

**EGG QUALITY TRAITS AND PERFORMANCE OF LAYERS
IN DIETS SUPPLEMENTED WITH GRADED LEVELS OF
ACTIVATED CHARCOAL**

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ABSTRACT

The study was conducted to determine the effect of graded levels of activated charcoal in the diets of laying hens on nutrient composition, performance response, internal and external egg qualities. A total of 120 Hyline hens, 44-week-old with mean body weight of 2060.70 g and egg production level of 88.92% were randomly allotted into five treatment groups, with three replicates per treatment and 8 hens per replicate. Hens were fed *ad libitum* on a basal diet supplemented with activated charcoal at 0, 0.5, 1.0, 1.5 and 2% levels to give treatments T1, T2, T3, T4 and T5, for 42 days. Supplementation of basal diet of laying hens with 0, 0.50, 1.00, 1.50 and 2.00% activated charcoal produced significant ($P < 0.05$) variation in dietary crude protein, crude fat, ash, calcium, phosphorus and salt, while crude fiber, nitrogen free extract and metabolisable energy did not differ significantly ($P > 0.05$) There was no significant ($P > 0.05$) nutritional advantage of feeding activated charcoal as a dietary supplement to laying hens at up to 2% on their performance response. Activated charcoal supplementation significantly ($P < 0.05$) improved egg weight, egg width and shell weight (external egg indices) at 2% level, and also improved ($P < 0.05$) yolk height, albumen weight and yolk colour (internal egg quality characteristics) at 2% level. The result of the study showed that supplementation of the basal diet of laying hens with activated charcoal can be used at 2% level for enhancement of egg weight, egg width, shell weight, yolk height, albumen weight and yolk colour.

Keywords: Activated charcoal, laying hens, egg quality traits, performance

1.0 INTRODUCTION

Due to high inflation, prevalent ecological disasters, disruptions in food supply chains which occurs in regional conflicts, the world is experiencing unprecedented global food crisis. This occurs at a time when the stability of global food market is still recovering from economic downturn occasioned by the Covid-19 pandemic and climate-related crop failures. According to FAO (2023), global food insecurity has worsened consequent upon the conflict in Ukraine, which involves two major Agricultural nations. Global Network Against Food Crises (2022) reported that over a quarter of a billion people are facing acute hunger with economic shocks traceable to diverse crises, and more than 828 million people go to bed hungry every night (Georgieva *et al.*, 2022).

Animal agriculture is important for various reasons. It contributes to food security, economic development and sustainable agricultural development and agricultural systems. Livestock provide a source of high-quality food that improves nutritional status, and they also contribute additional resources such as manure for fertilizer, on-farm power, and other by-products, which can assist smallholder farmers in developing nations diversify their source of income and reduce poverty (Reynolds *et al.*, 2015). Direct sales of livestock products such as milk, eggs, wool, meat and hides and manure, as well as sales of live animals provide income. Meat, milk, eggs, fish and other animal products are excellent sources of dietary protein and other nutrients for man. Nutrition education is a very important concept which plays a crucial role in fostering a paradigm shift towards healthier lifestyle which can be achieved through various approaches, such as the application of technological advancements and innovative research.

A few methodologies have been suggested towards tackling the high feed cost issue including the utilization of local feed materials, manipulation of feed forms and feeding methods and use of feed additives (Ugwu and Okoli, 2017). Nutritionists and experts in animal production have also argued in favor of use of feed additives such as activated charcoal as a way to maximize the absorption of nutrients from ultimate feed source materials and boost output (Terrence, 2005). Feed additives are compounds that are added to feed to increase the effectiveness and the acceptability of the feed, or better metabolism and animal health. According to Peter *et al.* (2003), feed additives are introduced for a number of reasons such as addition of colour and flavour to the diet and to alter the efficiency and speed of growth of animals. Activated charcoal is added at low levels in diets of different livestock to optimize its benefits without negatively impacting nutrient absorption (Lavrentyev *et al.*, 2021). Furthermore, activated charcoal in layers diet improves gut health by binding toxins and foreign materials, and this leads to healthier hens and better egg quality (Okey *et al.*, 2021). The aim of the study was to investigate the efficacy of activated charcoal as a supplement in layer diets on performance and egg quality traits.

