EFFECTS OF FEED WITHDRAWAL AND STRAIN ON LAYING PERFORMANCE AND EGG QUALITY OF WHITE AND BROWN HY-LINE LAYERS

BY

MUDAU MULANGA LENTICIA

STUDENT NUMBER: 11621577

E-mail: lenticia.mudau@gmail.com

A dissertation submitted in fulfillment of the requirements for the degree of Master of Science in Agriculture (Animal Science)

Department of Animal Science

School of Agriculture

University of Venda

South Africa

	Signature:	Date:
Student name:Miss M.L Mudau	____________	____________
Supervisor: Dr E Bhebhe	____________	____________
Co-supervisor: Mr AJ Netshipale	____________	____________

February 2019

Declaration

I, **MUDAU MULANGA LENTICIA**, hereby declare that this dissertation handed in for Master of Science in Agriculture (Animal Science) at the University of Venda is my own work and has not been previously in part or in it's entirely submitted to any university for any other degree. I further declare that all references material contained herein has been duly acknowledged.

Signature: ____________________ Date: ___________________

Miss ML Mudau

Acknowledgement

I would love to pass my gratitude to the almighty God for giving me a chance, courage, protection, strength and wisdom throughout the investigation. I would like to give thanks to the institution (for funding my project), the department of Animal Science, supervisor (Dr E Bhebhe) and co-supervisor (Mr. AJ Netshipale) for giving me the opportunity, support and efforts they put in making this project a success. I would love to pass my gratitude to Miss MV Rakau for her assistance during data collection and Mr Lubisi MW for guidance and advises during the study.

Dedication

This dissertation is dedicated to God my savior, my family Ms SM Makahane mother, siblings Mr VT Makahane, Ms M Makahane, Mr U Makahane, Ms H Mudau, Mr ZS Mudau, Ms M Mudau, Ms RV Mudau, my son TJ Raphasha and his father Mr MJ Raphasha and my niece Chantel Mudau.

Abstract

The aim of the study was to investigate the effects of feed withdrawal and strain on laying performance and egg quality of White and Brown Hy-line layers. Fifty four hens for each strain (White Hy-Line and Brown Hy-line) aged 18 weeks (point of laying stage) were used in the investigation. Feed withdrawal had no effect (P>0.05) on laying performance, mortality rate, egg internal and external quality, but significantly affected (P<0.01) average feed intake, body weight, small and extra-large eggs percentages. Hens under *ad libitum* consumed more feed than hens under four hours and eight hours feed withdrawal. High body weight was observed on *ad libitum* fed hens, intermediate on eight hours feed withdrawn hens and lower at four hours feed withdrawn hens. High percentage of small graded eggs was observed on four hours feed withdrawn hens, intermediate on eight hours feed withdrawn hens and lower on *ad libitum* fed hens. High percentage of extra-large graded eggs was observed on *ad libitum* fed hens, intermediate on eight hours feed withdrawn hens and lower four hours feed withdrawn hens. Strain had a significant effect on average egg weight, median egg weight, albumen weight, extra-small, small, medium and large graded eggs percentages (P<0.01) and on body weight, egg height , egg width, average egg shell colour (P<0.05). Strain did not affect (P>0.05) average feed intake, body weight change, egg output, feed conversion ratio, mortality rate, egg shell breaking force, albumen height, yolk height, yolk weight, extra-large and jumbo graded eggs percentage. Brown Hy-Line layers had high average egg weight, median egg weight, egg height, egg width, and average egg shell colour and albumen weight than White Hy-Line layers. Small sized eggs percentage and body weight were high on White Hy-Line layers compared to Brown Hy-Line layers. Medium and large sized eggs were high on Brown Hy-Line layers than White Hy-Lines. Feed withdrawal by strain interaction effect was observed on body weight, average egg weight and median egg weight, albumen weight and egg height, percentage of small, medium and large graded eggs (P<0.05). Brown Hy-Line hens under eight hours feed withdrawal had high egg weight, median egg weight, egg height, albumen weight and under eight hours feed withdrawn White Hy-Line hens had lower albumen height compared to other interactions. In all interactions White Hy-Line had high percentage of small graded eggs whereas Brown Hy-line had high percentage of large and medium graded eggs.

Key words: Strain, feed withdrawal, laying performance and egg quality.

List of tables

List of abbreviations

HU	Haugh Unit
%	Percentage
$	US Dollar
<	Less than
>	Greater than
W	Width
L	Length
H	Height
cm^2	Square centimeter
cm	Centimeter
m	Meter
hrs	Hours
^0C	Degree Celsius
g	Grams
Kg	Kilograms
FI	Feed intake
BW	Body weight
BWC	Body weight change
FCR	Feed conversion ratio
EW	Egg weight
EO	Egg out put
EM	Egg mass
MR	Mortality rate
N	Number of observations
MEW	Median egg weight
AH	Albumen height

YH	Yolk height
AW	Albumen weight
YW	Yolk weight
HU	Haugh Unit
ESI	Egg shape index
ESBF	Egg shell breaking force
EH	Egg height
EW	Egg width
ESW	Egg shell weight
AESC	Average egg shell colour

