed}}{kg\ of\ egg} \quad [3]$$

2.5. Egg quality

2.5.1. *External quality*

External quality traits were evaluated at the end of every week for eight weeks from the 21st week of production to the 28th week's production period. A total of 50 eggs two from each replication were randomly selected at each evaluation period. Egg weight, Egg mass (number of eggs times average egg weight), egg shape, and eggshell were assessed to look into the external quality of the five treatment groups. Eggs were marked using a pencil and weighed using a battery-operated electronic digital balance. The average egg weight was considered from the replications.

Egg shape index: The shape index was expressed as the ratio of the width to the length of the egg. The length (mm) and width (breadth) (mm) of each egg were measured using a digital caliper meter and the egg shape index was calculated using the following formula by Anderson *et al*. (2004).

$$Egg\ shape\ index\ (\%) = \left(\frac{egg\ width(mm)}{egg\ length(mm)}\right) x100 \quad [4]$$

Eggshell thickness: The shell was broken and cleaned using tissue paper. The removed shell membrane was air dried at room temperature. After drying, three pieces of shells were taken from the narrow side (sharp end), the middle side (equatorial region), and the broad end side (blunt end). Each piece shell was measured using a digital caliper meter. An average shell thickness of three pieces was then calculated.

2.5.2. *Internal quality*

Haugh Unit: After completing measuring the external characters, the egg was broken out on a glass surface to measure the albumen and yolk heights. The height of the thick albumin and yolk were measured using an Ames tripod stand micrometer as described by Haugh, (1937). The height of the thick albumen was measured on the moth sides opposite to the chalazae then the average was taken. Haugh Unit was calculated as the ratio between egg weight and albumen height (mm) following the formula below (Haugh, 1937).

$$HU = 100 \log(AH + 7.57 - 1.7EW) \quad [5]$$

Where

- AH = Albumen height in mm
- EW = egg weight in grams7.57 and 1.7 are correction factors

Yolk index: The yolk index was expressed as the ratio of yolk height to yolk diameter. The measurement was done after the egg was broken on a glass surface using an Ames tripod stand micrometer as described by Haugh (1937). The height of the yolk was determined by measuring the distance between the glass plate and the top of the yolk. The yolk diameter was measured horizontally by a digital caliper meter. The yolk index was then calculated using the following formula.

$$Yolk\ index = \frac{Yolk\ height\ (mm)}{Yolk\ diameter(mm)} \quad [6]$$

Yolk and albumen weight: The yolk was carefully separated from the albumen and placed in two different Petri dishes. Both Petri dishes used in weighing the egg contents were initially weighed and the difference in the weights of the petri dish after and before the egg component was taken as the weight of the egg components. After each weighing, the Petri dishes were washed in clean water and wiped dry before the next weighing.

Yolk color: The yolk color was determined using a Roche color fan (RCF) using 1 to 16 scale where 1 = very pale and 16 = deep orange (Ashton and Fletcher, 1962).

2.6. Statistical analysis

The data collected on egg production, egg weight, and internal and external egg quality was analyzed using General Linear Models Procedure (SAS

Institute, 2002, ver. 9.2). Mean separation was performed using Multiple Range test (Duncan, 1955).

Single-factor ANOVA model was used to evaluate the effect of JSM on egg production (number of eggs, rate of laying (Hen-day egg production (HDEP), Hen-housed egg production (HHEP)), and internal and external egg quality.

3. Results and Discussion

3.1. Feed consumption and Production performance

The effect of JSM on daily feed intake (DFI) and egg production performance is presented in Table 2. Chicken that fed with T1 (control) had higher ($p<0.05$) DFI than chicken that fed with treated and untreated JSM. Chicken that fed on the T2 diet (untreated JSM) had lower DFI than chickens that fed on T3 T4, and T5, which were statistically similar when compared to each other ($p>0.05$). The possible reasons for higher DFI in the standard diet compared to other diets could be associated with the anti-nutritional elements present in diets that affect palatability. A combination of the negative effect of anti-nutritive and toxic compounds in the diet decreased feed consumption which then inhibited chicken growth (Barros *et al*., 2015). The concentration of 0.13 mg/g phorbol esters present in the Jatropha curcas has been reported as having a significant adverse effect on food intake and growth rate of rats (Aregheore *et al*., 2003). The decrease in DFI in chicken receiving the rations with JSM in the current study is in line with the work of Sumiati *et al*. (2012) who reported that feeding fermented 7.5% Jatropha curcas meal decreased the feed consumption of the laying hen.

