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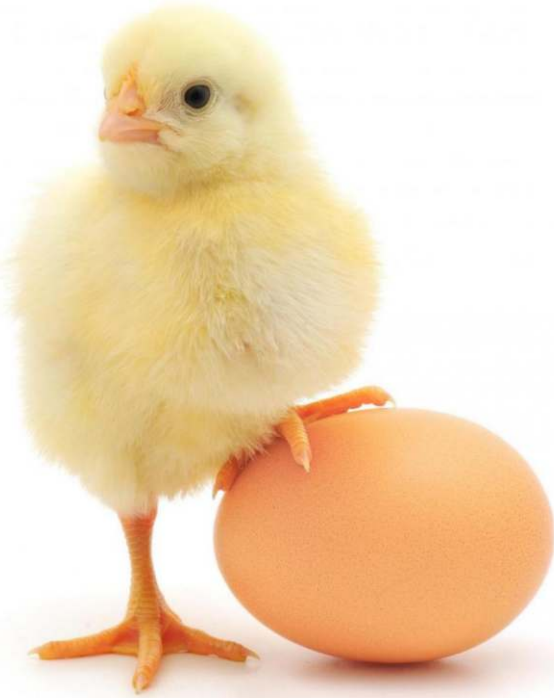

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Research Article
Effects of Dietary Palm Oil on Production Performance and Serum Parameters of Laying Hens

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Abstract
Background and Objective: Difficulties in satisfying the energy requirements of birds with cereals, especially maize, have led researchers to investigate the effects of different levels of dietary palm oil on the production performance of laying hens. This study was conducted to investigate the effects of dietary palm oil on the egg production performance and serum parameters of laying hens. **Materials and Methods:** One hundred eighty 55-week-old *Isa Brown* laying hens were used in a completely randomized study involving four treatments (groups). Birds in the four groups were fed for 14 weeks with diet 0, 1, 2 or 3. Diet 0 was the basal diet without palm oil, while diets 1, 2 and 3 contained 1, 2 and 3% palm oil obtained by a traditional procedure, respectively. Data were collected on feed intake, egg production, organ weight and biochemical parameters. **Results:** The results showed that feed intake decreased with an increase in dietary palm oil. Groups D1 (diet 1) and D2 (diet 2) showed high laying rates, low egg weights, low liver weights and a low feed conversion ratio, whereas group D3 (diet 3) had the heaviest eggs and the highest serum total protein concentration. These results might be related to the ability of palm oil to influence feed transit and to improve nutrient digestibility and absorption. **Conclusion:** Feed containing up to 2% palm oil had a beneficial effect on the egg production performance of laying hens.

Key words: Palm oil, egg weight, egg component, laying rate, feed conversion ratio, serum parameter

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Competing Interest: The authors have declared that no competing interest exists.

Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

The diversity of feeding strategies used in poultry rearing reveals the immense ability of raw materials to enhance these species[1]. Birds' daily consumption of feed ultimately governs their growth and production performance, making feed an excellent indicator of the quality of poultry farm management[2]. The energy provided by the diet plays a pivotal role in nutrient utilization by poultry[3]. Once energy requirements are achieved, birds will not consume any more feed, even if the protein, vitamin and mineral requirements have not been satisfied[4]. Therefore, the choice of dietary energy level in commercial poultry farming is often based on economics. The study by Giachetto *et al.*[5] evaluated the performance and hormonal profile of broilers fed different levels of energy and found that an appropriate level of energy in the diet improves feed consumption and feed conversion. For poultry, most of the dietary energy comes from maize, sorghum and soybeans, which are also important sources of energy for humans. Humans and other animals compete for these conventional ingredients, making them less accessible to poultry farmers as raw materials[6,7]. One strategy to reduce the pressure on conventional energy sources is to identify alternative sources of dietary energy, such as lipids. It is common practice in modern poultry production to add lipids to diets as they supply energy, improve the absorption of fat-soluble vitamins (A, D, E and K) and minerals and increase the palatability of the diet[8,9]. Fats or oils from animals or plants, such as palm oil, which is mostly available in tropical areas, are added with the aim of formulating poultry feed with appropriate energy levels[10]. Palm oil is currently the second most abundant edible oil in the world, with global production levels projected to increase by over 30% by 2020[11,12]. Palm oil contains 50% saturated fatty acids, 40% monounsaturated fatty acids and 10% polyunsaturated fatty acids, as well as sufficient amounts of β-carotene, tocopherols and tocotrienols, which are natural antioxidants. It provides a high energy density in the diet[13]. Other components of palm oil include phytosterols, squalene, coenzyme Q10, polyphenols, phospholipids, quinones, ubiquinones, thiols, coumarins and amino acids[14,15]. Based on its vital contents, palm oil is used in animal feed to improve growth, health and physiological parameters[16,17]. However, the effects of palm oil on egg production have not been properly evaluated. The aim of this study was to investigate the effects of dietary palm oil on the egg production performance and serum parameters of hens.

