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# Response of laying hens to dietary ginger (*Zingiber officinale*) rhizome powder supplementation pre- and post moulting

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**Abstract**

*Induced moulting in hens generate enormous physiological stress which compromises health, post moult performance, and food safety. To minimize moulting stress and mitigate its negative impacts, requires the adoption of management practices that reduce microbial infection, and spread, and enhance performance before, during, and after moulting. The present study therefore, evaluated the effects of ginger (Zingiber officinale) rhizome powder dietary supplementation on pre- and post-moult performance of shaver brown (SB) and indigenous (IC) layer chickens (85 weeks of age, 65 weeks in lay). The study was in three phases namely Phase I: pre-moulting evaluation, phase II: moulting treatment, and phase III: post moult evaluation. For each study, birds received 12 h natural light, and darkness, and were housed in individual laying cages provided with water nipples and feeding trough. Parameters measured were body weight (BW), hen day egg production (HDEP), and egg weight (EW). Results showed improved pre- and post-moult BW, HDEP, and EW in both genotypes in the groups fed dietary ginger powder. Genotypes did not differ significantly within dietary groups in the studied traits. Fasted SB hens fed ginger diet oviposited earlier than counterparts fed basal diet but the latter group attained 50 % HDEP earlier. Moulting BW loss was higher in fasted birds and in birds fed ginger diet pre-moulting than those fed basal diet. Whereas fasted SB hens oviposited during the period of study, the IC could not. Laying attained 100 % in Zn moulted genotypes and 66.8 % in fasted SB within 21 d post moulting. It is concluded that high dietary Zn is equally effective as fasting in moulting aged layer chickens and that ginger rhizome powder dietary supplementation improves pre- and post moult performance of laying hens. A shorter than 14 days moulting treatment or moulting to a target body weight loss is recommended for light breeds like the IC to enhance recovery and early postmoult egg production.*

**Key words:** feed additive, layer chicken, pre- moult, post moult, performance

## Réponse des poules pondeuses à la supplémentation alimentaire en poudre de rhizome de gingembre (*Zingiber officinale*) avant et après la mue

**Résumé**

*La mue induite chez les poules génère un énorme stress physiologique qui compromet la santé, les performances après la mue et la sécurité alimentaire. Pour minimiser le stress de la mue et atténuer ses impacts négatifs, il faut adopter des pratiques de gestion qui réduisent l'infection microbienne et la propagation, et améliorent les performances avant, pendant et après la mue. La présente étude a donc évalué les effets de la supplémentation alimentaire en poudre de rhizome de gingembre (Zingiber officinale) sur les performances avant et après la mue des poules pondeuses brunes (PB) et indigènes (IC) (85 semaines d'âge, 65 semaines de ponte) . L'étude s'est déroulée en trois phases, à savoir la phase I : évaluation avant la mue, la* *phase II : traitement de la mue et la phase III : évaluation après la mue. Pour chaque étude, les oiseaux ont reçu 12 h de lumière naturelle et d'obscurité, et ont été logés dans des cages de ponte individuelles munies de tétines d'eau et d'abreuvoirs. Les paramètres mesurés étaient le poids corporel (PC), la production d'œufs par jour de poule (PŒJP) et le poids des œufs (PŒ). Les résultats ont montré une amélioration du poids corporel, du PŒJP et de le PŒ avant et après la mue pour les deux génotypes dans les groupes nourris avec de la poudre de gingembre alimentaire. Les génotypes ne différaient pas significativement au sein des groupes alimentaires dans les traits étudiés. Les poules PB à jeun nourries au gingembre ont pondu plus tôt que leurs homologues nourries au régime de base, mais ce dernier groupe a atteint 50 % de PŒJP plus tôt. La perte de poids corporel pendant la mue était plus élevée chez les oiseaux à jeun et chez les oiseaux nourris au gingembre avant la mue que chez ceux nourris avec un régime de base. Alors que les poules PB à jeun ont pondu pendant la période d'étude, l'IC ne le pouvait pas. La ponte a atteint 100 % chez les génotypes mués Zn et 66,8 % chez les PB à jeun dans les 21 jours suivant la mue. Il est conclu qu'une alimentation riche en Zn est aussi efficace que le jeûne chez les poules pondeuses âgées en mue et que la supplémentation alimentaire en poudre de rhizome de gingembre améliore les performances avant et après la mue des poules pondeuses. Un traitement de mue de moins de 14 jours ou une mue vers une perte de poids cible est recommandé pour les races légères comme l'IC afin d'améliorer la récupération et la production d'œufs après la mue.*

**Mots clés** : additif alimentaire, poule pondeuse, pré-mue, post-mue, performance

## Introduction

Age is an important determinant of productivity in laying flocks (Holt, 2003; Tumova and Gous, 2012) influencing the health, and livability of individual birds as well as rate of lay, and egg quality (Tumova and Gous, 2012; Saibaba *et al*., 2021). When productivity becomes uneconomic due to aging, the farmer continues the enterprise by force moulting the flock to rapidly enter a second laying cycle (Aygun and Olgun, 2010; Wein *et al*., 2020) or by replacement of the flock. The choice is based on economic considerations. Ogbu *et al*. (2019) highlighted the benefits of induced moulting to include extending the lifetime performance of hens, and income to the farmer while raising replacement stock. Programs employed to force moult hens include feed deprivation, photoperiod reduction, mineral supplementation and feeding of high fiber or low energy diets. Fasting is the traditional method of inducing hens to moult (Berry, 2003; Ricke *et al*., 2013; Bozkurt *et al*., 2016) and provides the standard for comparing results from other moulting programmes (Landers *et al*., 2005; Santos *et al*., 2014). Moulting is a complex physiological process that involves remodeling of the body and resetting of the neural system to respond to photostimulation (Kuenzel, 2003; Ricke *et al*., 2013). The regeneration of the reproductive organs, and improved livability post moulting leads to improved egg production, and egg quality compared to the immediate pre-moulting period. Among other factors, bird genotype could influence the rate and degree of body weight loss, reproductive involution, impact of moulting stress, and hence post moult performance. Our previous study had shown differential rate, and percent body weight loss and cessation of egg production in exotic and indigenous chickens subjected to the same moulting programmes (Ogbu *et al*., 2019).

The moulting process predisposes to health and welfare challenges (Verbeek and Blache 2019; Fard *et al*., 2020). Nutritional restriction, reduced photoperiod, induced anorexia, body fat catabolism, reduced immune status, generation of new feathers, vascularization of feather follicles and papillae, cyclic osteoporosis, increased rate of protein, feather keratin, and skeletal muscle synthesis, and changes in metabolic rate are components of moulting stress (Golden *et al*., 2008; Ricke *et al*., 2013). Increased levels of reactive oxygen species (ROS), serum corticosteroids, serum and tissue malondyaldehyde (MDA), high heterophil:lymphocyte ratio (Campo *et al*., 2008; Mazzuco *et al*., 2011; Mert and Yildirim, 2016; Wein *et al*., 2020), enhanced spread of pathogens within and between flocks (Yousaf and Ahmed, 2006; Filho *et al*., 2019) and exacerbation of existing infections mark the oxidative stress associated with moulting. Again, bird genetics could influence the generation and susceptibility to these adverse factors and hence post moult performance.

To minimize the negative impact of forced moult on hen welfare, and performance, there is need to employ management practices that minimize and mitigate the impact of moulting stress, and enhance flock wellbeing before, during, and after moulting. Administration of antibiotics (Seo *et al*., 2000), and immunization (Holt *et al*., 2002) prior to moulting were shown to dramatically reduce the shedding and internal organ colonization by Salmonella enteritidis in moulted hens. Following the campaign to limit antibiotic use in animal production, it becomes imperative that alternative additives with equivalent beneficial effects be evaluated. Prebiotics such as plant spices that have proven efficacy against oxidative stress, and intestinal pathogens (Baurhoo *et al*., 2009; Swiatkiewicz *et al*., 2010; Bozkurt *et al*., 2016) are ready possibilities. Ginger (Z. officinale), a tropical rhizome acclaimed to have antimicrobial, anti-parasitic, and antioxidant effects (Ibtisham *et al*., 2019; Wen *et al*., 2019) resulting from contained bioactive compounds such as gingerdione, gingerdiol, gingerol, and zingibain (Aikpitanyi *et al*., 2019; Wen *et al*., 2019) could be beneficial in this regard. Ginger alleviates oxidative stress, enhances antioxidant status, egg production, and egg quality in laying hens (Gurbuz *et al*., 2017; Ibtisham *et al*., 2019). Ginger is available and affordable to the resource poor farmers in Nigeria. We hypothesize that the inclusion of ginger rhizome powder in the diet pre- and post moulting will enhance the performance of aged and moulted laying hens. The present study therefore, seeks to evaluate the effects of ginger rhizome powder dietary supplementation on pre- and post-moult performance of exotic and indigenous layer chickens.