List of figures

Table of Contents

Chapter 1: introduction

1.1 Background of the study

Chicken rearing is one of the easiest agricultural activities needing small capital to set it up which people, mostly in rural areas, use to make a living (Ogunlade and Adebayo, 2009). Poultry eggs are regarded as a healthy and high nutritious food, which makes them important in diet of people (Mausa, 2008). Amos (2006) indicated that a small-scale poultry enterprise has a quick monetary turnover. Magdelaine *et al.* (2008) reported that poultry meat has become a mass consumer product throughout the world regardless of the region and the level of development. Poultry production is effected by many factors such as strain of chickens used, environmental conditions in the poultry houses, management practices, feed and feeding management (Bell and Weaver, 2002). Introduction of feed restriction or withdrawal in housed layers fed commercial layer diets could address challenges related to feeding and productivity faced especially by small scale farmers (Oyedeji *et al.,* 2007). When farming with laying hens, good housing system, management and production efficiency is important for producers to reduce production costs and be able to improve profitability and compete with the imported products in both quality and price. Singh *et al.* (2009) reported that egg production, egg quality and production efficiency depend on genetic makeup of the laying hens. Apart from investigating the effect of feed withdrawal of laying performance, egg quality and body weight changes, the study will also determine if there is a significant strain by feed withdrawal interaction that will improve the productivity of laying hens.

1.2 Problem statement

Chickens tend to consume feed whenever it is available, which lead to high abdominal fat gain, high mortality rates, less feed conversion efficiency, less and light egg production and high body weight gain. This affects farmer's income as more money is spent on buying feeds and reduces profit margins due to high production costs. There is little local literature on the effect of feed withdrawal on the performance and egg quality of Brown and White Hy-line layers. Also a shortage of resolution on poultry production, low performance, and high mortality in farms leads to job cuts and security is negatively affected. This study will assist in selection of strains in accordance to their productivity and performances and this will increase the amount of eggs on the market.

1.3 Justification

Since feed cost is relatively high in poultry production (contributing 60-70% of production costs, Wilson and Beyer, 2000) and chickens consume more feed than they require for production and maintenance, feed withdrawal and other feeding regimes may be introduced to minimize the expenditure on feed, to enhance egg output, egg quality, to reduce mortality rate, minimize body weight gain and abdominal fat gain (Olawumi, 2014). Having specific feed withdrawal and strain that leads to high production, low mortality rate and profit margins that occurred locally, farmers will be encouraged to get into egg production with no fear of income losses. Having information published for the community to use in generating more income in poultry industry is very important. the study aim to give back to the community create layers farming management awareness to small scale farmers, emerging farmers and people who depend on egg production for a living so that they can solve their challenges in production.

Knowing which strain to use for good production, less expenses in feeding, low mortality rate and good egg quality will increase of people rearing and selling layers (point of lay). Also having local suppliers to the farmers will cut the cost on transportation and hens will be well adaptable to the environment. By so doing the eggs as human staple nutritious food will always be available at a low price. Since eggs are in high consumption demand in the society, more people will start selling eggs as their livelihood and the employment rate will increase as well as the economy. Farmers who are currently farming with egg laying chickens will be encouraged to extend or grow their farms therefore more hands will be needed and job creation rate increases. Free range chickens will be saved from the predators once the households who are rearing them get the information about feed restriction that enhances the production and reduced feed cost in housed hens.

1.4 Objectives of the study

1.4.1 Broad objective

To determine the effects of feed withdrawal and strain on laying performance and egg quality characteristics of White Hy-Line and Brown Hy-Line layers.

1.4.2 Specific objectives.

To determine the effects of feed withdrawal and genotype (White, Brown Hy-Line) on:

- Laying performance (egg output, egg weight).

- Egg quality (egg shell colour, yolk height and weight, albumen height and weight, egg shell weight, egg shell breaking strength, Haugh unit, egg shape index).
- Body weight and body weight change of layers.
- Egg grade.

1.5 Null hypotheses

Feed withdrawal and strain have no significant effect on:

- Laying performance (egg output, egg weight).
- Egg quality (egg shell colour, yolk height and weight, albumen height and weight, egg shell weight, egg shell breaking strength, Haugh unit, egg shape index).
- Body weight and body weight change of layers.
- Egg grade.

Chapter 2: literature review

2.1 Introduction

Any attempt to improve egg production should include the manipulation of feeding regimes and diets. Improving production efficiency is essential for producers to reduce production costs and be able to improve profitability and compete with the imported products in terms of price and quality. Feed restriction or withdrawal is the removing of feed from the feeding trough or closing of feeders to prevent chickens from eating for a period of time to enhance feed convention ratio and to avoid excessive feeding that leads to high body weight gain, poor performance and increased mortality due to diseases or disorders caused by excessive abdominal fat gain. Maintaining correct body weight during the laying period through controlled feeding will reduce feed intake by pullets (Kostal *et al.,* 1992). Feed Management practice of chickens includes the restriction of feed allowance during both rearing and breeding to limit body weight gain, to reduce incidence of obesity and improve egg production. Despite the fact that chickens subjected to restricted feeding reach sexual maturity later than unrestricted chickens, the advantages of restricted feeding are more beneficial regardless of the delay in the onset of laying. These advantages include increased egg production, fertility, hatchability and egg quality; reduced number of double-yoked or malformed eggs; and reduced hen mortality (Robinson *et al*., 1978, and Bruggeman *et al*., 1999). Faulty feed and feeding methods are sometimes responsible for reduced egg production, small egg size, reduced shell quality, reduced growth, excess fat storage, overfeeding and high mortality (Oyedeji *et al*., 2007).