The food conversion rate (FCR) of the hen was influenced by the treatment groups. Accordingly chicken reared using the control diet (T1) had lower FCR than chicken kept on treated and untreated JSM ($p<0.05$). The results revealed that chickens that fed on T2 had higher ($p<0.05$) FCR than chickens receiving T4 and T1 diets. No significant difference in FCR was observed between chicken getting T3 and T5 experimental diets. The reason for a decrease in FCR in the control and an increase in other diets with treated and untreated JSM could be associated with better nutrient utilization in the control and poor utilization of JSM due to the anti-nutritional elements and toxic substance (Tiurma *et al*., 2010).

Mortality was also influenced by the diet groups used in the present study (Table 2). A higher mortality rate was recorded in chicken that fed on diets containing treated and untreated JSM than the control diet. Chicken that fed on T5 had the highest mortality percentage of 5% compared to other experimental diet groups ($p<0.05$), while the chicken in the control ratio had the lowest mortality percentage 1.25%. The reason for high mortality rate of hens that fed on rations containing untreated and treated JSM could be due to the toxic substances found in jatropha. Ojediran *et al.* (2014) reported a high mortality rate ranging from 43.3 to 83.3% in broilers that fed on both treated and untreated JSM. In this study, mortality has occurred only during the first three weeks of the experimental period and there was no mortality afterward. This could be partly associated with the change of environment related to the house.

Table 2: Daily feed intake, feed conversion ratio, and egg production of Lohmann brown commercial layers as influenced by jatropha seed meal

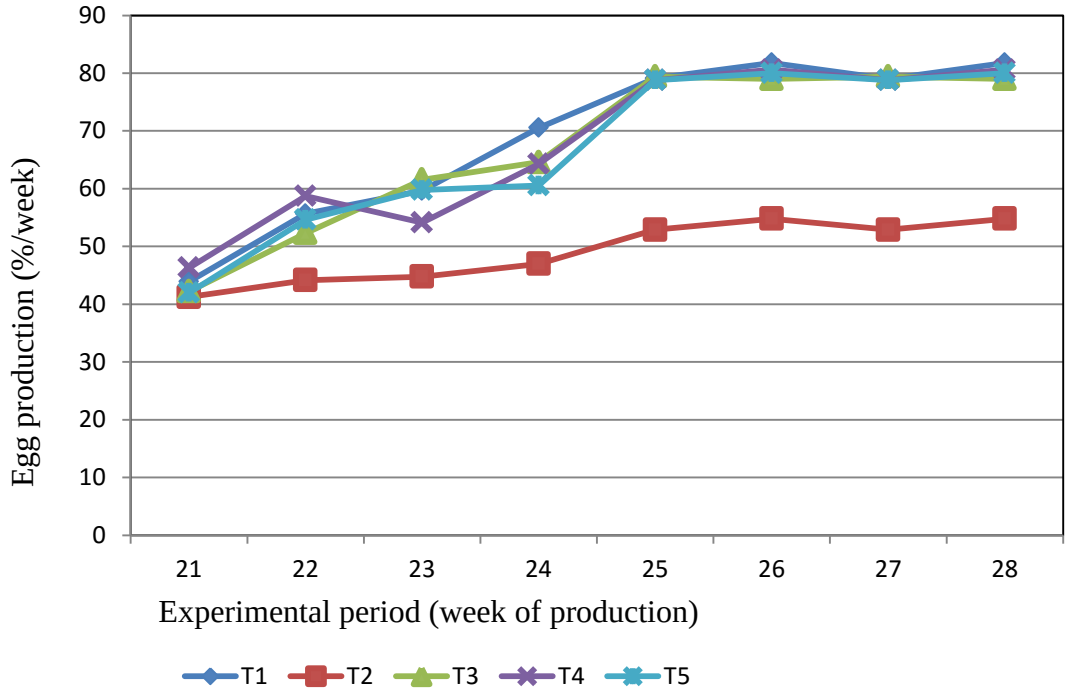
Performance	Treatments						
	T1	T2	T3	T4	T5	SEM	P-value
DFI g/b/d	122^{a}	116^{c}	120^{b}	120^{b}	120^{b}	0.297	0.0001
FCR	3.4^{d}	4.6^{a}	4.4^{b}	4.1^{c}	4.3^{b}	0.046	0.0001
HDEP (%)	69.4^{a}	49.0^{b}	67.2^{a}	67.8^{a}	66.8^{a}	1.05	0.0001
HHEP (%)	61.7^{a}	45.3^{b}	61.0^{a}	62.0^{a}	61.0^{a}	0.97	0.0001
Mortality (%)	1.25^{d}	2.50^{c}	3.75^{b}	3.75^{b}	5.0^{a}	0.33	0.0001