## Materials and methods

Three hundred and twenty aged laying hens (85 weeks of age, 65 weeks in lay) belonging to two genotypes namely local chicken, and Shaver brown (160/genotype) were used for the study conducted in three phases. Phase I (lasted 21 days) evaluated the effect of ginger rhizome powder supplementation in laying diet on body weight, and egg production of the laying hens. For this study, 40 birds of each genotype were randomly selected and assigned to control group (layer mash: 16 % CP and 3250 Kcal ME/kg as basal diet) while the rest (120/genotype) were assigned to supplemented group (basal diet supplemented with ginger rhizome (*Z. officinale*) powder at 20g/kg). For each treatment, birds were housed in individual laying cages equipped with water nipples and feeding trough. Birds were fed at 125g/bird/day in two parts at 08:30 h (morning feeding) and 14:00 h (afternoon feeding). Water was given *ad libitum*. In phase II (lasted 14 days), the response of hens of each genotype fed ginger diet to different moulting methods was evaluated. For this purpose, birds of each genotype in the supplemented groups in phase I were randomly shared into three treatments of 40 birds each namely unmoulted control group, zinc supplemented group (Zn group), and feed deprived group (fasting group). Again, birds were housed in individual cages and provided with water *ad libitum*. The Zn groups (for both genotypes) were fed basal diet supplemented with zinc as ZnO at 20,000 mg/kg or 20,000 ppm (El-Deek and Al-Harthi 2004) at 125g/hen/day as in phase I. Phase III (lasted 21 days) evaluated the effect of dietary ginger supplementation on post moult performance. Birds in each moulted group were randomly share into two groups of 20 birds each namely Zn moulted group fed basal diet (Zn control group), Zn moulted group fed ginger supplemented diet (Zn ginger group), fasted group fed basal diet (fasted control group), and fasted group fed ginger supplemented diet (fasted ginger group). For both supplemented and control groups, birds were fed ad libitum for the first week post moult followed by 125g/bird/day for the remaining duration of the study. In all phases birds received 12 h of light and darkness throughout the period of study.

**Data collection and Analysis**

The experimental groups were evaluated for body weight, egg production, and egg weight. Body weight was determined weekly using a digital scale. Egg production was recorded daily for individual birds in an egg chart. Egg weight was obtained daily by weighing on a digital weighing balance. Weekly egg production was obtained by summing the daily egg number for each group for seven days while percent hen day egg production (HDEP %) was calculated from daily egg record for each group. Data were subjected to analysis of variance in completely randomized design and independent samples t-test to compare between groups and genotypes, respectively.

**Results**

**Trend in Pre-moult performance of layer chickens fed basal or ginger diets**

The trend in body weight (BW), egg weight (EW), and hen day egg production (HDEP) before moulting treatment is presented in Table 1. For SB birds fed basal diet, BW, HDEP and EW remained statistically similar across the experimental period ranging from 1.68 to 1.80 kg, 35.71 to 71.43 %, and 54.72 to 59.55 g, respectively. Laying performance was also similar across the study period in SB hens fed ginger diet but BW increased significantly from the initial value of 1.76 to 2.18 kg at the end of the pre-moulting treatment. For the IC, BW increased significantly from 0.95 to 1.28 kg and 1.12 to 1.46 kg for basal and ginger diet groups, respectively while HDEP and EW were significantly higher during the pre-moulting treatment compared to initial values.

**Effect of diet on pre-moult performance of layer chicken genotypes**

Birds fed ginger diet had higher BW and EW ($p < 0.05$) than their counterparts fed basal diet in both genotypes (Table 2). Overall, body weight gain (BWG) was 420 g vs 70 g for ginger group vs basal diet group in SB. Hen day egg production (HDEP %) did not differ significantly between the treatment groups in the two genotypes but values for the ginger groups were consistently higher especially for SB hens. Shaver brown hens fed ginger gained 4.77 % in HDEP while a decrease of 21.43 % was observed in those maintained on basal diet. An increase of 21.43 vs 15.72 % for ginger vs basal diet group was observed in the IC.

**Table 1: Trend in pre -moult performance of layer chicken genotypes fed basal diet or basal diet supplemented with ginger (Z. officinale) rhizome powder**

| | Performance variables | | |
|---|---|---|---|
| Shaver brown (Diet) | BW (kg) | HDEP (%) | EW (g) |
| Basal | | | |
| Initial | 1.73 ± 0.07 | 71.43 ± 10.56 | 59.55 ± 1.20 |
| $WK_1$ | 1.78 ± 0.04 | 42.86 ± 13.04 | 54.72 ± 1.38 |
| $WK_2$ | 1.68 ± 0.11 | 35.71 ± 9.22 | 55.42 ± 0.55 |
| $WK_3$ | 1.80 ± 0.12 | 50.00 ± 15.43 | 57.34 ± 1.57 |
| Ginger | | | |
| Initial | $1.76 \pm 0.14^{b}$ | 71.43 ± 10.56 | 59.62 ± 1.15 |
| $WK_1$ | $1.76 \pm 0.15^{b}$ | 57.20 ± 11.99 | 65.88 ± 1.81 |
| $WK_2$ | $1.81 \pm 0.14^{b}$ | 57.16 ± 11.99 | 61.01 ± 1.20 |
| $WK_3$ | $2.18 \pm 0.16^{a}$ | 76.20 ± 9.53 | 61.99 ± 1.15 |
| Indigenous chicken (Diet) | | | |
| Basal | | | |
| Initial | $0.95 \pm 0.05^{b}$ | $35.71 \pm 3.69^{c}$ | 39.08 ± 0.54 |
| $WK_1$ | $1.01 \pm 0.04^{b}$ | $65.71 \pm 7.19^{a}$ | 37.74 ± 0.38 |
| $WK_2$ | $0.94 \pm 0.04^{b}$ | $74.29 \pm 3.69^{a}$ | 38.07 ± 0.47 |
| $WK_3$ | $1.28 \pm 0.06^{a}$ | $51.43 \pm 5.95^{b}$ | 38.55 ± 0.61 |
| Ginger | | | |
| Initial | $1.12 \pm 0.17^{b}$ | $35.71 \pm 3.69^{b}$ | $39.04 \pm 0.68^{b}$ |
| $WK_1$ | $1.38 \pm 0.15^{ab}$ | $51.43 \pm 10.56^{a}$ | $42.84 \pm 1.08^{a}$ |
| $WK_2$ | $1.33 \pm 0.15^{ab}$ | $60.00 \pm 8.73^{a}$ | $42.46 \pm 1.03^{a}$ |
| $WK_3$ | $1.46 \pm 0.08^{a}$ | $57.14 \pm 9.18^{a}$ | $43.93 \pm 0.68^{a}$ |

a,b,c: column means followed by different superscripts are significantly different ($p < 0.05$), BW: body weight, HDEP: hen-day egg production, EW: egg weight.

**Effect of genotype on pre-moult HDEP and changes in performance traits**

Comparison between genotypes within dietary groups for pre-moulting HDEP and changes in performance traits shows that SB hens had significantly higher HDEP compared to IC at onset of dietary treatments (71.43 ± 10.56 vs 35.71 ± 3.69 %) for SB vs IC in both basal and ginger diet groups (Table 3). HDEP was however, significantly lower at week 2 in SB hens fed basal diet compared to IC counterparts (35.71 ± 9.22 vs 74.29 ± 3.69 %). Summed over the pre-moulting phase, HDEP did not differ significantly between genotypes in the two dietary groups, and changes in the performance variables were mostly not significantly different between genotypes except cumulative gain in BW which was higher in IC fed basal diet compared to SB counterparts (0.32 vs 0.07 kg or 33.7 vs 4.1 %), reduction in egg weight at wk 1 in basal diet group (4.83 g for SB vs 1.42 g for IC), and at wk 2 and 3 in ginger diet group.

**Trend in post moult egg production of fasted and Zn moulted hens**

The trend in post moult HDEP of fasted or Zn moulted SB and IC fed basal or ginger diets postmoulting is presented in Figure 1. Laying commenced in fasted SB hens fed basal diet on d 18 post moulting and they laid between 50 and 100 % thereafter while counterparts fed ginger diet oviposited first on d 7, attained 50 % lay first on d 14, and laid between 50 and 100 % from d 16 (panel A). For the IC, egg laying did not commence in both dietary treatments within the 21 days of post moult evaluation. For the groups moulted by Zn, oviposition first occurred in SB hens on d 2 post moulting in both dietary groups, reached 50 % and above from d 14 in basal diet group;

but from d 19 in ginger diet group (Panel B). In this genotype, laying became regular (none zero HDEP) from d 10 post moulting in basal diet group but from d 12 in ginger diet group. For the IC, egg production commenced on d 2 post moulting and reached 50 % and above on d 16 in basal diet group; while in ginger diet group laying commenced on d 8, reached 50 % on d 11 and higher than 50 % for the first time on d 16 (Panel C). Laying did not become regular in the IC genotype over the period of study.