The internal quality of the egg begins to decline as soon as the egg is laid. Internal egg quality, egg handling and storage practices do have a significant impact on the quality of the egg reaching the consumer. The Haugh unit (Haugh, 1937) is a measure of egg protein quality based on the albumen height. A minimum measurement in Haugh Units (HU) for eggs reaching the consumer is 60. However, most eggs leaving the farm should be between 75 and 85 HU (Coutts and Wilson, 1990). Yolk quality is determined by the colour, texture, firmness and yolk smell (Jacob *et al.,* 2000). Although yolk colour is a key factor in any consumer survey relating to egg quality (Jacob *et al.,* 2000), consumer preferences for yolk colour are highly subjective and vary widely from country to country. Ragheb *et al.* (2013) reported that it is very crucial for producers to use the best performing type of strains (Brown and White egg laying hens) in order to improve the production level, income and quality of products for the purpose of achieving good export pricing. Olawumi (2014) reported that severe (from 12 to 24 hours) feed withdrawal is discouraged as it appears to badly affect birds performance. Feed withdrawal minimized the overall feed cost compared to standard feeding program *(ad libitum*), the highest net revenue/hen and economic efficiency was recorded in 90% *ad libitum* ($1.19,112.26) intermediate ($1.06, 100) in *ad libitum* and lowest ($1.10, 95.28) in 80% *ad libitum* (Olawumi 2014). The reduction in feed cost represented about 7.68% and 11.93% for laying hens fasted about 4 and/or 8 hours per day respectively compared to those fed *ad libitum* during the entire laying period (Osman *et al*., 2010). Increasing fasting period has insignificantly decreased total feed cost during the production period of laying hens (Osman *et al*., 2010). Furthermore reduction in total feed cost by feed restriction was a result of the negative effect of feed restriction on total feed consumption.

2.2 Effect of week or hens age on laying performance, egg quality traits (internal and external)

Rayan *et al.* (2013) found that age had a significant effect on laying performance (body eight, feed intake, egg weights and production). Hani *et al.* (1999) reported an increase in egg weight as the hen age increased of White Leghorn from 26 to 54 weeks of age. Rizzi and Chiericato (2005) reported a significant (P<0.01) increase of egg weight as hens age increased. Osman *et al* (2010) reported that feed intake, egg output, egg mass and egg weight was increasing with an increase in hen's age. Osman *et al*. (2010) results also showed that week had a significant effect on feed conversion ratio. Osman *et al*. (2010) reported that egg quality (yolk index, Haugh Units, albumen and shell strength) reduced with an increase in hen's age. Rizzi and Chiericato (2005) also reported a significant (P<0.01) decrease of Haugh Unit as age increased and the current study agree with this report, on table 4 Haugh Unit was decreasing with hens age increase. Haugh (1937) also indicated that egg shell quality reduced with hens age and storage time increase. Albumen index, yolk index and Haugh Unit were reported to be significantly decreasing with hen's age (Premavalli and Viswanangthan, 2004). Egg weight, yolk weight, Haugh Unit increased with the hen's age, but albumen and eggshell percentage decreased, eggshell thickness and strength improved with age (Zita *et al*., 2008). Baumgartner *et al*. (2007) reported a significant effect of age on egg weight in the Leghorn type hens. Egg weight influences the weight of its components as well. The correlations between the egg weight and the albumen weight, yolk weight, egg shell weight are high and range from 0.67 to 0.97 (Zhang *et al*., 2005).

2.3 Effects of feed withdrawal on laying performance, egg quality traits (internal and external).

Osman *et al.* (2010) revealed that fasting laying hens for about 4 or 8 hours per day during the laying period decreased ($P<0.05$) cumulative feed intake by about 7.7% or 11.4% respectively compared to hens fed *ad libitum*, but there was no significant decrease in cumulative feed intake for increasing fasting time from 4 to 8 hours/days. Fasting laying hens for 4 to 8 hours/day improved ($P<0.05$) cumulative feed conversion from 3 to 7 weeks point of laying periods, but this improvement began to decrease with the progress in laying (at 8 and 9 weeks laying period) and disappeared at the end of laying periods (from 10 to 13 week laying periods). Fasting laying hens for about 4 or 8 hours/day during laying decreased the cost of feed by about 7.68 and 11.39% and mortality rate by about 6.54% and 8.92% respectively compared to hens fed *ad libitum* (Osman *et al.,* 2010). Feed restriction had no significant effect on egg number, egg weight, egg mass, hen day production and egg quality (Osman *et al*., 2010). According to Summers and Robinson. (1995), feed restriction during laying period can be used to control body weight gain and maximize egg production. Feed restriction significantly affected egg output and hen-day egg output regardless of the hen's strain from 54 weeks of age, (Olawumi *et al.,* 2014).