Row means with different superscript letters differ significantly at $p< 0.05$. SEM = standard error of the mean, T1 = control (42% white maize + 15% wheat bran + 7% noug cake + 25% soybean + 4% bone and meat meal + 4% limestone +2.5% premix + 0.5% salt), 5% of soybean seed in T1 was replaced by 1.25% untreated (T2), heat treated (T3), NaOH treated (T4) and yeast treated (T5) Jatropha seed meal; DFI = Daily feed intake, FCR = feed conversion ratio, HDEP = hen day egg production, HHEP = hen housed egg production

The trend of egg production during the experimental period is presented in Figure 1 below. Chicken that fed on T4 showed an irregular pattern of HDEP in which there was a decrease in egg production from the 22nd week to the 23rd week of production and went up from the 24th week of production. Chickens on T2 showed a smaller increment of egg production up to the 26th week of production and slightly dropped from the 26th week of production to 27th and then showed an increment at a lower rate compared to other treatments. Except for hens fed on the T2 diet the 26th week of production was the pick production period with values of 81.8, 80.6, and 80% for T1, T4, T3, and T5 respectively.

The values of HDEP and HHEP were low for hens getting T2 than the control and other treatment diets because of the low feed intake due to the anti-nutritional element that could affect protein consumption.

The result of HDEP in the current study is comparable to the work earlier reported by Fasuyi *et al.* (2007); but higher than the earlier finding by Sumiati *et al.* (2012).



T1 = control (42% white maize + 15% wheat bran + 7% noug cake + 25% soybean + 4% bone and meat meal + 4% limestone +2.5% vit. Premix + 0.5% salt), 5% of soybean seed in T1 was replaced by 1.25% untreated (T2), heat treated (T3), NaOH treated (T4) and yeast treated (T5) Jatropha seed meal

Figure 1: Pattern of HDEP of Lohmann Brown commercial layer during the experimental period (21 to 28 weeks of production)

3.2. Egg quality Parameters

3.2.1. *External egg quality*

Effects of feeding diets on egg quality parameters of Lohmann Brown commercial layers are presented in Table 3. There were significant variations in egg mass among the treatment groups. Hens that on fed T1 had the highest $p<0.05$) egg mass compared to hens that fed on all other treatment diets. Similarly, hens that received the T2 diet produced eggs with the lowest egg mass compared to those that fed on all other groups. On the other hand, no variations in egg weight, egg shape index, and eggshell thickness were recorded from all treatment groups ($p>0.05$). ()

Higher egg mass and production in chicken fed T1 than the other treatment diets could be associated with the higher amount of feed consumed resulting in higher egg production. A decrease in energy and protein intake resulted in decreasing egg

production (Leeson and Summers, 2005). The similarity in egg weight in all experimental groups indicated that the inclusion of 5% treated and untreated JSM to replace the soybean meal had no adverse effect on egg weight. Similar results were observed by Sumiati *et al*. (2012) who reported that there was no variation in the egg weight among the treatment groups that were fed fermented Jatroph curass meal. The egg weight in this study is relatively lower than the values observed in previous research (62.67 to 68.30 g) as indicated by Fasuyi *et al*. (2007).