**Table 2: Effect of ginger (Z. officinale) rhizome powder dietary supplementation on Pre-moult performance of layer chickens**

| | Shaver brown (Diet) | | Indigenous chicken (Diet) | |
|---|---|---|---|---|
| Parameter | Ginger | Basal | Ginger | Basal |
| BW (kg) | | | | |
| $BW_0$ | 1.76 ± 0.14 | 1.73 ± 0.07 | 1.12 ± 0.17 | 0.95 ± 0.05 |
| $BW_1$ | 1.76 ± 0.15 | 1.78 ± 0.04 | 1.38 ± 0.15$^a$ | 1.01 ± 0.04$^b$ |
| $BW_2$ | 1.81 ± 0.14$^a$ | 1.68 ± 0.11$^b$ | 1.33 ± 0.15$^a$ | 0.94 ± 0.04$^b$ |
| $BW_3$ | 2.18 ± 0.16$^a$ | 1.80 ± 0.12$^b$ | 1.46 ± 0.08$^a$ | 1.28 ± 0.06$^b$ |
| $\Delta BW_{0-3}$ | 0.42$^a$ | 0.07$^b$ | 0.34 | 0.33 |
| HDEP (%) | | | | |
| $HDEP_0$ | 71.43 ± 10.56 | 71.43 ± 10.56 | 35.71 ± 3.69 | 35.71 ± 3.69 |
| $HDEP_1$ | 57.20 ± 11.99 | 42.86 ± 13.04 | 51.43 ± 10.56 | 65.71 ± 7.19 |
| $HDEP_2$ | 57.16 ± 11.99 | 35.71 ± 9.22 | 60.00 ± 8.73 | 74.29 ± 3.69 |
| $HDEP_3$ | 76.20 ± 9.53 | 50.00 ± 15.43 | 57.14 ± 9.18 | 51.43 ± 5.95 |
| $\Delta HDEP_{0-3}$ | 4.77 | -21.43 | 21.43 | 15.72 |
| EW (g) | | | | |
| $EW_0$ | 59.62 ± 1.15 | 59.55 ± 1.20 | 39.04 ± 0.68 | 39.08 ± 0.54 |
| $EW_1$ | 65.88 ± 1.81$^a$ | 54.72 ± 1.38$^b$ | 42.84 ± 1.08$^a$ | 37.74 ± 0.38$^b$ |
| $EW_2$ | 61.01 ± 1.20$^a$ | 55.42 ± 0.55$^b$ | 42.46 ± 1.03$^a$ | 38.07 ± 0.47$^b$ |
| $EW_3$ | 61.99 ± 1.15$^a$ | 57.34 ± 1.57$^b$ | 43.93 ± 0.68$^a$ | 38.55 ± 0.61$^b$ |
| $\Delta EW_{0-3}$ | 2.37 | -2.21 | 4.89$^a$ | -0.53$^b$ |

a,b: row means followed by different superscripts are significantly different ($p < 0.05$).

**Table 3: Comparison between genotypes for pre-moult performance of layers fed basal diet or diet supplemented with ginger (Z. officinale) rhizome powder**

| | **Basal diet** | | **Ginger diet** | |
|---|---|---|---|---|
| **Parameter** | **Shaver brown** | **Indigenous hen** | **Shaver brown** | **Indigenous hen** |
| HDEP (%) | | | | |
| Initial | 71.43 ± 10.56$^a$ | 35.71 ± 3.69$^b$ | 71.43 ± 10.56$^a$ | 35.71 ± 3.69$^b$ |
| $WK_1$ | 42.86 ± 13.04 | 65.71 ± 7.19 | 57.20 ± 11.99 | 51.43 ± 10.56 |
| $WK_2$ | 35.71 ± 9.22$^b$ | 74.29 ± 3.69$^a$ | 57.16 ± 11.99 | 60.00 ± 8.73 |
| $WK_3$ | 50.00 ± 15.43 | 51.43 ± 5.95 | 76.20 ± 9.53 | 57.14 ± 9.18 |
| Overall | 50.00 ± 7.72 | 53.81 ± 11.20 | 65.50 ± 4.90 | 51.07 ± 7.66 |
| $^*\Delta$HDEP (%) | | | | |
| $WK_{0-1}$ | -28.57 ± 14.38 | 30.00 ± 8.73 | -14.23 ±11.13 | 15.71 ± 11.31 |
| $WK_{1-2}$ | -7.14 ± 13.04 | 8.57 ± 5.95 | -0.04 ± 20.59 | 8.57 ± 12.99 |
| $WK_{2-3}$ | 14.29 ± 17.98 | -22.86 ± 8.08 | 19.04 ± 14.30 | -2.86 ± 13.40 |
| $WK_{0-3}$ | -21.43 ± 15.95 | 15.71 ± 6.49 | -4.77 ± 16.44 | 21.43 ± 8.57 |
| $^*\Delta$BW (kg) | | | | |
| $WK_{0-1}$ | 0.06 ± 0.09 | 0.08 ± 0.07 | 0.01 ± 0.21 | 0.26 ± 0.18 |
| $WK_{1-2}$ | -0.10 ± 0.11 | -0.06 ± 0.02 | 0.06 ± 0.18 | -0.04 ± 0.16 |
| $WK_{2-3}$ | 0.12 ± 0.07 | 0.33 ± 0.05 | 0.37 ± 0.16 | 0.13 ± 0.14 |
| $WK_{0-3}$ | 0.07 ± 0.12$^b$ | 0.32 ± 0.04$^a$ | 0.42 ± 0.19 | 0.34 ± 0.16 |
| $^*\Delta$EW (g) | | | | |
| $WK_{0-1}$ | -4.83 ± 1.01$^a$ | -1.42 ± 0.69$^b$ | 6.31 ± 2.32 | 3.33 ± 1.57 |
| $WK_{1-2}$ | 0.70 ± 0.12 | 0.19 ± 0.66 | -4.87 ± 1.38$^a$ | -0.38 ± 0.07$^b$ |
| $WK_{2-3}$ | 1.92 ± 0.14 | 0.48 ± 0.92 | 0.98 ± 0.20$^b$ | 1.47 ± 0.14$^a$ |
| $WK_{0-3}$ | -2.22 ± 1.05 | -0.53 ± 0.56 | 2.37 ± 1.65 | 4.89 ± 1.05 |

a,b: row means followed by different superscripts are significantly different ($p < 0.05$), ΔHDEP: change in hen day egg production; * a negative value indicates a loss in trait value.

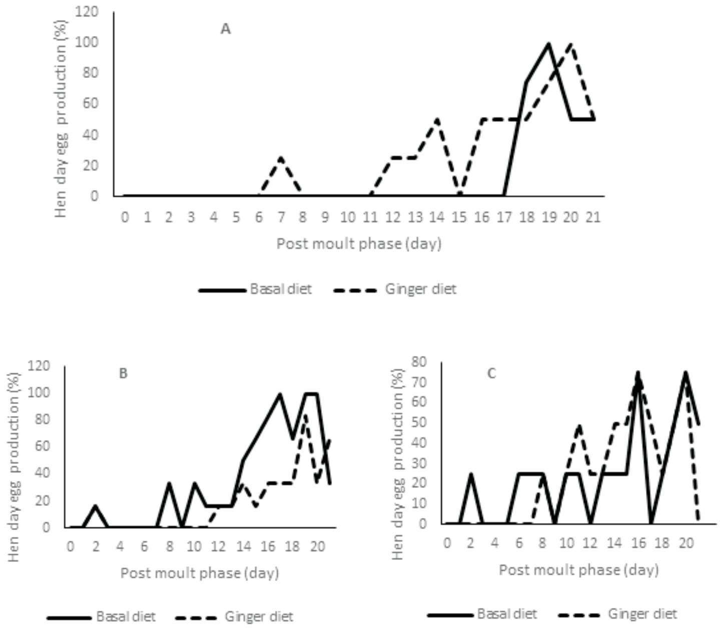


**Figure 1: Trend of HDEP in moulted layer chickens. Panel A: Shaver brown hen, fasted group; Panel B: Shaver brown hen, Zn moulted group; Panel C: indigenous chicken, Zn moulted group.**

**Effect of diet on post moult performance of fasted and Zn moulted layer chickens**

Body weight loss following fasting was higher in SB and IC belonging to ginger diet group compared to counterparts fed basal diet (0.99 vs 0.64 kg or 45.4 vs 35.6 % for SB, and 0.54 vs 0.40 kg or 37.0 vs 31.3 % for IC) however, there were no significant differences in post moult BW between dietary groups in both genotypes except at week 1 when fasted IC fed basal diet had higher BW compared to counterparts fed ginger diet (Table 4). Fasted SB hens fed ginger diet had significantly higher HDEP at week 2 compared to counterparts fed basal diet but EW did no differ significantly between dietary groups in this genotype. The IC could not oviposit during the experimental period.

Zinc moulted hens fed ginger diet had higher BW loss at the end of moulting treatment than counterparts fed basal diet (0.76 vs 0.42 kg or 34.9 vs 23.1 % for SB and 0.25 vs 0.14 kg or 17.1 vs 10.9 % for IC) (Table 5) however, there were no significant differences in post moult BW values between dietary groups in both genotypes.

Hens fed basal diet had higher ($p < 0.05$) HDEP in wk1 for IC and week 3 for SB compared to counterparts fed ginger diet ($10.71 \pm 5.05$ vs $0.00 \pm 0.00$ % for IC; and $78.75 \pm 9.43$ vs $42.84 \pm 8.80$ % for SB). Egg weight differed significantly only at week 2 post moulting in favour of SB hens fed ginger diet but did not differ significantly between dietary groups in Zn moulted IC.

**Effect of genotype on trend of post moult HDEP in hens fed basal or ginger diet**

Laying commenced on d 18 in fasted SB hens fed basal diet but their IC counterparts did not oviposit within the study period (Fig. 2, panel A). In fasted groups fed ginger diet (Panel B), laying commenced on d 7 but became consistent from d 16. Again, the IC did not oviposit during the study.