Olawumi *et al.* (2014) revealed that feed restriction had no significant effect on mortality with hens on *ad libitum* feeding and hens on restricted feeding having zero mortality. Altan *et al.* (2000) reported that feed restriction had an effect on egg production (reduced) and egg quality of brown and white Hy-line, but the brown Hy-line egg production and egg quality was highly and positively affected compared to the ones of white Hy-line. Hens on restricted feeding exhibited significant increase in body weight loss and a decrease in egg production, feed consumption, final body weight and abdominal fat, but no significant effects were observed on egg weight, shell thickness and mortality (Lebbie *et al.,* 2008). Oyedeji *et al.* (2007) reported that *ad libitum* feeding leads to over feeding that encourages the excessive accumulation of abdominal fat resulting in heat stress and high mortality rate in laying hens, the hens used in the study were 40 weeks of age. Feed restriction decreased body weight and hen-day egg production relatively to the feed withdrawal level (Oyedeji *et al*., 2007). Albumen height was greater with an increased feed restriction (Scott *et al.,* 1999). Scott *et al.* (1999) also reported that feed restriction effect on egg production actually depended on the strain of laying hen. Quantitative feed restriction reduced body weight and feed consumption without reducing egg production (Crounch *et al.,* 2002). Nofal and Hassan (2004) reported that feed withdrawn hens showed an insignificant better conversion ration than ad libitum fed hens. Hasnath (2002) reported the insignificant differences in egg shape index, egg shell thickness, albumen index and Haugh Unit between *ad libitum* fed hens and hens fed 80% of *ad libitum*.

2.4 Effects of strain on laying performance, egg quality (internal and external traits).

According to Osman *et al.* (2010), Hisex Brown strain produced more ($P<0.01$) eggs, hen day production, higher egg mass and feed intake, and utilized feed better ($P<0.05$) than Bovans White strain during the laying period from 20 to 70 weeks of age. The Hisex Brown strain produced eggs of higher quality than the Bovans white strain based on yolk index and Haugh units at the first stage of egg production and higher quality based yolk index, Haugh units, yolk color and shell strength at the mid stage (42-52 weeks) of egg production. At the late stage of egg production (after 52 laying weeks), Hisex Brown strain recorded lower ($P<0.05$) yolk colour, shell strength and the eggs tended to be rounder compared to eggs produced by Bovans white strain. Benyi *et al.* (2006) found that strain had significant effect on egg production and egg weight both at $p<0.05$ as well as feed per egg at $p<0.01$ but did not affect the other egg traits significantly. Hy-line Brown hens laid more eggs of low weight and had lower feed intake than Hy-line White hens, but strain had no significant effect on egg output and feed consumed per gram of egg produced (Benyi *et al.,* 2006).

Fairful and Gowe (1990) reported that Hy-line Brown hens gained more body weight and higher egg production as compared to Hy-line White hens. Hens with low body weight produced more eggs compared to hens of high body weight (Falconer and Mackay 1996). However according to Rayan *et al.* (2013) strain did not affect egg production, but age had a significant effect on laying performance. Ragheb *et al*. (2013) reported a highly significant egg production on Brown Hy-Line than White Hy-Line layers between 22-69 weeks of age and Brown Hy-Line consumed less feed, gained more weight and laid heavy eggs than White Hy-Line layers. Ragheb *et al*. (2013) also found the significant ($P<0.05$) high feed efficiency, egg production, egg weight and egg mass on Brown laying hens. Non-significant differences on feed intake and on Haugh Unit were observed between the two strains. Brown laying hens had lower egg yolk weight and better shell weight and percentage (Ragheb *et al*., 2013). The body weight gain was high ($P>0.05$) on Brown laying hens than White laying hens. Egg production was high on Brown laying hens than White laying hens. The albumen weight and percentage of the two strains were the same (Ragheb *et al*., 2013). Rizzi and Chiericato (2005) found that egg weight of Brown Hy-

Line was higher (P<0.01) than that of White Hy-Line layers at point of lay. Silversides *et al*. (2006) reported that ISA-brown hens produced heavier eggs than Babcock hens from 19 to 74 weeks of age. Grobas *et al*. (2001) who found that, egg mass produced by ISA-Brown was more than that from White strain. Also Badawe *et al*. (2005) found that, Brown Hy-line strain produced higher egg mass than White Hy-line strain. Wall *et al*. (2010) reported a high yolk percentage on White Hy-Line than Brown Hy-Line layers. Furthermore non-significant difference was observed on Haugh Unit. Sigh *et al*. (2009) found that Lohmann brown eggs had more albumen than Lohmann white eggs.