2.0 MATERIALS AND METHODS

2.1 Experimental Site and Location

The study was conducted at the National University of Lesotho Teaching and Research Farm, Roma. Roma is located in the Foothills agro-ecological zone (AEZ) of Lesotho. Its climate alternates between warm summers and cold winters. Summer temperatures can range from 10 °C to 30 °C, while winter temperatures can vary from below 0 °C to 15 °C (World Bank, 2021). The study was conducted during winter between June to August.

2.2 Experimental Animals Management and Design

A total of one hundred and twenty 44-week-old layers were used for a six-week feeding trial. The birds were randomly distributed into five treatment groups T1, T2, T3, T4 and T5 in three replicates, each with eight birds per replicate. The control group T1 was fed a basal layer mash only, while the other groups T2, T3, T4 and T5 were fed same layer mash but to which activated charcoal at 0.5, 1.0, 1.5, and 2%, respectively were added as a supplement. The experiment was a completely randomized design (CRD). The birds had comparable mean initial live body weight of 2060.70 g and egg production level of 88.92%. The birds were reared in a 3-tier battery cages, and had free access to clean water and served fresh feed *ad libitum*. The poultry house was three-quarter walled to mitigate the effect of prevalent strong wind. All the chickens were raised under the same management conditions and practices of feeding, watering and hygiene.

2.3 Feed Supplement and Experimental Diets

The feed supplement used in the experiment was ground activated charcoal 0.02 mm size from Oos vrystaat kaap (OVK) Ficksburg, Republic of South Africa. The activated charcoal (AC) was then mixed thoroughly with a commercial brand basal layer mash (LM) at a percentage ratio of 0 AC:100.0 LM (T1), 0.5 AC:99.5 LM (T2), 1.0 AC:99.0 LM (T3), 1.5 AC:98.5 LM (T4) and 2 AC:98 LM (T5).

2.4 Chemical Analysis of Activated Charcoal and Layer Mash

The proximate analysis of the layer mash was done using Sup NIR-2700 (Near Infra-Red Analyzer Series). The proximate analysis of activated charcoal was determined using the standard methods (AOAC, 2000). Metabolizable energy contained in the experimental diets and activated charcoal was computed using Ponzenga (1985). The calcium content of activated charcoal was determined using Talapatra *et al.* (1940) and phosphorus content was determined using AOAC (2000).

2.5 Data Collection

A total of 60 eggs were collected from the experimental birds per week for both external and internal egg characteristics evaluation, in the Animal Science Laboratory, the National University of Lesotho. Four eggs per replicate were randomly picked in a treatment per week at the rate of two eggs each on thursdays and sundays for a total of six weeks. The eggs were first weighed separately, and external and internal quality indices determined. Thereafter, they were carefully broken with a spatula at the equatorial region into a clean, white smooth plain surface to determine the following internal characteristics; yolk diameter, albumen height, egg yolk index, yolk height and yolk colour. Haugh unit was calculated using (Ayanwale *et al.*, 2006). The external egg traits determined were egg weight, egg length, egg width, egg shell thickness, egg shell weight and egg shape index (Moraleco *et al.*, 2019).

2.5.1 Egg internal quality indices

Each egg was gently cracked open with a spatula on a clean flat white surface to evaluate the following internal traits:

- a) **Albumen height** was measured with a micrometer screw gauge Model PGA5024 at approximately one centimeter away from the egg yolk.
- b) **Yolk height** was determined with Digital vernier calipers Model SR070438 by measuring the height of the egg yolk from the surface of egg white. The caliper was placed perpendicular to the surface.
- c) **Haugh unit** (HU) was calculated as; $HU = 100 \times \log (H - 1.7W^{0.37} + 7.6)$
Where H = height of albumen in millimeters, W = weight of egg in g
- d) **Yolk weight** was taken with a precision electronic weighing balance as for egg weight after yolk of each egg was carefully separated with a table spoon (Fig. 1) and carefully rolled on a damp paper to remove any adhering albumen.
- e) **Yolk diameter** was measured using electronic digital vernier calipers Model SR070438 along the axis bisecting the short and the long sides of the yolk.
- f) **Yolk colour** was determined using the DSM yolk colour fan (yolk fan) which was placed on a white non-reflective surface, viewed vertically from above and matched the yolk colour to the closest blade.
- g) **Albumen weight** was calculated as the difference between the weight of the entire egg and the combined weight of the yolk and the egg shell (g).
Albumen weight = Egg weight - (shell weight + yolk weight)
- h) **Yolk index** was calculated as the ratio of yolk height to yolk diameter