**Table 4: Effect of diet on post moult performance of layer chickens moulted by fasting**

| | **Shaver brown (Diet)** | | **Indigenous chicken (Diet)** | |
|---|---|---|---|---|
| | **Basal** | **Ginger** | **Basal** | **Ginger** |
| BW (kg) | | | | |
| Pre-moult | 1.80 ± 0.12$^{b}$ | 2.18 ± 0.16$^{a}$ | 1.28 ± 0.06$^{b}$ | 1.46 ± 0.08$^{a}$ |
| End of moult | 1.16 ± 0.05 | 1.19 ± 0.05 | 0.88 ± 0.05 | 0.92 ± 0.06 |
| BW loss (%) | 0.64 (35.6) | 0.99 (45.4) | 0.40 (31.3) | 0.54 (37.0) |
| Post moult | | | | |
| Week$_1$ | 1.51 ± 0.02 | 1.44 ± 0.04 | 1.29 ± 0.03$^{a}$ | 1.08 ± 0.07$^{b}$ |
| Week$_2$ | 1.64 ± 0.01 | 1.66 ± 0.03 | 1.33 ± 0.04 | 1.22 ± 0.08 |
| HDEP (%) | | | | |
| Pre-moult | 50.00 ± 15.43 | 76.20 ± 9.53 | 51.43 ± 5.95 | 57.14 ± 9.18 |
| End of moult | 0.00 ± 0.00 | 0.00 ± 0.00 | 0.00 ± 0.00 | 0.00 ± 0.00 |
| Post moult | | | | |
| Week$_1$ | 0.00 ± 0.00 | 0.00 ± 0.00 | 0.00 ± 0.00 | 0.00 ± 0.00 |
| Week$_2$ | 0.00 ± 0.00$^{b}$ | 14.29 ± 7.43$^{a}$ | 0.00 ± 0.00 | 0.00 ± 0.00 |
| Week$_3$ | 39.29 ± 15.29 | 53.57 ± 11.48 | 0.00 ± 0.00 | 0.00 ± 0.00 |
| EW (g) | | | | |
| Pre-moult | 57.34 ± 1.57$^{b}$ | 61.99 ± 1.15$^{a}$ | 38.55 ± 0.61$^{b}$ | 43.93 ± 0.68$^{a}$ |
| End of moult | - | - | - | - |
| Post moult | | | | |
| Week$_1$ | - | - | - | - |
| Week$_2$ | - | 61.98 ± 3.35 | - | - |
| Week$_3$ | 59.86 ± 1.01 | 63.36 ± 1.44 | - | - |

a,b: row means within genotypes followed by different superscripts are significantly different ($p < 0.05$).

**Table 5: Effect of diet on post moult performance of layer chickens moulted by Zn dietary supplementation**

| | Shaver brown (Diet) | | Indigenous chicken (Diet) | |
|---|---|---|---|---|
| | Basal | Ginger | Basal | Ginger |
| BW (kg) | | | | |
| Pre-moult | 1.80 ± 0.12$^{b}$ | 2.18 ± 0.16$^{a}$ | 1.28 ± 0.06$^{b}$ | 1.46 ± 0.08$^{a}$ |
| End of moult | 1.38 ± 0.04 | 1.42 ± 0.05 | 1.14 ± 0.08 | 1.21 ± 0.04 |
| BW loss (%) | 0.42 (23.3) | 0.76 (34.9) | 0.14 (10.9) | 0.25 (17.1) |
| Post moult | | | | |
| Week$_1$ | 1.52 ± 0.04 | 1.49 ± 0.03 | 1.24 ± 0.08 | 1.24 ± 0.07 |
| Week$_2$ | 1.72 ± 0.03 | 1.66 ± 0.03 | 1.36 ± 0.10 | 1.28 ± 0.08 |
| HDEP (%) | | | | |
| Pre-moult | 50.00 ± 15.43 | 76.20 ± 9.53 | 51.43 ± 5.95 | 57.14 ± 9.18 |
| End of moult | 5.94 ± 4.71 | 5.94 ± 4.71 | 10.71 ± 4.25 | 12.50 ± 4.56 |
| Post moult | | | | |
| Week$_1$ | 2.39 ± 2.39 | 2.39 ± 2.39 | 10.71 ± 5.05$^{a}$ | 0.00 ± 0.00$^{b}$ |
| Week$_2$ | 23.81 ± 6.14 | 9.53 ± 4.95 | 17.86 ± 4.61 | 28.57 ± 6.52 |
| Week$_3$ | 78.57 ± 9.43$^{a}$ | 42.84 ± 8.80$^{b}$ | 42.86 ± 1.51 | 46.43 ± 10.10 |
| EW (g) | | | | |
| Pre-moult | 57.34 ± 1.57$^{b}$ | 61.99 ± 1.15$^{a}$ | 38.55 ± 0.61$^{b}$ | 43.93 ± 0.68$^{a}$ |
| End of moult | 62.40 ± 1.60 | 62.40 ± 1.60 | 40.77 ± 2.57 | 40.77 ± 2.57 |
| Post moult | | | | |
| Week$_1$ | 59.30 ± 2.01 | 61.50 ± 0.00 | 37.07 ± 3.69 | - |
| Week$_2$ | 58.37 ± 1.76$^{b}$ | 64.78 ± 2.02$^{a}$ | 39.06 ± 1.52 | 36.85 ± 1.31 |
| Week$_3$ | 58.34 ± 1.00 | 60.23 ± 1.57 | 38.98 ± 1.15 | 39.13 ± 1.43 |

a,b: row means within genotypes followed by different superscripts are significantly different ($p < 0.05$).

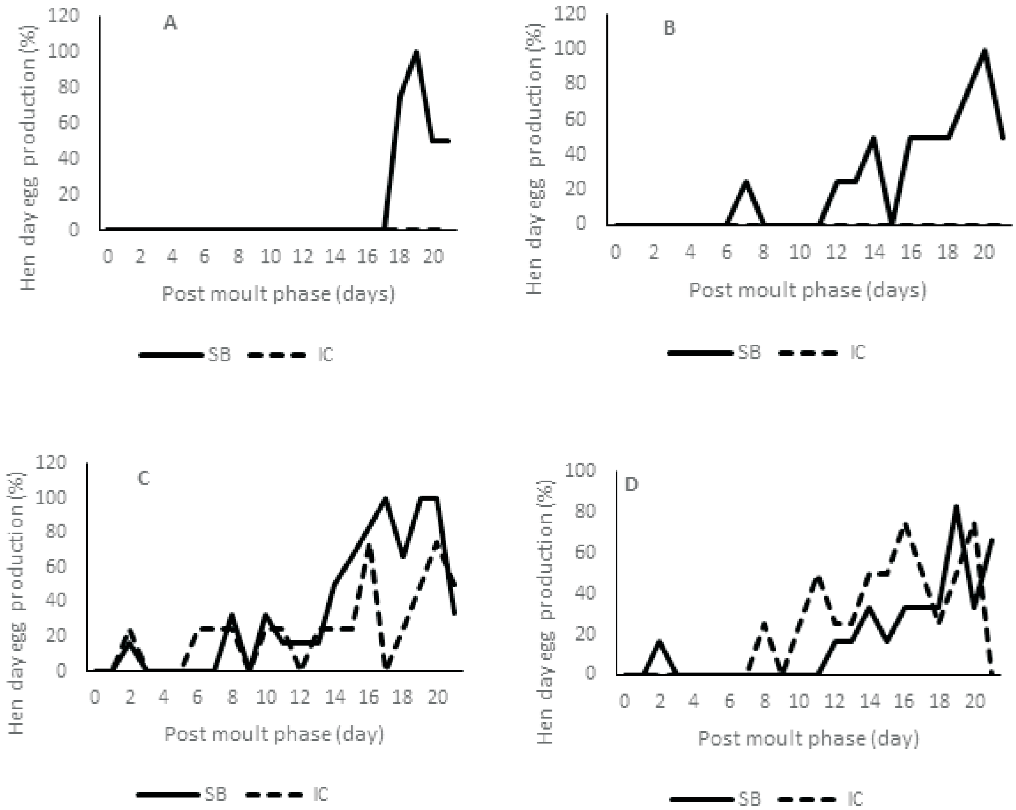


**Fig. 2: Trend in post moult HDEP of moulted hens. Panel A: fasted basal diet group; Panel B: fasted ginger diet group; panel C: Zn basal diet group; panel D: Zn ginger diet group.**

For hens moulted by Zn and fed basal diet post moult, oviposition commenced on d 2 in both genotypes but became regular (above 0 %) from d 10 in SB (range: 33 and 100 %) while laying fluctuated between 0 and 75 % in the IC (Panel C). In the groups fed ginger diet (Panel D), laying commenced on d 2 in SB but became regular from d 12 (range 16 and 83 %) while in IC, laying commenced on d 8 but fluctuated between 0 and 75 % during the study.

**Effect of moulting method on moult and post moult performance**

The effect of moulting method on moult and post moult performance of SB and IC in the dietary groups is presented in Tables 6 to 9. Fasted SB hens had significantly lower BW at the end of moulting compared to Zn moulted and control groups (Table 6).

Moulting BW loss was thus higher at 0.64 kg or 35.5 % in fasted hens compared to 0.42 and 0.05 kg or 23.3 and 2.8 % for Zn moulted and control groups, respectively. Post moult BW was however, similar between moulted groups fed basal diet and these were significantly smaller compared to control group at week 1 but did not differ significantly between moulted and control groups at week 2. The control group had low and fluctuating HDEP but this trait increased steadily in the moulted groups while egg weight did not differ significantly between the experimental groups. For the groups fed ginger diet post moulting (Table 7), BW was highest ($p < 0.05$) in the control group and least in the fasted groups. Again, HDEP fluctuated between 50 and 76 % in the control group but increased steadily in the moulted groups reaching 42 % in Zn group and 53 % in fasted group. Egg weight remained relatively stable at between 59 and 65 g in all groups and did not differ significantly between treatments.