MATERIALS AND METHODS

Experimental design: The experiment was carried out in the experimental unit of Centre d'Excellence Regional sur des Sciences Aviaires (CERSA). One hundred eighty 55-week-old *Isa Brown* laying hens were used during a 14-week study. Hens were randomly divided into 4 treatment groups (D0, D1, D2 and D3) with 3 replicates of 15 birds in each group. These birds were housed in the same poultry house and each group was assigned to a space that was 1.20 m wide × 3.00 m long. Birds in groups D0, D1, D2 and D3 were fed *ad libitum* with diet 0, diet 1, diet 2 and diet 3, respectively. Diet 0 was the basal diet containing 0% palm oil, while diets 1, 2 and 3 contained 1, 2 and 3% palm oil, respectively. Diets were formulated to be isoenergetic and contain the same level of protein (Table 1).

Production and blood parameters measurements: Daily feed consumption and egg totals were calculated. Eggs were weighed per group and egg weight and feed intake were used to determine the feed conversion ratio. During the same

Table 1: Gross composition of experimental diets (%)

	Treatment groups			
Feed stuffs	D0	D1	D2	D3
White maize	58	54.5	51.25	49
Wheat bran	8	10.5	12.75	13.5
Roasted soya seed	15	13	12.25	10.3
Cotton seed cake	2	2	2.75	5.2
Fish meal	8	10	10	10
Layer concentrate	2	2	2	2
Oyster shell	7	7	7	7
Palm oil	0	1	2	3
Total	100	100	100	100
Calculated components				
Metabolizable energy (kcal kg^{-1})	2838.08	2835.86	2853.32	2898.00
Crude protein (%)	17.32	17.34	17.36	17.37
Crude fiber (%)	5.05	5.06	5.27	5.71

period, nine randomly chosen eggs per group were weighed and broken to collect the albumen, yolk and shell. These different components were weighed to determine the egg component ratios. The yolk color intensity was assessed using the Roche Scale. At the end of the experiment, 12 layers in each group were weighed and slaughtered, 5 mL of blood was collected in nonheparinized tubes and the heart, liver, gizzard, ovarian grape and abdominal fat were dissected and weighed. Blood samples were immediately centrifuged at 3000 rpm for 10 min using a Shimadzu electric centrifuge (Tokyo, Japan) to collect serum. The serum was used to determine the concentrations of glucose, cholesterol, total protein and triglycerides with a Technicon RA automated biochemistry analyzer (Technicon Instruments Corporation, Tarrytown, New York, USA). The relative organ weight was determined according to the following formula: organ weight $\times$100/body weight.

Statistical analysis: All values were presented as the Mean$\pm$SEM. Significant differences between groups were determined with one-way analysis of variance (ANOVA) using GraphPad Prism 5 (Software, Inc., California, USA). Pairwise comparisons were performed using Tukey's test at $p<0.05$.

RESULTS

Effect of palm oil on production parameters: Feed intake, laying rate, egg weight and feed conversion ratio are shown in Table 2. The feed intake in group D0 was significantly higher ($p<0.05$) than that in groups D2 and D3 but was similar to that in group D1. Moreover, birds in groups D1 and D2 had similar feed intake, while birds in group D2 had greater ($p<0.05$) feed intake than those in group D3.

Groups D1 and D2 had similar laying rates, which were higher ($p<0.05$) than those in group D0 and D3. However, there was no significant difference in the laying rate of birds fed the control diet and of those fed the diet containing 3% palm oil. Moreover, egg weights were comparable between groups D1 and D3. Birds in group D3 had heavier eggs than those in groups D0 and D2 ($p<0.05$). Birds in groups D1 and D2 produced eggs that weighed the same. Groups D0 and D3 had comparable feed conversion ratios but these ratios were significantly higher ($p<0.05$) than those in groups D1 and D2.

Effect of dietary palm oil on egg components: Table 3 shows the ratio of egg components of hens fed different levels of palm oil. There were no significant differences in the egg shell ratio among the treatment groups. However, the albumen ratio of eggs was significantly higher ($p<0.05$) in group D0 than in groups D2 and D3, while the albumen ratios were similar among groups D1, D2 and D3. The yolk ratio was not affected by the concentration of palm oil in the treated groups. However, the yolk ratio was significantly heavier in group D0 than those in groups D1, D2 and D3 ($p<0.05$).

Effect of palm oil on yolk color: The yolk color of chickens fed different levels of palm oil is presented in Fig. 1. The color score increased with increasing incorporation of palm oil. The yolk color score was significantly lower ($p<0.05$) in eggs from chickens in group D0 than those from chickens in groups D1, D2 and D3. Moreover, the yolk color score was significantly lower ($p<0.05$) in group D1 than those in groups D2 and D3, which had similar yolk color.