Figure 1: Measurement of egg length with Venier caliper



Figure 2: Egg shell thickness measurement with Micrometer screw gauge



Figure 3: Egg yolk separation from albumen with a Plastic sieve

2.6 Data analysis

The data obtained from each parameter determined were entered into excel spreadsheet. The response variables were analysed as one-way analysis of variance (ANOVA) with five variables as the main effects using SPSS (2011) version 20. Significant differences between treatment means were compared and separated using Duncan's multiple range test of the same package at a probability value of $P \leq 0.05$. Correlation was done to check the relationship between the main effects and some production indices

3. RESULTS

3.1 Chemical Composition of Activated Charcoal Supplement

The nutrient analysis of the activated charcoal (AC) used as a dietary supplement showed it contained 90.38% dry matter, 0.05% crude protein, 6.83% crude fibre, 0.00% crude fat, 7.76% ash, 0.13% Ca and 0.02% P.

3.2 Nutrient Composition of Activated Charcoal Supplement Diets

The nutrient composition of the five experimental diets T1, T2, T3, T4 and T5 is presented in Table 1. Activated charcoal augmentation had a significant negative correlation effect ($r = -0.03$, $P <$

0.05), ($r = -0.96, P < 0.05$) and ($r = -0.48, P < 0.05$) on crude protein, crude fat and ash, respectively and significant positive correlation effect ($r = 0.57, P < 0.05$), ($r = 0.87, P < 0.05$) and ($r = 0.75, P < 0.05$) on dietary calcium, phosphorus and salt, respectively. T2 and T3 had comparable ($P > 0.05$) crude protein of 18.73% and 18.63%, respectively but significantly ($P < 0.05$) higher than T1, T4 and T5 with values of 17.56, 17.50 and 17.64%, respectively. Crude fat decreased linearly from 3.10% in T1 to 1.28% in T5, with increasing levels of activated charcoal. Ash content was highest in T2 (14.10%) and significantly ($P < 0.05$) higher than T1 (13.69%), and progressively reduced from 0.50% to 2.00% AC supplementation. Calcium was significantly ($P < 0.05$) higher in T2, T3, T4 and T5 compared to control group T1 and similarly, phosphorus was significantly ($P < 0.05$) higher in T2, T3, T4 and T5 compared to control group T1 (0.56%). Addition of activated charcoal caused increase in dietary salt compared to the control diet, and progressive decline in dietary energy from 2586.43 kcal ME/kg to 2498.19 kcal ME/kg.

Table 1: Nutrient Composition of Activated Charcoal Supplement Diets

Nutrients (%)	T1	T2	T3	T4	T5	SEM	P-value	r
Dry matter	88.20	89.18	89.01	88.99	88.75	0.14 ^{ns}	0.16	0.25
Crude protein	17.56 ^c	18.73 ^a	18.63 ^{ab}	17.50 ^{bc}	17.64 ^{bc}	0.52	0.02	-0.03
Crude fibre	6.80	7.46	7.10	7.87	7.51	0.21 ^{ns}	0.59	0.34
Crude fat	3.10 ^a	2.53 ^b	1.92 ^c	1.60 ^{cd}	1.28 ^d	0.18	0.00	-0.96
Ash	13.69 ^b	14.10 ^a	13.81 ^{ab}	13.71 ^{bc}	13.53 ^c	0.08	0.02	-0.48
NFE	47.37	46.68	47.98	50.24	49.02	0.38 ^{ns}	0.25	0.61
Calcium	3.34 ^b	4.33 ^a	4.22 ^a	4.28 ^a	4.24 ^a	0.11	0.02	0.57
Phosphorus	0.56 ^b	0.79 ^a	0.93 ^a	0.98 ^a	0.97 ^a	0.04	0.00	0.87
Salt (NaCl)	0.48 ^b	0.50 ^b	0.53 ^a	0.53 ^a	0.53 ^a	0.01	0.01	0.75
ME (kcal/kg)	2586.43	2547.56	2546.08	2511.96	2498.19	12.38 ^{ns}	0.16	-0.74