For IC fed basal diet post moulting (Table 8), BW was higher in the group moulted with Zn compared to fasted and control groups which did not differ significantly. Fasted hens however, lost greater percentage of their BW compared to the group moulted with Zn (31.3 vs 10.9 %). Hen day egg production increased steadily in Zn moulted group reaching 42.86 ± 10.51 % in 3 weeks but fluctuated continuously in the control group between 35.7 % and 74.3% although it remained significantly higher in the control group compared to moulted groups until week 3 at which no significant difference was observed between Zn moulted group and control.

**Table 6: Post moult performance of Shaver brown hens subjected to different moulting protocols and fed basal diet post moulting**

| | Experimental groups | | |
|---|---|---|---|
| | **Zn** | **Fasting** | **Control** |
| BW (kg) | | | |
| Pre-moult | 1.80 ± 0.12 | 1.80 ± 0.12 | 1.78 ± 0.04 |
| End of moulting | $1.38 \pm 0.04^{b}$ | $1.16 \pm 0.05^{c}$ | $1.73 \pm 0.02^{a}$ |
| BW loss (%) | 0.42 (23.3) | 0.64 (35.5) | 0.05 (2.8) |
| Post moult | | | |
| $Week_1$ | $1.52 \pm 0.04^{b}$ | $1.51 \pm 0.02^{b}$ | $1.78 \pm 0.01^{a}$ |
| $Week_2$ | 1.72 ± 0.03 | 1.64 ± 0.01 | 1.68 ± 0.04 |
| HDEP (%) | | | |
| Pre-moult | 50.00 ± 15.43 | 50.00 ± 15.43 | 50.00 ± 15.43 |
| End of moulting | $5.94 \pm 4.71^{b}$ | $0.00 \pm 0.00^{c}$ | $71.43 \pm 10.56^{a}$ |
| Post moult | | | |
| $Week_1$ | $2.39 \pm 2.30^{b}$ | $0.00 \pm 0.00^{c}$ | $42.86 \pm 13.04^{a}$ |
| $Week_2$ | $23.81 \pm 6.14^{a}$ | $0.00 \pm 0.00^{b}$ | $35.71 \pm 9.22^{a}$ |
| $Week_3$ | 78.57 ± 9.42 | 39.29 ± 15.29 | 50.00 ± 15.43 |
| EW (g) | | | |
| End of moulting | 62.40 ± 1.60 | - | 59.55 ± 1.20 |
| Post moult | | | |
| $Week_1$ | 59.30 ± 2.01 | - | 54.72 ± 1.38 |
| $Week_2$ | 58.37 ± 1.76 | - | 55.42 ± 0.55 |
| $Week_3$ | 58.34 ± 1.00 | 59.86 ± 1.01 | 57.34 ± 1.57 |

a,b,c: row means followed by different superscripts are significantly different ($p < 0.05$).

**Table 7: Post moult performance of Shaver brown hens subjected to different moulting protocols and fed ginger diet post moulting**

| | Experimental groups | | |
|---|---|---|---|
| | **Zn** | **Fasting** | **Control** |
| BW (kg) | | | |
| Pre-moult | 2.18 ± 0.16 | 2.18 ± 0.16 | 1.78 ± 0.04 |
| End of moulting | $1.42 \pm 0.05^{b}$ | $1.19 \pm 0.05^{c}$ | $1.76 \pm 0.05^{a}$ |
| BW loss (%) | 0.72 (34.9) | 0.99 (45.4) | 0.02 (0.01) |
| Post moult | | | |
| $Week_1$ | $1.49 \pm 0.03^{b}$ | $1.44 \pm 0.04^{b}$ | $1.76 \pm 0.05^{a}$ |
| $Week_2$ | $1.66 \pm 0.03^{b}$ | $1.66 \pm 0.03^{b}$ | $1.81 \pm 0.05^{a}$ |
| HDEP (%) | | | |
| Pre-moult | | | |
| End of moulting | $5.94 \pm 4.71^{b}$ | $0.00 \pm 0.00^{b}$ | $71.43 \pm 10.56^{a}$ |
| Post moult | | | |
| $Week_1$ | $2.39 \pm 2.39^{b}$ | $3.57 \pm 3.57^{b}$ | $57.20 \pm 11.99^{a}$ |
| $Week_2$ | $9.53 \pm 4.95^{b}$ | $14.29 \pm 7.43^{b}$ | $57.16 \pm 11.99^{a}$ |
| $Week_3$ | $42.84 \pm 8.80^{b}$ | $53.57 \pm 11.48^{ab}$ | $76.20 \pm 9.53^{a}$ |
| EW (g) | | | |
| End of moulting | 62.40 ± 1.60 | - | 59.62 ± 1.15 |
| $Week_1$ | 61.50 ± 0.00 | 61.00 ± 0.00 | 65.88 ± 1.81 |
| $Week_2$ | 64.78 ± 2.02 | 61.98 ± 3.35 | 61.01 ± 1.20 |
| $Week_3$ | 60.23 ± 1.57 | 63.36 ± 1.44 | 61.99 ± 1.15 |

a,b,c: row means with different superscripts are significantly different ($p < 0.05$).

**Table 8: Post moult performance of indigenous chicken (IC) subjected to different moulting protocols and fed basal diet post moulting**

| | Experimental groups | | |
|---|---|---|---|
| | **Zn** | **Fasting** | **Control** |
| BW (kg) | | | |
| Pre-moult | 1.28 ± 0.06 | 1.28 ± 0.06 | 1.28 ± 0.06 |
| End of moulting | $1.14 \pm 0.08^{a}$ | $0.88 \pm 0.05^{b}$ | $1.08 \pm 0.05^{b}$ |
| BW loss | 0.14 (10.9) | 0.40 (31.3) | 0.20 (1.6) |
| Post moult | | | |
| $Week_1$ | $1.24 \pm 0.08^{a}$ | $1.29 \pm 0.06^{a}$ | $1.01 \pm 0.04^{b}$ |
| $Week_2$ | $1.36 \pm 0.10^{a}$ | $1.33 \pm 0.05^{a}$ | $0.94 \pm 0.04^{b}$ |
| HDEP (%) | | | |
| Pre-moult | 51.43 ± 5.95 | 51.43 ± 5.95 | 51.43 ± 5.95 |
| End of moulting | $10.71 \pm 4.25^{b}$ | $0.00 \pm 0.00^{c}$ | $35.71 \pm 3.69^{a}$ |
| Post moult | | | |
| $Week_1$ | $10.71 \pm 5.05^{b}$ | $0.00 \pm 0.00^{b}$ | $65.71 \pm 7.19^{a}$ |
| $Week_2$ | $17.86 \pm 4.61^{b}$ | $0.00 \pm 0.00^{c}$ | $74.29 \pm 3.69^{a}$ |
| $Week_3$ | $42.86 \pm 10.51^{a}$ | $0.00 \pm 0.00^{b}$ | $51.43 \pm 5.95^{a}$ |
| EW (g) | | | |
| Pre-moult | 38.55 ± 0.61 | 38.55 ± 0.61 | 38.55 ± 0.61 |
| End of moulting | 40.77 ± 2.57 | - | 39.04 ± 0.68 |
| Post moult | | | |
| $Week_1$ | 37.07 ± 3.69 | - | 37.74 ± 0.38 |
| $Week_2$ | 39.06 ± 1.52 | - | 38.07 ± 0.47 |
| $Week_3$ | 38.98 ± 1.15 | - | 38.55 ± 0.61 |

a,b,c: row means with different superscripts are significantly different ($p < 0.05$).

Fasted IC did not commence egg laying during the period of evaluation and post moult EW did not differ significantly between control and Zn moulted groups (range: 37.74 ± 0.38 - 39.04 ± 0.68 g for control group vs 37.07 ± 3.69 - 39.06 ± 1.52 g for Zn group). In moulted IC fed ginger diet (Table 9), end of moult and post moult BW did not differ significantly between the experimental groups however, fasted hens lost 37 % of pre-moult BW compared to 17.1 % for Zn group.

Egg production was significantly higher in the control group compared to moulted groups except at week 3 at which no significant difference was observed between Zn moulted group and the control (46.43 ± 10.10 and 57.14 ± 9.18 %, respectively). Again, whereas HDEP increased steadily in the Zn moulted group, it fluctuated continuously in the control group (range: 35.71 ± 3.71 - 60.00 ± 8.73 %). Egg weight was higher in the control group compared to Zn group only at week 2 post moulting (36.85 ± 1.31 vs 42.46 ± 1.03 g).

**Effect of genotype on HDEP and changes in performance traits in Zn moulted hens**

Comparison between genotypes for HDEP and changes in performance traits in hens moulted by Zn is presented in Tables 10 for basal diet group and Table 11 for ginger diet group.