Effect of dietary palm oil on relative organ weight: Table 4 shows the effect of palm oil on the relative organ weights of

Table 2: Feed intake, egg weight, laying rate and feed conversion ratio according to treatment group

	Treatment groups			
Parameters	D0	D1	D2	D3
Feed intake (g)	121$\pm$2.96^{a}	117.8$\pm$2.67^{ab}	115.4$\pm$2.81^{bc}	113.2$\pm$2.44^{c}
Egg weight (g)	60.83$\pm$0.43^{a}	58.61$\pm$0.28^{b}	58.73$\pm$0.26^{b}	60.37$\pm$0.50^{a}
Laying rate (%)	71.41$\pm$2.12^{b}	76.6$\pm$1.71^{a}	76.38$\pm$1.43^{a}	66.79$\pm$1.55^{b}
Feed conversion ratio	2.86$\pm$0.13^{a}	2.550$\pm$0.07^{b}	2.59$\pm$0.08^{b}	2.83$\pm$0.05^{a}

^{a,b,c}Within a row, data sharing no common letter are significantly different ($p<0.05$)

Table 3: Ratio of egg components (%)

	Treatment groups			
Egg components	D0	D1	D2	D3
Shell ratio	12.30$\pm$0.22^{a}	12.02$\pm$0.25^{a}	12.44$\pm$0.19^{a}	12.14$\pm$0.19^{a}
Albumen ratio	65.46$\pm$0.22^{a}	64.55$\pm$0.35^{ab}	63.84$\pm$0.44^{b}	63.92$\pm$0.46^{b}
Yolk ratio	22.24$\pm$0.61^{b}	23.43$\pm$0.25^{a}	23.72$\pm$0.42^{a}	23.94$\pm$0.40^{a}

^{a,b}Within a row, data sharing no common letter are significantly different ($p<0.05$)

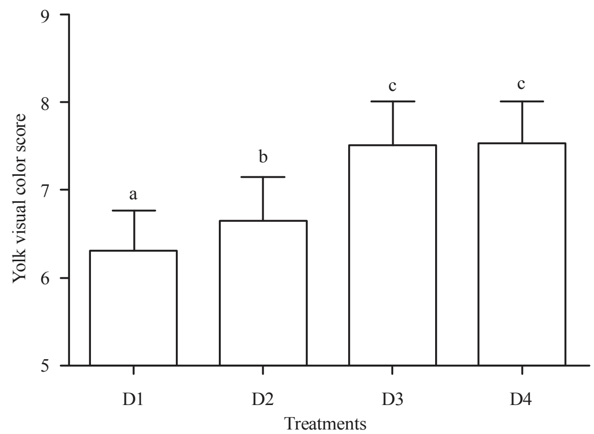

Fig. 1: Yolk visual color score according to treatment group
[a,b,c]Data sharing no common letter are significantly different (p<0.05)

Table 4: Effect of palm oil on relative organ weight

	Treatment groups			
Organs	D0	D1	D2	D3
Heart	0.45 ± 0.02^{a}	0.39 ± 0.02^{a}	0.44 ± 0.05^{a}	0.38 ± 0.03^{a}
Liver	2.07 ± 0.09^{a}	1.56 ± 0.08^{b}	1.64 ± 0.10^{b}	1.62 ± 0.07^{b}
Gizzard	1.92 ± 0.09^{a}	1.50 ± 0.09^{a}	1.70 ± 0.06^{a}	2.06 ± 0.33^{a}
Abdominal fat	1.30 ± 0.40^{a}	2.91 ± 0.80^{a}	2.58 ± 0.44^{a}	1.54 ± 0.35^{a}
Ovarian grape	1.83 ± 0.14^{a}	1.91 ± 0.15^{a}	2.05 ± 0.10^{a}	1.68 ± 0.03^{a}

[a,b]Within a row, data sharing no common letter are significantly different (p<0.05)

Table 5: Serum concentration of glucose, cholesterol, triglycerides and total protein according to treatment group

	Treatment groups			
Serum parameters	D0	D1	D2	D3
Glucose (g L^{-1})	2.77 ± 0.35^{a}	3.08 ± 0.40^{a}	2.87 ± 0.33^{a}	3.70 ± 0.22^{a}
Triglycerides (mg dL^{-1})	7.24 ± 1.36^{a}	4.23 ± 1.14^{a}	5.12 ± 0.96^{a}	6.82 ± 0.65^{a}
Cholesterol (mg dL^{-1})	0.71 ± 0.15^{a}	0.69 ± 0.13^{a}	0.80 ± 0.15^{ab}	1.29 ± 0.10^{b}
Total protein (g dL^{-1})	55.79 ± 4.48^{b}	43.90 ± 4.98^{bc}	27.94 ± 4.01^{c}	68.90 ± 8.94^{a}

[a,b,c]Within a row, data sharing no common letter are significantly different (p<0.05)

the hens. There were no significant differences in the relative weights of the heart, gizzard, abdominal fat and ovarian grape among the groups. However, the liver weight of birds in group D0 was significantly higher (p<0.05) than those in the treated groups, among which the liver weights were similar.