Regarding egg quality, it has been reported that eggs laid by Brown Hy-line had significantly higher egg, shell, albumen weight and less yolk weight compared to White Hy-line ones, (Scott and Silverside 2000). The White Hy-line had higher Haugh unit compared to Brown Hy-line (Rayan *et al.,* 2013). Eggs laid by Brown Hy-line were heavier, and had high egg shell weight (Riczu *et al.,* 2004). Anderson (2002) reported that egg weight of Brown Hy-line was greater than that of White Hy-line. Vits *et al.* (2005) stated that percentage egg output, egg weight, shell thickness, shell breaking strength of Brown Hy-line were high compared to those of White Hy-line hens. Silversides *et al*. (2006) reported that ISA-brown hens produced heavier eggs than Babcock hens. Al-Khalifa *et al.* (2013) reported that production performance and efficiency for Brown Hy-line hens was greater than that of White Hy-line ones, and also that the overall average of yolk weight and percentage in eggs laid by brown Hy-line were less than that of eggs laid by White Hy-line, but the difference was non-significant. The overall albumen weight and percentage of the Brown Hy-line eggs was greater than that of White Hy-line eggs (Al-Khalifa *et al.,* 2013).

Rayan *et al.* (2016) reported that Brown Hy line showed high mortality compared to White Hy-line hens. Brown Hy-line had a greater eggshell quality than White Hy-line but there was no significant difference on their egg weight (Rayan *et al.,* 2016). Rayan *et al.* (2016) also reported that White Hy-line had higher percentage of hen-day and hen housed egg production compared to the Brown Hy-line. Strain affected the egg shell weight significantly, Brown Hy-line hen's egg shell weight was greater than that of White Hy-line hens, Rayan *et al.* (2013) also reported that strain had a significant effect on egg output per bird, net revenue and economy efficiency. There is a great difference between studies which shows high egg laying advantages of rearing Brown Hy-line over White Hy-line layers, (Mutaf *et al.,* 2009). Breed had a significant effect on egg weight, egg length, width, breaking strength, and shape index and albumen height, the study compared egg quality traits of the four breeds namely, Barred Plymouth Rock, White Leghorn, Rhode Island Red and White Rock between 31 and 37 weeks of age (Monira *et al.,* 2003). Jones (2006) said that strain played a major role in albumin consistency since some strains produce eggs with thin albumin, Brown egg layers produced eggs with high Haugh Units compared to White egg producing layers. Osman *et al*. (2010) revealed that Hi-sex Brown strain recorded better (P<0.05) cumulative feed conversion ratio than Bovans white strain. The little effect of strain on feed conversion ratio in spite of its significant effect on both egg mass and feed intake could be attributed to the fact that, as feed intake increased, egg mass also increased with the same level and vice versa (Osman *et al.,* 2010).

The egg shape index of brown eggs was significantly higher than white eggs and insignificant egg shell breaking force was reported (Badawe *et al*., 2005). Grabas *et al*. (2001) reported that ISA- Brown hens had better feed efficiency than Dekalb white strain. Also Al-Nasser *et al*. (2006) found that feed efficiency of Brown egg strain was better than that for white egg strain. Badawe *et al*. (2005) also reported a significant (P<0.01) high albumin weight percentage on Brown Hy-line layers than that of white Hy-line layers and strain did not affect egg yolk percentage . Hassanein and Toson (2005) found that, Hi-sex Brown eggs were superior in shape index, shell percentage, yolk index and albumin percentage than those recorded for Bovans white eggs at 26 weeks of age However, Bovans white eggs were higher in shell strength and yolk percentage than that of Hi-sex Brown eggs.

2.5 Effect of feed withdrawal × strain on laying performance, egg quality (internal and external traits).

Olawumi *et al*. (2014) reported significant interaction between strains by short-term feed restriction on production traits of Brown and Black plumage commercial layer strains at late phase of egg production. The interaction between feed restriction (a*d libitum,* 4hours and 8hours) and strain (Hisex Brown and Bovans White) had insignificant effect on egg weight during all productive periods, (Osman *et al.,* 2010). The effect of interaction between strain and feed restriction on cumulative egg mass was negligible (Osman *et al*., 2010).

Chapter 3: materials and methods

3.1 Experimental site

The study was conducted at the School of Agriculture experimental farm and food chemistry laboratory University of Venda, Thohoyandou (22^{0}58'32" S, 30^{0}26'45" E; 596m above sea level). The daily temperatures in Thohoyandou vary from about 25^{0}C to 40^{0}C in summer and between 12^{0}C and 26^{0}C in winter (Mzezewa and Gwata, 2012).

3.2 Experimental procedure

3.2.1 Experimental design and housing

A 3x2 factorial experiment (Three feed withdrawal regimes and two strains) was used in the study. One hundred and eight layers (54 Brown and 54 White Hy-line) at 18 weeks (point of lay) of age were used to investigate the effects of feed withdrawal and strain on laying performance and egg quality over two months. On the first day of experimental data collection, three hens were randomly selected, tagged for identification using cable tires, weighed and put into cages. Birds were subsequently put on different feeding regimes namely; unrestricted feeding (*ad libitum* feeding), 4hrs feed withdrawal and 8hrs feed withdrawal daily. Each strain occupied 18 cages (six replicates per treatment) measuring 44×50×37cm(W×L×H) in size giving each hen a floor space of 733cm^2. Each strain consisted of three treatments with six replicates in each treatment. In the house hens occupied 36 cages and each cage accommodated three hens. The 36 cages made two rows (upper row with 9 cages and lower row with 9 cages) of White Hy-Line hens and other two rows (upper row with 9 cages and lower row with 9 cages) of Brown Hy-Line hens as it appears on figures 3 and 4. The hens were housed in a side opening house which was 14 meters long, 4 meters width, 4 meters high and the roofing was 2m from the cages top. The side openings had manual curtains installed which were used to close during windy, cold and rainy days, but in hot days they kept open.