Table 10 shows that HDEP increased steadily from 2.39 ± 2.39 % in week 1 to 78.57 ± 9.42 % in week 3 in SB hens and from 10.71 ± 5.05 to 42.86 ± 10.51 % over the same period in IC with significantly higher HDEP in SB compared to IC by the end of the study (78.57 ± 9.42 vs 42.86 ± 10.51). Gain in HDEP, and BW was also

**Table 9: Post moult performance of indigenous chicken (IC) subjected to different moulting protocols and fed ginger diet post moulting**

| | Experimental groups | | |
|---|---|---|---|
| | Zn | Fasting | Control |
| BW (kg) | | | |
| Pre-moult | 1.46 ± 0.08 | 1.46 ± 0.08 | 1.46 ± 0.08 |
| End of moulting | 1.21 ± 0.04$^{ab}$ | 0.92 ± 0.06$^{b}$ | 1.32 ± 0.17$^{a}$ |
| BW loss (%) | 0.25 (17.1) | 0.54 (37.0) | 0.14 (9.6) |
| Post moult | | | |
| Week$_1$ | 1.24 ± 0.07 | 1.08 ± 0.07 | 1.38 ± 0.15 |
| Week$_2$ | 1.28 ± 0.08 | 1.22 ± 0.08 | 1.33 ± 0.15 |
| HDEP (%) | | | |
| Pre-moult | 57.14 ± 9.18 | 57.14 ± 9.18 | 57.14 ± 9.18 |
| End of moulting | 10.71 ± 4.25$^{b}$ | 0.00 ± 0.00$^{c}$ | 35.71 ± 3.71$^{a}$ |
| Post moult | | | |
| Week$_1$ | 0.00 ± 0.00$^{b}$ | 0.00 ± 0.00$^{b}$ | 51.43 ± 10.56$^{a}$ |
| Week$_2$ | 28.57 ± 6.52$^{b}$ | 0.00 ± 0.00$^{c}$ | 60.00 ± 8.73$^{a}$ |
| Week$_3$ | 46.43 ± 10.10$^{a}$ | 0.00 ± 0.00$^{b}$ | 57.14 ± 9.18$^{a}$ |
| EW (g) | | | |
| Pre-moult | 43.93 ± 0.68 | 43.93 ± 0.68 | 43.93 ± 0.68 |
| End of moulting | 40.77 ± 2.57 | - | 39.04 ± 0.68 |
| Post moult | | | |
| Week$_1$ | - | - | 40.02 ± 0.54 |
| Week$_2$ | 36.85 ± 1.31$^{b}$ | - | 42.46 ± 1.03$^{a}$ |
| Week$_3$ | 39.13 ± 0.65 | - | 38.93 ± 0.68 |

a,b,c: row mean followed by different superscripts are significantly different ($p < 0.05$).

significantly higher in SB compared to IC (72.63 ± 11.31 vs 32.14 ± 11.53 % for week 0-3; 0.19 ± 0.02 vs 0.12 ± 0.03 g for week 1-2 and 0.33 ± 0.03 vs 0.22 ± 0.04 g for week 0-2) while gain in egg weight did not differ significantly between genotypes. Table 11 shows that HDEP did not differ significantly between genotypes fed ginger diet post moulting however, IC gained higher at week 2 (0.00 to 28.57 %) compared to SB (2.39 to 9.53 %). Gain in BW was higher ($p < 0.05$) in SB in week 2 and over the period of evaluation while IC gained more in EW at week 3.

**Table 10: Comparison between genotypes for post moult HDEP and changes in performance of Zn moulted hens fed basal diet post moulting**

| | Genotype | |
|---|---|---|
| **HDEP (%)** | **Shaver brown** | **Indigenous chicken** |
| End of moulting ($wk_0$) | 5.94 ± 4.71 | 10.71 ± 4.25 |
| Post moult | | |
| $Week_1$ | 2.39 ± 2.39 | 10.71 ± 5.05 |
| $Week_2$ | 23.81 ± 6.14 | 17.86 ± 4.61 |
| $Week_3$ | 78.57 ± 9.42$^a$ | 42.86 ± 10.51$^b$ |
| ΔHDEP (%) | | |
| $Week_{0-1}$ | -3.56 ± 5.10 | 0.00 ± 0.00 |
| $Week_{1-2}$ | 21.43 ± 7.90 | 7.14 ± 7.14 |
| $Week_{2-3}$ | 54.76 ± 13.95 | 25.00 ± 13.36 |
| $Week_{0-3}$ | 72.63 ± 11.31$^a$ | 32.14 ± 11.53$^b$ |
| ΔBW (kg) | | |
| $Week_{0-1}$ | 0.14 ± 0.04 | 0.09 ± 0.02 |
| $Week_{1-2}$ | 0.19 ± 0.02$^a$ | 0.12 ± 0.03$^b$ |
| $Week_{0-2}$ | 0.33 ± 0.03$^a$ | 0.22 ± 0.04$^b$ |
| ΔEW (g) | | |
| $Week_{0-1}$ | -2.73 ± 3.60 | -5.03 ± 0.97 |
| $Week_{1-2}$ | 0.67 ± 1.88 | 0.30 ± 4.56 |
| $Week_{2-3}$ | 0.75 ± 2.31 | -2.42± 3.15 |
| $Week_{0-3}$ | -2.76 ± 2.85 | -2.72 ± 2.03 |

a, b: significantly different means ($p < 0.05$).

**Effect of genotype on HDEP and changes in performance traits in fasted hens**

Comparison between fasted genotypes fed basal diet (Table 12) or ginger diet (Table 13) post moulting shows that HDEP was higher in fasted SB hens in week 3 compared to their IC counterparts (Table 12). Indeed, the IC did not commence egg production within the study duration. Gain in BW from week 1 to week 2 was higher in SB hens compared to IC (0.14 ± 0.01 vs 0.04 ± 0.02 kg) however, overall gain in BW ($week_0$ – $week_3$) was similar in the two genotypes. Table 13 shows that increase in HDEP was significantly ($p < 0.05$) higher in fasted SB fed ginger diet (14.29 ± 7.43% in week 2, and 39.29 ± 10.71 % in week 3; cumulative: 53.57 ± 11.48 %) compared to zero lay in IC counterpart. Body weight gain was also higher in SB hens at week 2 compared to IC (0.22 ± 0.02 vs 0.13 ± 0.02 kg) but cumulative BWG did not differ significantly between the genotypes.

**Table 11 : Comparison between genotypes for HDEP and changes in performance traits of Zn moulted hens fed ginger diet post moulting**

| | Genotype | |
|---|---|---|
| | **Shaver brown** | **Indigenous chicken** |
| HDEP (%) | | |
| End of moulting | 5.94 ± 4.71 | 12.50 ± 4.56 |
| $Week_1$ | 2.39 ± 2.39 | 0.00 ± 0.00 |
| $Week_2$ | 9.53 ± 4.95 | 28.57 ± 6.52 |
| $Week_3$ | 42.84 ± 8.80 | 46.43 ± 10.10 |
| ΔHDEP (%) | | |
| $Week_{0-1}$ | -3.57 ± 5.10 | -10.71 ± 4.25 |
| $Week_{1-2}$ | $7.14 \pm 6.15^b$ | $28.57 \pm 6.52^a$ |
| $Week_{2-3}$ | 33.31 ± 6.29 | 17.86 ± 16.10 |
| $Week_{0-3}$ | 36.90 ± 12.04 | 35.71 ± 8.81 |
| ΔBW (kg) | | |
| $Week_{0-1}$ | 0.08 ± 0.04 | 0.03± 0.05 |
| $Week_{1-2}$ | $0.17 \pm 0.02^a$ | $0.04 \pm 0.01^b$ |
| $Week_{0-3}$ | $0.24 \pm 0.05^a$ | $0.07 \pm 0.05^b$ |
| ΔEW (g) | | |
| $Week_{0-1}$ | -0.90 ± 1.60 | - |
| $Week_{1-2}$ | 3.28 ± 2.02 | - |
| $Week_{2-3}$ | $-0.65 \pm 0.65^b$ | $5.04 \pm 1.72^a$ |
| $Week_{0-3}$ | -0.68 ± 3.51 | -0.73 ± 2.83 |

a, b: significantly different means ($p < 0.05$).

**Table 12: Comparison between genotypes for HDEP and changes in performance traits of fast moulted hens fed basal diet post moulting**

| | Genotype | |
|---|---|---|
| | **Shaver brown** | **Indigenous chicken** |
| HDEP (%) | | |
| End of moult | 0.00 ± 0.00 | 0.00 ± 0.00 |
| Post moult | | |
| $Week_1$ | 0.00 ± 0.00 | 0.00 ± 0.00 |
| $Week_2$ | 0.00 ± 0.00 | 0.00 ± 0.00 |
| $Week_3$ | $39.29 \pm 15.29^a$ | $0.00 \pm 0.00^b$ |
| ΔHDEP (%) | | |
| $Week_{0-1}$ | 0.00 ± 0.00 | 0.00 ± 0.00 |
| $Week_{1-2}$ | 0.00 ± 0.00 | 0.00 ± 0.00 |
| $Week_{2-3}$ | $39.29 \pm 15.29^a$ | $0.00 \pm 0.00^b$ |
| $Week_{0-3}$ | $39.29 \pm 15.29^a$ | $0.00 \pm 0.00^b$ |
| ΔBW (kg) | | |
| $Week_{0-1}$ | 0.35 ± 0.04 | 0.41 ± 0.02 |
| $Week_{1-2}$ | $0.14 \pm 0.01^a$ | $0.04 \pm 0.02^b$ |
| $Week_{0-3}$ | 0.49 ± 0.04 | 0.45 ± 0.00 |
| ΔEW (g) | | |
| $Week_{0-1}$ | - | - |
| $Week_{1-2}$ | - | - |
| $Week_{2-3}$ | - | - |
| $Week_{0-3}$ | - | - |

a, b: significantly different means ($p < 0.05$).