^{a, b, c, d}Means with different superscripts in the same row differed significantly ($p < 0.05$), ^{ns}Not significantly different, SEM = Standard Error of Mean, NFE = Nitrogen Free Extract, ME = Metabolizable Energy, AC = activated charcoal, LM = layer mash, r=correlation coefficient
 T1 = Diet with 0 AC: 100 LM (control)
 T2 = Diet containing 0.50 AC: 99.5 LM
 T3 = Diet containing 1.00 AC: 99 LM
 T4 = Diet containing 1.50 AC: 98.5 LM
 T5 = Diet containing 2.00 AC: 98 LM

3.3 Effect of Activated Charcoal Supplementation on Performance Response of Laying Hens

The effect of activated charcoal supplement on the performance response of laying hens is presented in Table 2. The experimental diets had no significant ($P > 0.05$) effect on the final body weight and feed intake of laying hens. The final body weight varied from 2046.70 g/bird to 2063.30 g/bird, feed intake from 106.44 g/bird to 107.42 g/bird and egg production percentage from 86.00 to 88.00%.

Table 2: Effect of Experimental Diets on Growth Performance of Layer Chickens

Growth indices	Experimental Diets					SEM	P-Value
	T1	T2	T3	T4	T5		
Initial body weight (g/bird)	2096.70	2056.70	2086.70	2036.70	2036.70	0.01 ^{ns}	0.20
Final body weight (g/bird)	2063.30	2046.70	2050.00	2046.70	2050.00	0.01 ^{ns}	0.98
Feed intake (g/bird/day)	107.37	107.42	106.81	107.38	106.44	00.41 ^{ns}	0.05
Egg production level (%)	88.00	86.00	87.00	87.00	87.00		

^{ns}Not significantly different, SEM = Standard Error of Mean, AC = activated charcoal, LM = layer mash

T1 = Diet with 0. AC: 100 LM (control)

T2 = Diet containing 0.50 AC: 99.5 LM

T3 = Diet containing 1.00 AC: 99 LM

T4 = Diet containing 1.50 AC: 98.5 LM

T5 = Diet containing 2.00bAC:98 LM

3.4 Effect of Activated Charcoal Supplementation on External Egg Quality Indices of Hens

The effect of activated charcoal feed supplement on external egg quality traits is presented in Table 3. Significant and positive correlation were observed in egg weight ($r = 0.05$, $P < 0.05$), egg width ($r = 0.13$, $P < 0.05$) and shell weight ($r = 0.05$, $P < 0.05$), whereas there was no significant ($P > 0.05$) effect on egg length, shell thickness and shape index. The egg weight seemed to increase significantly with a higher level of activated charcoal supplementation, and thus T5 group had the highest egg weight of 68.03 g compared to T1 (63.94 g), T2 (63.64 g), T3 (64,68 g) and T4 (62.53 g) which did not differ significantly ($P > 0.05$). A similar trend was observed in the egg width and shell weight with higher levels of activated charcoal and hence T5 had the highest egg width of 46.77 mm and shell weight of 6.27 g.

Table 3: Effect of Activated Charcoal Supplement Diets on External Egg Quality Indices of Hens

Indices	Activated Charcoal Supplement Diets					SEM	P-value	r
	T1	T2	T3	T4	T5			
Egg weight (g)	63.94 ^b	63.64 ^b	64.89 ^b	62.53 ^b	68.03 ^a	0.58	0.00	0.05
Egg length (mm)	55.96	56.56	56.75	56.46	57.18	0.17 ^{ns}	0.26	0.48
Egg width (mm)	44.61 ^b	44.36 ^b	44.63 ^b	44.69 ^b	46.77 ^a	0.26	0.00	0.13
Shell weight (g)	5.87 ^b	5.98 ^b	6.02 ^b	6.00 ^b	6.27 ^a	0.04	0.00	0.09
Shell thickness (mm)	0.36	0.36	0.36	0.37	0.36	0.00 ^{ns}	0.07	-0.36
Egg shape index	79.90	78.79	78.94	79.12	79.18	0.22 ^{ns}	0.60	-0.34

^{a, b} Means with different superscripts in the same row are significantly different (p<0.05), ^{ns}Not significantly different, SEM = standard error of mean, AC = activated charcoal, LM = layers mash , r= correlation coefficient.