The shape of the egg is a very important trait in handling during incubation and packaging for transport. Eggs having Irregular shapes will be broken in packaging because they may not fit into the tray or containers. The treated and untreated JSM inclusion in chicken diets had no influence on the egg shape index compared to the control diets. The egg shape index in this study is slightly higher than the values observed in earlier research (71.5 to 73.3%) as reported by Welelaw *et al*. (2018). The possible reasons for the difference between the earlier report and the present study could be breed and feed source differences. Based on the classification of Sarica and Erensayin (2009) the shape index observed in the present study is categorized as normal or standard (SI = 72–76), which is important to reduce damages during transportation.

The eggshell thickness is an important indicator of the specific gravity (relative density) of eggs. The shell thickness and porosity help to regulate the exchange of carbon dioxide and oxygen between the developing embryo and the air during incubation (Roque and Soares, 1994). Shell thickness also has a significant effect on moisture loss during incubation and shortage. Thin-shelled eggs lose more moisture than thick-shelled eggs, causing the chicks to have difficulty in hatching (Roque and Soares, 1994). Eggshell thickness and strength are very important to handle the egg during transportation from the time of laying up to consumption (Aberra *et al*., 2005). In the present study, the replacement of soybean by 5% treated and untreated JSM in the diet did not affect the shell thickness of eggs. The eggshell thickness observed in the present study was however lower than the values in the previous study (Fasuyi *et al*., 2007) which reported values in the range of 0.39 to 0.47 mm. On the other hand shell thicknesses obtained in this study were relatively higher than those observed by Welelaw *et al*. (2018).

Table 3: External egg quality parameters of Lohmann brown commercial layers as influenced by jatropha seed meal

Egg Quality	Treatments						
	T1	T2	T3	T4	T5	SEM	P-value
Egg shape index	75.1	75.66	74.95	75.75	74.89	0.22	0.043
Egg mass (g/h)	29.9^{a}	20.3^{d}	22.2^{c}	$22.^{5bc}$	23.1^{b}	0.34	0.00
Egg Wt. (g)	60.0	59.7	58.7	59.3	59.7	0.2	0.002
Shell thickness (mm)	0.39	0.39	0.39	0.40	0.40	0.002	0.76

Row means with different superscript letters differ significantly at ($p< 0.05$). SEM= standard error of the mean. T1=control (42% white maize + 15% wheat bran + 7% noug cake + 25% soybean + 4% bone and meat meal + 4% limestone +2.5% + 0.5% salt), 5% of soybean seed in T1 was replaced by 1.25% untreated (T2), heat treated (T3), NaOH treated (T4) and yeast treated (T5) Jatropha seed meal

3.2.2. *Internal egg quality*

The effect of dietary inclusion of JSM on internal egg quality parameters of Lohmann brown commercial layers is presented in Table 4. Eggs from hens that fed on T5 had the highest Haugh Unit (81.4) value, which was statistically similar to the eggs from hens that fed on T1 and T4 diets. On the other hand, the lowest Haugh Unit (77.4) was recorded on the egg from hens fed diet T2, which was statistically similar to those produced from T3 ($p<0.05$).

Eggs from hens that fed on T2 and T3 diets reduced the albumen height compared to eggs from hens that fed the other rations. Eggs from hens fed on T1 and T5 had a higher ($p<0.05$) yolk index (0.43) than eggs from hens fed on T2, T3, and T4 (0.41). Hens fed on T1 and T2 had higher ($p<0.05$) Value of albumen weight (32.2 g) than hens fed T3 and T4 (31.7 and 30.9), however, there was no variation between hens fed T3 and T4 and among hens fed T1, T2 and T5 at $p>0.05$.

The result indicated significant differences in yolk height, yolk weight, and yolk color among the treatment groups. Eggs from hens that fed on T1, T4 and T5 diets had higher ($p< 0.05$) yolk height (16.1, 16 and 15.9 mm) than chicken reared on T2 and T3 diets. There were no differences in yolk weight between T1 and T5, and between T3 and T4 at ($p>0.05$). Eggs from hens that fed on T3 and T4 had a higher ($p<0.05$) value of yolk weight (17.9g) compared to those fed on T1, T2 and T5, While eggs from hens fed on T2 had the lowest value of yolk weight (16.3 g). Hens fed on T1 produced eggs with a higher ($p<0.05$) value of RCF (1.9) (dark yellow) on yolk color than hens that received T3, T4 and T5 diets. Eggs from hens that fed on T2 and T4 had higher ($p<0.05$) values of RCF than those fed on the T5 diet.