**Table 13: Comparison between genotypes for post-moult HDEP and changes in performance traits in fasted hens fed ginger diet post moulting**

| | Genotype | |
|---|---|---|
| | **Shaver brown** | **Indigenous chicken** |
| HDEP (%) | | |
| End of moulting ($wk_0$) | 0.00 ± 0.00 | 0.00 ± 0.00 |
| Post moult | | |
| $Week_1$ | 0.00 ± 0.00 | 0.00 ± 0.00 |
| $Week_2$ | 14.29 ± 7.43$^a$ | 0.00 ± 0.00$^b$ |
| $Week_3$ | 53.57 ± 11.48$^a$ | 0.00 ± 0.00$^b$ |
| ΔHDEP (%) | | |
| $Week_{0-1}$ | 0.00 ± 0.00 | 0.00 ± 0.00 |
| $Week_{1-2}$ | 14.29 ± 7.43$^a$ | 0.00 ± 0.00$^b$ |
| $Week_{2-3}$ | 39.29 ± 10.71$^a$ | 0.00 ± 0.00$^b$ |
| $Week_{0-3}$ | 53.57 ± 11.48$^a$ | 0.00 ± 0.00$^b$ |
| ΔBW (kg) | | |
| $Week_{0-1}$ | 0.24 ± 0.02 | 0.17 ± 0.06 |
| $Week_{1-2}$ | 0.22 ± 0.02$^a$ | 0.13 ± 0.02$^b$ |
| $Week_{0-3}$ | 0.46 ± 0.03 | 0.30 ± 0.08 |
| ΔEW (g) | | |
| $Week_{0-1}$ | - | - |
| $Week_{1-2}$ | 0.20 ± 0.02 | - |
| $Week_{2-3}$ | -0.35 ± 0.35 | - |
| $Week_{0-3}$ | - | - |

a, b: significantly different means ($p < 0.05$).

**Pre- and post-moult trend in HDEP of SB and IC fed basal or ginger diets**

Pre-moult HDEP ranged from 45.0 to 75.0 % in SB hens belonging to Zn basal and ginger diet groups while the corresponding post-moult values were 0.0 to 100 % and 0.0 to 83.3 %, respectively (Fig. 3, Panel A). For fasted hens (Panel B), it was 52.0 to 67.0 %, respectively during pre-moult but 0.0 to 100.0 and 0.0 to 66.8 %, respectively during post-moult. For the IC, pre-moult HDEP ranged between 12.5 and 62.5 % in the Zn basal and ginger diet groups but between 25 and 75 %, respectively post-moult (Panel C) while in the fasted group (Panel D), HDEP varied between 40 and 80 % during pre-moult in basal and ginger diet groups but remained zero post moult in both dietary groups over the period of evaluation.

**Dynamics of egg weight in pre- and post moulting phases in SB and IC**

In Zn moulted SB hens fed basal or ginger diets, EW varied between 60.0 and 67.0 g pre-moulting and between 52.9 and 66.1 g, and 55.4 and 69.6 g, respectively post-moulting (Fig. 4, Panel A) whereas in the fasted groups EW ranged between 60.3 and 64.7 g pre-moulting, but between 58.9 and 61.5 g; and 59.7 and 66.8 g, respectively post-moulting (Panel B).

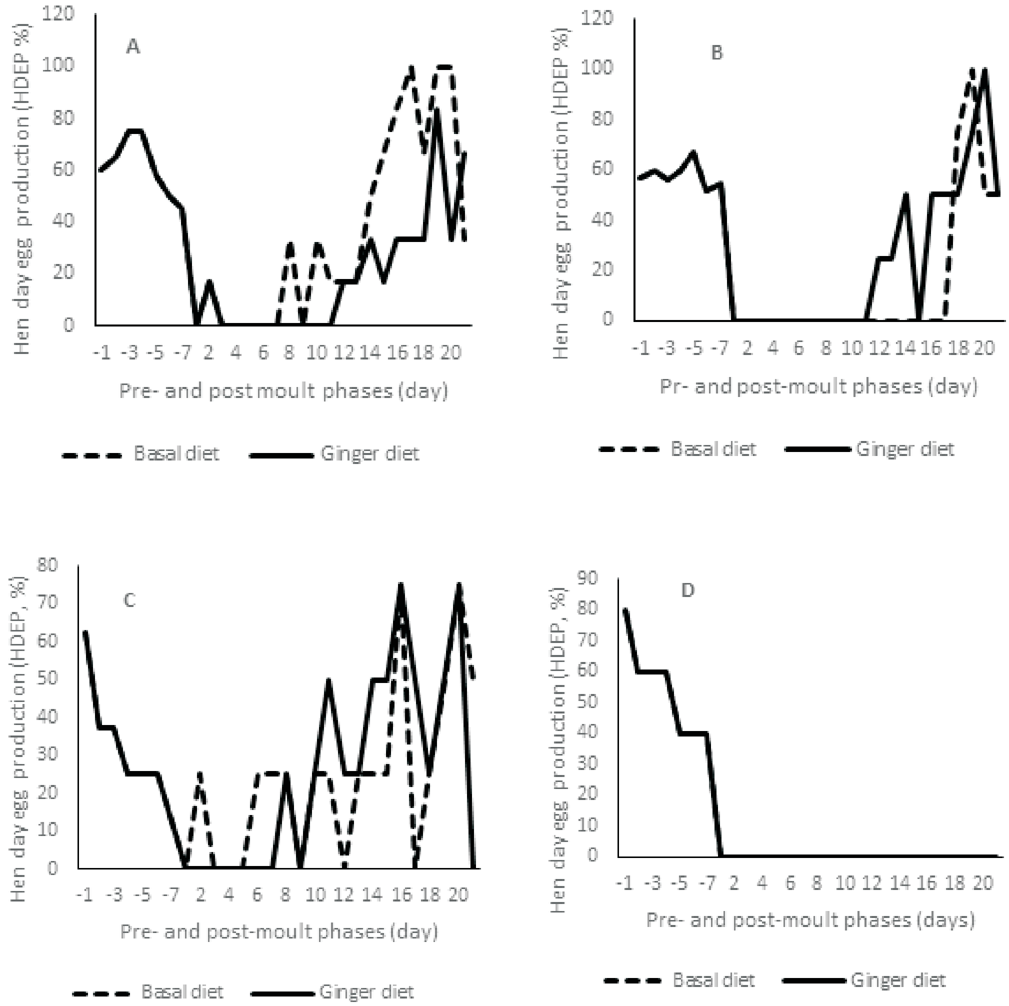


**Fig. 6: Trend in pre- (d -1 to -7) and post-moult (d 1 to 21) HDEP of SB and IC. Panel A: SB, Zn group; B: SB, fasted group; Panel C: IC, Zn group; D: IC, fasted group.**

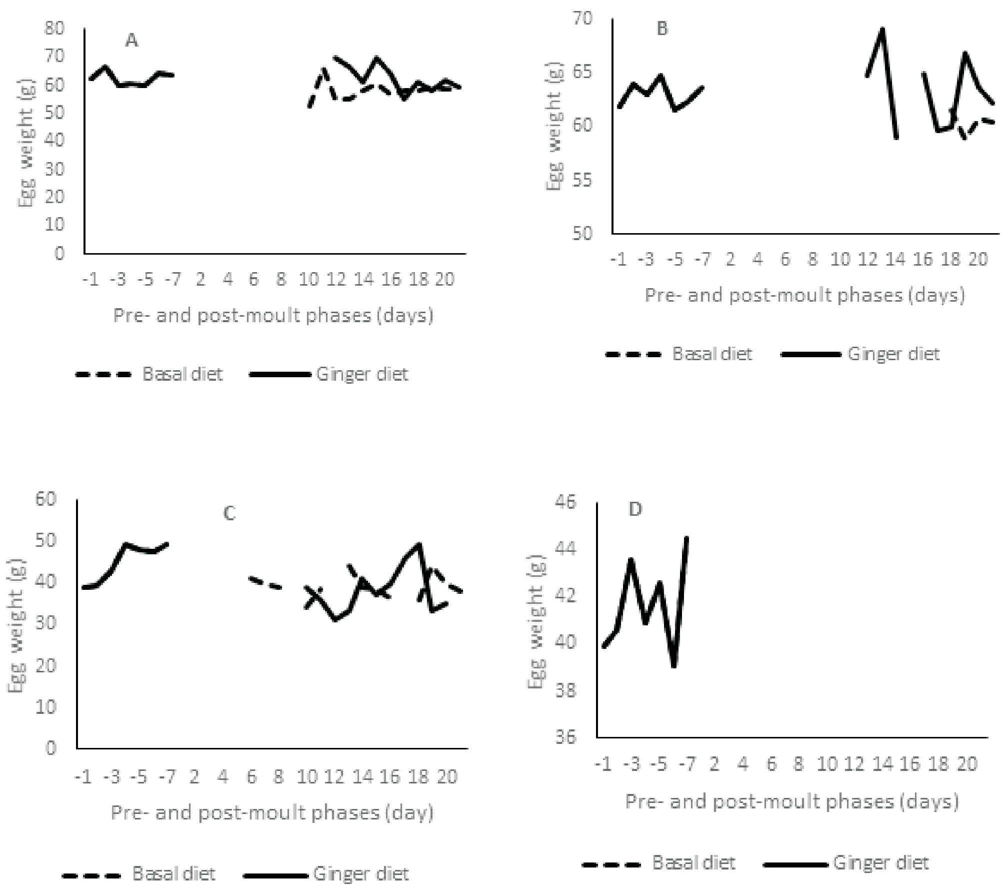


**Fig. 7: Dynamics of pre- and post-moult egg weight of SB and IC fed basal or ginger diet post moult. Panel A: SB, Zn group; panel B: SB, fasted group; panel C: IC, Zn group; panel D: IC, fasted group.**

For the IC, pre-moulting EW ranged between 39.2 and 49.6 g in Zn basal and ginger diet groups but between 34.4 and 44.0 g, and 31.3 and 49.5 g, respectively post moult (Panel C) while in the fasted group, pre-moulting EW varied between 39.1 and 45 g for the dietary groups. Eggs were not laid in both dietary groups during post moult evaluation (Panel D).