T1 = Diet with 0 AC: 100 LM (control)

T2 = Diet containing 0.50 AC: 99.5 LM

T3 = Diet containing 1.00 AC: 99 LM

T4 = Diet containing 1.50 AC: 98.5 LM

T5 = Diet containing 2.00 AC:98 LM

3.5 Effect of Activated Charcoal Supplementation on Internal Egg Quality Indices of Hens

The effect of activated charcoal dietary supplementation on the internal egg quality of hens is presented in Table 4. Significant and positive correlation effect was observed for yolk height (r = 0.57, P < 0.05), albumen weight (r = 0.03, P < 0.05) and yolk colour (r = 0.81, P < 0.05) with increase in dietary activated charcoal, but did not affect significantly (P > 0.05) yolk diameter, yolk weight, albumen height, yolk index and haugh unit. Yolk height significantly increased from 18.49 mm (T1) to 19.20 mm (T5), albumen weight tended to increase from 40.07 g (T1) to 43.60 g (T5) and the yolk colour intensity increased from 3.40 (T1) to 9.65 (T5).

Table 4: Effect of Activated Charcoal Supplement Diets on Internal Egg Quality Indices of Hens

Parameters	Activated Charcoal Supplement Diets					SEM	P-value	r
	T1	T2	T3	T4	T5			
Yolk height (mm)	18.49 ^c	18.65 ^{bc}	18.80 ^{bc}	19.01 ^{ab}	19.20 ^a	0.08	0.00	0.57
Yolk diameter (mm)	42.08	41.86	42.03	41.82	42.24	0.09 ^{ns}	0.65	-0.26
Yolk weight (g)	17.96	17.72	18.03	17.78	18.26	0.12 ^{ns}	0.68	0.31
Albumen height (mm)	9.35	9.42	9.51	9.49	9.60	0.03 ^{ns}	0.22	0.63
Albumen weight (g)	40.07 ^b	39.83 ^b	40.44 ^b	39.37 ^b	43.60 ^a	1.48	0.01	0.03
Yolk index	0.44	0.44	0.44	0.45	0.45	0.00 ^{ns}	0.23	0.72
Haugh unit	95.70	95.30	95.95	96.47	95.80	0.18 ^{ns}	0.40	0.43
Yolk colour	3.40 ^d	6.95 ^c	8.15 ^b	8.51 ^b	9.65 ^a	0.58	0.00	0.81

^{a, b, c, d}Means with different superscripts in the same row are significantly different ($p < 0.05$), ^{ns}Not significantly different SEM = standard error mean, AC = activated charcoal, LM = layers mash, r=correlation coefficient

T1 = Diet with 0 AC: 100 LM (control)

T2 = Diet containing 0.5 AC: 99.5 LM

T3 = Diet containing 1 AC: 99 LM

T4 = Diet containing 1.5 AC: 98.5 LM

T5 = Diet containing 2 AC: 98 LM

4.0 DISCUSSION

4.1 Chemical Composition of Activated Charcoal Feed Supplement

The activated charcoal supplement has a high dry matter content in the range of 90.96% reported for activated sheabutter charcoal (Ayanwale *et al.*, 2006). High dry matter is a requirement for long shelf-life. The supplement has negligible amounts of crude protein and fat which are key dietary nutrients in laying hen performance. The primary causes of activated charcoal low protein and zero fat content can be attributed to its production process and intended use as an anti-poison treatment. According to Al-Hamed and Kharoufa (2022), activated charcoal is mostly made of carbon and contains few organic components, including proteins because of its production technique. The crude fibre level in the charcoal supplement is moderate and within the range of 6.89% and 7.56% (Ayanwale *et al.*, 2006) and its presence can be advantageous for sustainable digestive gut health. It has been reported that increasing fibre consumption might result in faster transit times in the digestive system, which is advantageous to overall gut health (Savaci and Karaca, 2023). Both calcium and phosphorus are present in low amounts in the activated charcoal. While these minerals are essential for various physiological functions in the laying hen, their low levels in activated charcoal indicate that they can only be relied upon as a source of supplemental Ca and P. It has

been reported that Ca in activated charcoal can increase immunological function and gastrointestinal health, resulting in greater growth performance and egg-laying efficiency in layers (Muadifah *et al.*, 2023). Also, according to Felicia *et al.* (2006), the calcium content in activated charcoal may have an impact on the balance of other minerals, such as phosphorus, which is necessary for healthy bones and the production of eggs.