The results in the current study noted that JSM treated with NaOH and baking yeast has a positive effect on HU which was related to the production of eggs with better egg weight and albumen height. The values of HU in the current study were higher than the results observed by Fasuyi *et al*. (2007) who reported values ranged from 61.30 to 67.67. The reasons for different reports on HU values compared to the current study could be due to differences in strain and age of hens (Silversides and Scott, 2001).

T2 and T3 reduced the albumen height compared to the other rations. The height of the albumen influences Haugh's unit of the egg. The higher the height of the albumen, the greater the value of Haugh's unit and the better the quality of the egg will be (Oluyemi and Roberts, 2007). Albumen height in this study is in good agreement with the study by Yilkal *et al*. (2018) who reported values ranging from 7.89 to 8.38mm. Albumen weight and height are related to the weight of the egg, which increases gradually with the weight of the egg (Sinha *et al*., 2017). The result of albumen weight in this study was higher than the work of Sinha *et al*. (2017) who reported values (of 27.361 and 33. 126 g). The reason for these variations might be due to differences in age, breed, feed and environment.

Yolk height in the present study is comparable with literature values ranging from 15.74 to 17.35mm (Sinha *et al*., 2017) but lower values were also reported (Welelaw *et al*., 2018). Treated JSM had a positive influence on yolk weight which indicates that the replacement of 5% soybean meal with treated JSM in layer rations increased the yolk weight more than the untreated JSM. The result noted that eggs collected from chickens reared under the control ration and ration containing UJSM had better yolk color.

Table 4: Internal egg quality parameters of Lohmann brown commercial layers as influenced by influenced by jatropha seed meal

Egg Quality	Treatments						
	T1	T2	T3	T4	T5	SEM	P-value
Albumen Height (mm)	8.3^{a}	7.9^{b}	7.9^{b}	8.2^{ab}	8.3^{a}	0.052	0.02
Yolk Height (mm)	16.1^{a}	15.6^{b}	15.6^{b}	16.0^{a}	15.9^{a}	0.06	0.006
Yolk Wt. (g)	17.2^{b}	16.3^{c}	17.9^{a}	17.9^{a}	17.2^{b}	0.120	0.0001
Albumen Wt.(g)	33.2^{a}	33.2^{a}	31.7^{bc}	30.9^{c}	32.5^{ab}	0.24	0.005
Haugh Unit (HU)	80.7^{ab}	77.4^{c}	78.0^{bc}	80.7^{ab}	81.4^{a}	0.49	0.022
Yolk Index	0.43^{a}	0.41^{b}	0.41^{b}	0.41^{b}	0.43^{a}	0.002	0.0002
Yolk color(RCF)	1.9^{a}	1.8^{ab}	1.2^{bc}	1.5^{b}	1.0^{c}	0.61	0.0001

Means with different superscript letters in the row differ significantly at $p< 0.05$. SEM = standard error of the mean

4. Conclusion

The inclusion of JSM in the diet of Lohmann Brown commercial layers influences the performance and egg quality parameters. Substitution of 5% of soybean with untreated 1.25% of JSM reduced DFI, HDEP and HHEP, and all the external and internal egg quality traits except egg shape index, egg weight and shell thickness. This treatment also increased FCR and mortality of hens. On the other hand, the substitution of 5% of soybean with heat, NaOH and yeast-treated 1.25% JSM diet did not influence the HDEP, HHEP, Egg shape index, Egg weight, Shell thickness, Albumin height, Yolk height, Yolk weight and Haugh Unit compared to the standard control diet. Therefore 1.25% heat, NaOH and yeast-treated JSM could be

used to replace 5% of the soybean seed in the Lohmann Brown layers diet.

Conflict of Interest

The authors declare no conflict of interest exists.

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