3.2.2 Diet, feeding regimes and layer management

Layers were kept in a well-ventilated open sided layer house measuring 14m long and 5m high. During the first week after arrival, hens were fed a commercial layer ration *ad libitum*. On the evening of day 7 at 18:00hrs to the morning of day eight at 06:00hrs feed was removed to starve the birds to get an accurate initial body weight. Weighing of birds was thereafter carried out every morning of day eight. Clean drinking water was freely available through a nipple drinking system. Bodyweight changes for adjacent weeks were calculated. Removable wooden planks were used to cover the feeding troughs during feed withdrawal periods. Twelve-hour natural lighting plus four hours of light before sunrise were provided throughout the experiment. Lights were switched off between 18:00hrs and 02:00hrs so that the 16 hours lighting would be met using light timer that was programmed to meet required lighting time for layers production. Feeds were weighed and recorded when offered and left overs at the end of each week. Hen weight gain or weight loss was determined weekly by computing the difference in average hen weight for the previous week and that for the current week. Feed consumption was determined as the difference between weekly total feed offered less left overs. Daily egg collection was carried out three times a day at 08:00hrs, 12:00hrs and 16:00hrs. Daily weighing of eggs was carried out using a digital weighing scale. Mortality was recorded daily. Weekly removal of droppings from underneath the layer cages was practiced keeping the layer house clean.

3.3 Measurements

3.3.1 Mortality rate per cage

Mortality rate (%) =$\frac{\text{Number of dead birds in the week}}{\text{Total number of birds for the week}}$X100

3.3.2 Egg production (laying performance).

The total number of eggs per day per cage was recorded. Hen-day-egg production was calculated from weekly egg production per experimental unit (cage) divided by number of days and number of birds. Egg weight (grams) was determined using an electronic digital scale.

3.3.3 Average egg weight.

The weekly average egg weight per cage was calculated by random sampling of seven median (one on each day) eggs, add in their weights together and divided by seven, using the formula:

average egg weight=$\frac{egg\ mass(7\ eggs)}{number\ of\ eggs(7)}$

3.3.4 Egg mass.

Egg mass was determined weekly per cage by adding up egg weights of all eggs laid.

3.3.5 Body weight change.

Weekly body weight change was determined by individually weighing hens on first day (initial body weight) and on the last day (final body weight) of the week. The following formula was used: Body weight change= final body weight - initial body weight.

3.3.6 Egg quality (internal and external).

Weekly egg quality measurements and determinations were done using one egg per replicate from eggs sampled for mean weight determination. Egg width and height (mm) were measured using a Vernier Caliper (Hussain *et al*., 2013). Egg shell colour was analyzed using a Spectrophotometry and interpreted using Easy Match® (Hunter Associate Laboratory, VA, USA) computer software. Easy Match® l* a* b* values were used to calculate the average egg shell colour using the formula: square root of ($l^2 + a^2 + b^2$) (Ingram *et al.,* 2008). The egg shell breaking strength was measured using the Texture Analyzer machine (Spectrometer Technologies, Cape Town, South Africa) connected to Exponent (Stable Micro Systems, Godalming, Surrey, UK) computer software program. After taking egg shell quality measurements, the egg was broken onto an open flat plate to enable measurements of the internal units. Egg yolk and albumen heights were measured by dipping a cable tire into the center of egg yolk and the albumen that showed a visible maximum height mark, subsequently the height on the cable tire was measured using a Vernier Caliper. Albumen height was determined according to (Silversides *et al.,* 2010). The egg yolk was then separated from the albumen by carefully holding the egg yolk with a glass beaker and pouring the albumen into another beaker. The egg yolk and albumen weight were measured using a digital scale. Egg yolk colour was measured and recorded using the Spectrophotometry as previously described for egg shell quality. The egg shell weight was determined as the difference between the whole egg weight less the combined weights of the egg yolk and albumen. All quality traits (egg height, egg width, egg shell breaking force, yolk height, albumen height, albumen weight and yolk weight) measurements were carried out in the food chemistry laboratory at the University of Venda.

3.3.7 Egg shape index

Egg shape index was calculated as: $\frac{\text{Egg width}}{\text{Egg length}} \times 100$ (Reddy *et al*., 1979 and Anderson *et al.,* 2004).

3.3.8 Haugh Unit.

The Haugh unit (Haugh, 1937) was calculated as follows:

$HU = 100 \log (h + 7.6 - 1.7w^{0.37})$

Where h = observed albumen height in mm

w = observed weight of the egg in grams.