Effect of dietary palm oil on blood parameters: Serum glucose, cholesterol, triglyceride and total protein concentrations are presented in Table 5. There were no significant differences in glucose or triglyceride concentration among groups. However, the cholesterol concentration was significantly higher (p<0.05) in groups D0 and D1 than those in group D3. The cholesterol concentration was similar in birds in groups D2 and D3. Serum total protein concentrations decreased progressively from D0-D2; this concentration in group D0 was similar to that in group D1 but significantly higher (p<0.05) than that in group D2. Serum total protein concentrations were not significantly different between groups D1 and D2 but were significantly lower (p<0.05) in these groups than in group D3.

DISCUSSION

This study reveals that incorporating palm oil into chickens' diets influenced feed intake and egg production even though the three diets were isoenergetic, contained the same concentration of protein and met the hens' nutritional requirements. The reduction of feed intake with the increase in the palm oil incorporation rate is in line with the study of Mateos *et al.*[18] who linked this feed intake reduction to the feed transit time. These authors fed White Leghorn hens with diets supplemented with different levels of yellow grease and they observed that the transit time significantly increased with grease level incorporation. Sturkie[19] has stated that fat slowed the feed passage rate, resulting in a reduction in feed intake and improving digestibility and absorption. Therefore, the improvement in the laying rate observed in D1 and D2, despite the low feed intake compared to the control group, can be due to a more complete digestion and utilization of nutrients allowed by the positive interaction between unsaturated and saturated fatty acids contained in palm oil as shown by Leeson and Summers[20] and Grobas *et al.*[21]. In addition, although the energy intake in D0, D1, D2 and D3 from feed intake was respectively 343.41, 334,06, 329.27 et 328.05 kcal g^{-1}, egg production performance in D1 and D2 can be explained by the energy intake. As the study by Mateos and Sell[22] demonstrated, birds fed with diets containing oil have received more metabolizable energy than expected. Based on the extra caloric effect of metabolizable energy attributed to lipids, Chilliard and Ollier[23], Grondret[24] and Jensen-Urstad and Semenkovich[25] have pointed out that reducing hepatic fatty acid synthesis can explain the decrease in the level of triglycerides and the relative weight of the liver observed in the treated groups. Despite the low laying rate, chickens in D3 produced the heaviest eggs most likely due to the improvement in digestion and the absorption of nutrients by fat. Accordingly, Leeson and Summers[20] reported that the incorporation of fat into the diet could increase the utilization of other dietary components. Palm oil incorporated at 3% in the diet may increase the utilization of some ingredients when provided with more protein, justifying the high level of serum protein and the high egg weight obtained. Moreover, when Meshreky *et al.*[26] and Muzvondiwa *et al.*[27] fed weaned rabbits and ewes, respectively, with diets containing palm oil, the fat had a significant effect on the profile of reproductive hormones and production performance. Fat contributes to cholesterol synthesis and cholesterol is a precursor to reproductive hormones. The low blood cholesterol concentrations obtained in groups D1 and D2 could be explained by the birds using the cholesterol to synthesize estrogens, which could stimulate ovarian grape weight and egg production. Despite the low egg weight, the improvement in egg production allowed a higher conversion ratio in D0 than in D3. The low laying rate of birds in D3 is related to the high concentration of palm oil in diet 3[28] and especially to the high level of cholesterol. The high level of cholesterol is supposed to increase the level of estrogens, which results in the impairment of ovogenesis[26,27]. Moreover, increasing the amount of palm oil was positively correlated to the yolk color score as explained by Ping and Gwendolin[29] and Tranbarger *et al.*[30]. Palm oil is known to contain a sufficient amount of β carotenoid[31,32], which escapes digestion and absorption and impairs transportation to ovarian follicles. Despite the low laying rates, egg weights of D0 and D3 were the highest. This increase in the egg weights of birds in D0 is due to their high albumen weight but the high egg weights from birds in D3 is related to the eggs' relatively high vitellus weight. This study revealed that the extra calories provided from the synergetic effect between unsaturated and saturated fatty acids contained in palm oil could be beneficial for improving egg production. Because of the observed synergetic effect, researchers should thoroughly explore the profitability of feeding alternative energy sources, such as palm oil, to hens.

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