4.2 Nutrient Composition of Activated Charcoal Supplemented Diets

The addition of activated charcoal to layers basal diet produced varying effects on the dietary nutrients. There was substantial reduction in crude fat and increase in calcium, phosphorus and dietary salt, compared with T1. The progressive decrease in dietary fat can be partly due to the zero percent fat content in the charcoal. Furthermore, it has been reported by Zhang *et al.* (2022) that activated charcoal is a highly porous structure and its large surface area allows it to attract and bind various substances including fats and fat-soluble vitamins thereby reducing their absorption in the diet. This binding effect reduces the total availability of fats for digestion and assimilation, resulting in a decreased fat level in the final product (Healthline, 2023). The dietary crude protein did not have any sequence and cannot be linked to the activated charcoal supplementation. However, the dietary crude protein levels met the requirement for hens. Increased protein levels in the diet will cause higher egg production, egg weight, and overall egg quality. It has been reported that layers fed diets with high crude protein levels produced more eggs with higher feed conversion ratios (Ribeiro *et al.*, 2024). Crude fibre of the AC supplemented diet was lower than 10% maximum crude fibre recommended by Nigerian Industrial Standards (1989). This agrees with the finding that adding activated charcoal to animal feed has no substantial effect on crude fibre content (Alzawqari *et al.*, 2021). Ash content generally indicates the overall mineral content, and activated charcoal may be affecting the availability or retention of minerals such as calcium and phosphorus. Calcium levels in the diets are higher than 3.25% minimum, and P lower than total available P of 1% (Nigerian Industrial Standards, 1989). Higher calcium and phosphorus levels in the diet promote strong eggshells in laying hens. Calcium is the major mineral necessary for eggshell formation, while phosphorus is essential for bone growth and general hen health (Pavan *et al.*, 2005). Dietary salt (NaCl) tended to increase and it is higher than 0.28 – 0.48% recommended by NRC (1994). Increased dietary salt can negatively affect eggshell quality, including thickness and strength (egg shell integrity). The metabolizable energy content is similar among treatments, adequate for layers performance, and within the recommended 2500 kcal ME/kg (Aduku, 2012) and 2600 kcal ME/kg (Olomu, 2011). This shows that the addition of activated charcoal had little effect on the dietary energy content. This agrees with Wang *et al.* (2020) that non-caloric additions such as charcoal have little effect on the total energy value of diets.

4.3 Effect of Activated Charcoal Supplementation on Performance Response of Laying Hens

The hens had similar live body weight at the start of the trial, which was crucial for verifying that any observed effects on performance metrics are due to nutritional treatments rather than pre-existing variations in body weight. The final body weights, feed intake, and egg production levels showed a generally comparable performance across all treatments. The final body weight of hens suggests that activated charcoal has no deleterious effect on hen's overall health and body weight stabilization expected over the period of study. This finding agrees with the work of Saleh *et al.* (2021) that, while some dietary oils (feed supplements) improved specific performance metrics body weight remained unaltered. This result is in line with Rattanawu *et al.* (2014). The feed intake pattern supports the observation that certain dietary supplements may not always improve performance in laying hens, especially when baseline nutritional requirements are satisfied as in this study.

There was little variation in egg production, T1 produced the most at 88.00%, followed by T2, T3, T4, and T5 at 86.00% and 87.00%, respectively. The comparatively large percentages of eggs produced in each treatment showed that the feed formulations supported reproductive performance well.