3.3.9 Weekly feed consumption.

Weekly feed consumption was calculated as total feed offered per week less the total feed left overs at the end of the week. Feed consumption per hen per day per cage was calculated by dividing weekly feed consumed by 3 (three birds per cage).

3.3.10 Feed conversion ratio

It was calculated as: $\frac{\text{Feed consumed (g)}}{\text{Weight gain (g)}}$ (Ragheb *et al.,* 2013).

3.3.11 Egg grading

It was determined by counting the number of extra small (33g-43g), small (43g-53g), medium (53g-63g), large (63g-73g), extra-large (73g-83g) and jumbo (83g-93g) sized eggs. Their percentage was calculated using the following formula: percentage of small graded eggs % $= \frac{\text{number of small eggs}}{\text{egg output}} \times 100$ the same procedure was repeated in all egg grades.

Table 1, Nutrient composition of the layers standard ration used

	Min (g/kg)	Max (g/kg)
Crude protein	280	
Lysine	12	
Methionine	8	
Moisture		240
Crude fat	50	
Crude fibre		140
Calcium	70	90
Phosphorus	10	
Salt		10

Source: De Heus (Pty) Ltd, P O Box 179, Umlaas Road, 2018

3.4 Statistical Analyses

Statistical analysis for a 3x2 factorial experiment was carried out using general linear model procedure of Minitab 16 (Minitab, 2014) to determine the effects of feed withdrawal and strain. Where significant differences were observed, mean separation tests were carried out using Tukey's multiple range test. Data was analyzed using the model;

$Y_{ijkl} = \mu + W_i + S_j + F_k + (SF)_{jki} + \varepsilon_{ijkl}$ where:

Y_{ijkl} is the l^{th} observation on the i^{th} week with the j^{th} strain and the k^{th} feeding regime;

Y= body weight change, feed intake, egg output, egg weight and egg quality traits;

μ is the overall mean;

W_i is the effect of the i^{th} week (i=1-8);

S_j is the effect of the j^{th} strain (j=1 and 2);

F_k is the effect of the k^{th} feed withdrawal (k=1, 2 and 3);

$(SF)_{jki}$ is the interaction of the j^{th} strain and the k^{th} feed withdrawal;

ε_{ijkl} random error term assumed to be normally and independently distributed with mean 0 and variance equal to d^2

Means were differentiated using the Tukey's multiple range test.

3.5 Ethical clearance

This study has been approved by the Ethics Committee of the University of Venda and had therefore been performed in accordance with the ethical standards laid down in the 1964 Declaration of Helsinki and its later amendments.

Chapter 4: Results

4.1 Effects of week, feed withdrawal, strain and feed withdrawal by strain interaction on average laying performance and mortality rate of White and Brown Hy-Line layers.

Week had a significant effect (P<0.01) on body weight, body weight change, egg output, feed conversion ratio for egg output, egg weight, egg mass, feed conversion ratio for egg mass, feed conversion ratio for body weight change and feed intake (P<0.5), feed conversion ratio for average egg weight (P<0.05) (Table 2). Week two and week five on feed intake were different from each other, but they were both comparable to the rest of the weeks. Body weight increased with an increase in hen's age. Body weight changes during the first five weeks were high than in the last three weeks which were low. Weeks one and two were different and the egg weight was increasing in time throughout the investigation, but it was statistically the same from week four to week eight. On egg output for the first two weeks was different and there was an increase with time throughout the investigation. Feed conversion ratio for egg output was high on week one and it decreased with time, however from week three to week eight there was no difference. The first three weeks on egg mass differed from the last five weeks. Feed conversion ratio for egg mass differed for two first weeks compared to the last five weeks. Week had an insignificant effect (P>0.05) on mortality rate.

Feed withdrawal had a significant effect (P<0.01) on feed intake and (P<0.05) body weight. As feed withdrawal period increased feed intake decreased. *Ad libitum* fed hens had high feed intake and was comparable on four and eight hours feed withdrawn hens. *Ad libitum* fed hens had high body weight, intermediate on eight hours feed withdrawn hens and lower on four hours feed withdrawn hens. No significant feed withdrawal effect (P>0.05) was observed on body weight change, feed conversion ratio for body weight change, egg output, feed conversion ratio for egg output, egg weight, feed conversion ratio for egg weight, egg mass, feed conversion ratio egg mass.

Strain had a significant effect (P<0.01) on body weight and egg weight. White Hy-Line layers (1739g) had high body weight than Brown Hy-Line layers (1669g). Brown Hy-Line layers egg weight was higher (49.4g) than that of White Hy-Line layers (45.1g). Strain showed no significant effect (P>0.05) on feed intake, body weight change, feed conversion ratio for body weight change, egg output, feed conversion ratio for egg output, feed conversion ratio for egg weight, egg mass, feed conversion ratio for egg mass and on mortality rate.