## Discussion

The low and fluctuating laying performance before moulting in the experimental groups was expected given the age of the birds and the duration in lay (85 weeks of age, 65 weeks in lay). The poor egg production indicate end of first laying cycle and that laying has become uneconomic and therefore unprofitable. Such flocks are recommended for replacement or forced moulting to rejuvenate the reproductive tract and bring the hens into a second laying cycle (Ogbu *et al*., 2019; Fard *et al*., 2020). Ogbu *et al*. (2019) identified the conditions necessitating artificial moulting of hens to include aging, poor egg production, and fall in demand of eggs at periods of high feed cost. The steady increases in BW in the groups fed ginger diet pre-moulting indicate beneficial effect of ginger supplementation on body weight gain (BWG). Also observed was a narrower range of HDEP in these groups which indicates lesser fluctuations in egg production and a positive effect of ginger supplementation on laying rate. Thus the significantly higher pre-moult BW in SB and IC fed ginger diet compared to counterparts fed basal diet confirms the positive effect of ginger supplementation on BWG in agreement with previous studies in broiler (Ogbuewu and Mbajiorgu, 2020; Saleem *et al*., 2020) and layer (Akanbi *et al*., 2020) chickens. The observed higher EW in the ginger groups could hence follow from the higher BW observed in these groups. The similarity in laying performance between the dietary groups within genotypes disagrees with Akbarian *et al*. (2011), Malekizadeh *et al*. (2012) and Yang *et al*. (2017) who reported significant effect of ginger powder dietary supplementation on laying performance of hens. These studies attributed the significant increase in egg production in the ginger treated groups to enhanced wellbeing due to reduced lipid peroxidation (lowered MDA) and increased activity of cellular antioxidants believed to result from the bioactive compounds in ginger. Our results however, agrees with Zhao *et al*. (2011), Zomrawi *et al*. (2014), Herve *et al*. (2019), and Wen *et al*. (2019) who observed non-significant effect of various ginger preparations on egg production. Akanbi *et al*. (2020) on the other hand reported inferior HDEP value in laying hens fed ginger powder compared to control group (59.75 vs 65.00 %). The predominant non-significant effect of genotype on HDEP and changes in measured traits over the pre-moulting period shows that aging affected the measured traits similarly in the two genotypes. The reported 18 days to first egg in SB hens fed basal diet post fasting is longer than the 11 days reported by Hassanabadi and Kermanshahi (2007) in fasted hens but shorter than three weeks (21 days) reported by Rafeeq *et al*. (2013), and 20, 21, and 25 days reported by Hassanien (2011) for birds fasted for 10, 12, and 15 days, respectively while our value of 7 days for those fed ginger diet post fasting is shorter. These disparities could arise from different breed of birds, management environment, and duration of fasting, degree of BW loss during fasting, and different post moult dietary treatments. In Hassanabadi and Kermanshahi (2007), birds were fasted for 5 days as against 14 days in the present study. Although the authors did not report percent BW loss in the birds, the longer fasting period in our study suggests higher BW loss which required longer recovery period to first egg. Even though first oviposition occurred in the ginger supplemented group 7 days post fasting, oviposition did not occur thereafter until d 12 and laying became regular in this group from d 16 post fasting indicating a longer than 7 days average duration to first oviposition for this group. The observed zero oviposition in fasted IC indicate that this genotype requires longer recovery period than the period of post moult evaluation considered in the present study or that the 14 days duration of fasting in the present study was too harsh given the light BW characteristic of the IC genotype. The commencement of oviposition in Zn moulted SB (both dietary groups) and IC (basal diet) just two days post moulting suggests that laying did not cease completely in these groups. This observation is in agreement with Soe *et al*. (2007) who reported only a decrease in rate of oviposition in birds moulted by feed restriction as against complete cessation of lay on d 8 until d 28 post moulting in the starved group. Sapkota *et al*. (2018) also observed only a decrease in HDEP in birds moulted by various feed restriction treatments. Ocak *et al*. (2004) had reported reduced laying rate to between 4.33 and 4.85 % in Zn moulted hens belonging to different BW groups. Hassanabadi and Kermanshahi (2007) however, observed complete cessation of egg production by d 8 until d 29 in birds moulted by Zn contrary to our finding. Machebe *et al*. (2013) also reported stoppage of lay from 5 to 9 days in hens moulted by different levels of dietary Zn supplementation. In Zn moulted IC fed ginger diet, laying commenced on d 8 which is quite early compared to a range of 22 to 39 days post moulting reported by other studies (Hassanabadi and Kermanshahi, 2007; Soe *et al*., 2007; Sariozkan *et al*., 2013) but in agreement with Machebe *et al*. (2013). In the present study, day to 50 % HDEP in Zn groups was 19 and 14 d post moulting for SB hens fed ginger and basal diets, respectively but 11 and 16 d for their IC counterparts. These values are shorter compared to 37 d reported by Hassanabadi and Kermanshahi (2007) for birds moulted by Zn and a range of 28 to 46 d reported by Sariozkan *et al*. (2013) for various moulting methods and dietary supplementations. The short period to 50 % HDEP in the present study could result from the non-cessation of egg production during the moulting treatment. In the study by Ocak *et al*. (2004), number of days to 50 % lay was 9.67 for the heavy BW group and 13.17 for the light BW group. The observed lack of oviposition in fasted IC fed basal or ginger diets post moulting indicate slower recovery rate from the effect of fasting in this genotype compared to the SB hens which commenced oviposition in wk 3 for those fed basal diet and in wk 2 for counterparts fed ginger diet post moulting. This result indicates slower recovery rate in fasted IC compared to their SB counterparts probably due to a lower genetic potential for growth. Thus, a shorter duration of fasting and lower BW loss should be targeted in moulting light BW chickens and chickens such as the Nigerian IC characterized by slow growth rate. The higher BW losses in genotypes fed ginger diet could result from the higher pre-moulting BW in these groups. Ocak *et al*. (2004) reported pre-moulting BW dependent BW loss in birds moulted by Zn with heavy BW strains suffering higher BW losses. Birds that suffer higher BW losses during moulting would equally require longer period of recovery of laying performance (Reddy *et al*., 2008; Sohail *et al*., 2011) and this could be responsible for the lower HDEP observed in the ginger fed groups especially in SB hens. The significantly higher EW in wk 2 in Zn moulted SB hens fed ginger diet most probably resulted from the lower laying rate in this group. The observed BW loss of 31 % and above due to fasting for 14 days in SB and IC suggests that the duration of fasting was too long for the genotypes involved in the present study and that shorter duration of fasting or fasting to the recommended optimal BW loss of 25 to 35 g (Reddy *et al*., 2008; Sohail *et al*., 2011) would be more appropriate when using the fasting method especially for the IC which could not oviposit over the 21 day post moult evaluation. Shaver brown hens however, demonstrated better capacity to tolerate the long fasting period by ovipositing within 14 to 21 day post fasting. The observed greater BW loss in all genotypes and dietary groups due to fasting is in agreement with earlier studies (El-Deek and Al-Harthi, 2004; Seo *et al*., 2007; Aygun, 2013; Ogbu *et al*., 2019). Fasting causes greater mobilization of body fat to meet the energy needs of the bird. It also leads to greater involution of the reproductive tract of the bird which further increases BW loss. The low or fluctuating HDEP in the control group was expected being the main reason for inducing a forced moult in commercial flocks (Machebe *et al*., 2013; Aygun, 2013; Sapkota *et al*., 2018) while the increasing trend in HDEP in the moulted groups indicate steady recovery and return to efficient laying performance in these groups which indicates beneficial effects of moulting in agreement with previous studies (El-Deek and Al-Harthi, 2004; Aygun, 2013; Sapkota *et al*., 2018). The observed higher HDEP in Zn moulted SB hens fed basal or ginger diet post moulting compared to IC counterpart confirms the superior genetic potential of SB in laying performance. Even though both genotypes gained steadily in rate of lay, it was significantly higher in SB compared to IC over the study period. A similar explanation accounts for the higher gain in BW observed in SB hens as this breed is a heavier breed compared to the IC. The present study revealed that HDEP reached 100 % (Zn group) and 66.8 % (fasted group) in moulted SB hens and 75 % in moulted IC (Zn group) within 21 d post moulting following complete cessation of oviposition (fasted group) during moulting. In the same vein, EW improved from between 60 and 67 g pre-moulting to between 66 and 69 g post moulting over the same period in SB hens belonging to the experimental groups. These results indicate beneficial effect of moulting on post-moult laying performance when compared to the low and fluctuating HDEP pre-moulting.

## Conclusion

Dietary supplementation with ginger (Z. officinale) powder improved pre- and post moult performance of layer chickens subjected to moulting by fasting and dietary Zn supplementation. Furthermore, dietary Zn supplementation was an equally effective moulting protocol as fasting in laying hens. Zn moulting or fasting to a target weight loss would be better in light strains like the Nigerian indigenous chickens.

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