4.4 Effect of Activated Charcoal Supplementation on External Egg Quality of Hens

The use of activated charcoal as a dietary supplement in laying hens produced significant changes in egg weight, egg width and shell weight across treatment groups, while the egg length, shell thickness, and egg shape index were not affected. Egg weight is an important metric in poultry production, and the result showed that hens in T5 diet produced heavier eggs (68.38 g) than other treatments which produced similar mean egg weight ranging from 62.53 g to 64.89g. It has been found that feed supplementation with activated charcoal can boost egg production parameters by improving nutrient absorption and metabolic efficiency (Majewska *et al.* 2012), and better poultry health and production (Raphael *et al.*, 2010). Activated charcoal in layers diet improves gut health by binding toxins and foreign materials, and this leads to healthier hens and better egg quality (Okey *et al.*, 2021). These explain the observed increase in egg weight in this study. Hens in T5 had a significantly wider egg width (46.77 mm) than the hens in T1, T2, T3 and T4 with comparable mean egg width varying from 44.36 mm to 44.69 mm. This increase in egg width may represent an overall improvement in the hens' nutritional state as a result of the detoxifying capabilities of activated charcoal, which can cause improved nutrient utilization, nutrient absorption, leading to increases in egg dimensions according to Firdus *et al.* (2020). There was no significant variation in egg length among the treatments, showing that while activated charcoal supplementation may improve specific quality indices, it does not impact other elements of egg quality. Santos and Eerden (2021) observed varying impacts of dietary supplements on egg quality

parameters, supporting the pattern of external egg traits result in this study. Kim *et al.* (2019) reported that charcoal supplementation improved egg production and quality, whereas (Rattanawut, 2014) found that the benefits varied depending on the dietary composition and environmental conditions. There was a substantial increase in shell weight with increasing dietary levels of activated charcoal, while shell thickness was comparable across the treatment groups. This is supported by Award *and* Bohm, (2009), who found that activated charcoal can improve shell quality by increasing calcium absorption. A study by Kutlu *et al.* (2000) indicated that including activated sheabutter charcoal in the diets of laying hens significantly increased egg shell weight. Egg shape index was found to be similar across treatments in line with an earlier report that while nutritional supplements can change some egg quality metrics, they may not significantly affect other indices (Zhao *et al.*, 2023).

4.5 Effect of Activated Charcoal Supplemented Diets on Internal Egg Quality of Hens

Yolk height of chickens fed activated charcoal supplemented diets varied significantly among the treatment groups, and hens in T5 diet had highest value than the other treatments. The result is not in line with the finding of Kalus *et al.* (2020) that addition of biochar (form of activated charcoal) to the diet of hens positively influenced laying performance and shell quality but did not significantly affect the yolk traits. Changes in dietary components, particularly protein and fats levels can significantly influence yolk traits including height (Gama *et al.* 2024). Yolk diameter and weight of the AC supplemented diets were comparable to the control. Suggesting that the nutrients intake by the hens had no effect on them. The albumen weight showed a positive correlation with increase in activated charcoal dose. This result is not in agreement with Okey *et al.* (2021) who reported no significant effect on albumen weight. Both yolk index and haugh unit did not vary significantly from the control group, suggesting that 0.5% to 2% activated charcoal feed supplement did not these internal traits. Consequently, haugh unit and yolk index which relate to egg freshness and overall quality remained stable. This result is in agreement with Kutlu *et al.* (2000) and Ayanwale *et al.* (2006) that activated charcoal supplementation does not markedly affect these internal egg indices. A positive significant correlation in yolk colour was observed with increase in the activated charcoal dose from 0% to 2%. This showed that higher activated charcoal levels can enhance yolk pigmentation. Increase in activated charcoal supplementation in layers' diet has been found to increase yolk colour due to a reduction in oxidative stress and inflammation in the hens' ovaries and liver, which precipitated yolk synthesis and deposition of pigment (Nys and Guyot, 2011).

5. CONCLUSION

There was positive correlation between the activated charcoal levels used and egg weight, egg length, egg width and shell weight (external egg traits), and yolk weight, egg height, albumen

height, albumen weight, yolk index, haugh unit and yolk colour (internal egg traits). Activated charcoal can be used as a feed supplement in layers' diet at a level of up to 2% to enhance egg weight, shell weight and yolk colour, which are critical consumers' preference considerations without any adverse effect on other external and internal traits.

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DECLARATION OF COMPETING INTERESTS

Authors have declared that no competing interests exist.

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