Feed withdrawal by strain interaction effect (P<0.05) was observed on body weight and average egg weight. White Hy-Line layers had high body weight than Brown Hy-Line layers under *ad libitum* feeding. Brown Hy-Line layers on eight hours feed withdrawal had high egg weight than White Hy-Line layers on eight hours feed withdrawal. No feed withdrawal by strain interaction effect (P>0.05) was observed on feed intake, body weight change, feed conversion ratio for body weight change, egg output, feed conversion ratio for egg output, feed conversion ratio for egg weight, egg mass, feed conversion ratio for egg mass and on mortality rate.

Table 2, Effects of week, feed withdrawal, and strain and feed withdrawal by strain on average laying performance and mortality rate percentage

Week	N	FI (g)	BW	BWC(g)	FCRBWC	EW (g)	FCREW	EO	FCREO	EM(g)	FRCEM	MR (%)
1	36	815.9^{ab}	1530^{d}	76.2^{a}	0.11^{ab}	23.1^{d}	19.9^{a}	1.4^{e}	362.1^{a}	73.4^{e}	9.1^{a}	0.00^{a}
2	36	757.9^{b}	1605^{cd}	62.6^{ab}	12.7^{ab}	40.2^{c}	20.9^{a}	3.3^{d}	291.4^{ab}	156.0^{d}	6.4^{ab}	0.00^{a}
3	36	798.9^{ab}	1669^{bc}	53.2^{abc}	23.7^{a}	48.2^{b}	17.4^{a}	5.2^{c}	187.6^{bc}	255.6^{c}	3.8^{bc}	0.93^{a}
4	36	784.6^{ab}	1722^{ab}	15.7^{cd}	4.41^{ab}	51.1^{ab}	15.4^{a}	5.9^{bc}	144.3^{c}	302.0^{b}	2.8^{bc}	0.00^{a}
5	36	866.7^{a}	1738^{ab}	50.0^{abc}	0.46^{ab}	52.3^{ab}	16.6^{a}	6.4^{ab}	136.1^{c}	344.3^{a}	2.5^{bc}	0.00^{a}
6	36	808.9^{ab}	1788^{a}	11.2^{d}	39.7^{b}	53.8^{ab}	15.1^{a}	6.7^{a}	120.8^{c}	361.5^{a}	2.2^{c}	0.00^{a}
7	36	821.0^{ab}	1777^{a}	25.2^{bcd}	21.8^{a}	54.2^{ab}	15.2^{a}	6.8^{a}	120.4^{c}	368.7^{a}	2.2^{c}	0.00^{a}
8	36	800.0^{ab}	1802^{a}	13.2^{cd}	21.5^{a}	55.0^{a}	14.6^{a}	6.8^{a}	117.0^{c}	375.2^{a}	2.1^{c}	0.00^{a}
SEM		22.0	19.6	9.8	13.0	1.4	1.6	0.2	30.8	8.8	1.0	0.33
FW (hrs)												
0hrs	96	885.2^{a}	1726^{a}	44.9^{a}	0.25^{a}	46.9^{a}	18.0^{a}	5.2^{a}	206.9^{a}	278.4^{a}	4.7^{a}	0.35^{a}
4hrs	96	776.7^{b}	1683^{b}	33.6^{a}	14.0^{a}	46.9^{a}	17.2^{a}	5.4^{a}	184.7^{a}	276.6^{a}	3.8^{a}	0.00^{a}
8hrs	96	758.3^{b}	1703^{ab}	28.4^{a}	-0.98^{a}	47.9^{a}	15.4^{a}	5.4^{a}	163.3^{a}	283.8^{a}	3.2^{a}	0.00^{a}
SEM		13.5	12.1	6.0	7.1	0.9	1.0	0.1	18.9	5.4	0.6	0.20
Strain												
W	144	811.6^{a}	1739^{a}	34.0^{a}	5.1^{a}	45.1^{b}	16.9^{a}	5.4^{a}	170.5^{a}	276.1^{a}	4.0^{a}	0.00^{a}
B	144	801.9^{a}	1669^{b}	37.3^{a}	3.7^{a}	49.4^{a}	16.9^{a}	5.3^{a}	199.4^{a}	283.1^{a}	3.9^{a}	0.23^{a}
SEM		11.0	9.8	4.9	6.5	0.7	0.8	0.1	15.4	4.4	0.5	0.16
FW*ST												
0hrs W	48	891.6^{a}	1783^{a}	36.4^{a}	2.8^{a}	45.9^{b}	18.3^{a}	5.4^{a}	197.3^{a}	279.1^{a}	5.3^{a}	0.00^{a}
0hrs B	48	878.8^{a}	1668^{b}	53.4^{a}	3.3^{a}	47.9^{ab}	17.8^{a}	5.1^{a}	216.6^{a}	277.1^{a}	4.0^{a}	0.69^{a}
4hrs W	48	795.5^{b}	1714^{b}	31.3^{a}	12.4^{a}	45.0^{b}	17.2^{a}	5.5^{a}	164.8^{a}	275.3^{a}	3.5^{a}	0.00^{a}
4hrs B	48	758.0^{b}	1652^{b}	35.9^{a}	15.5^{a}	48.8^{ab}	17.2^{a}	5.2^{a}	204.5^{a}	277.8^{a}	4.2^{a}	0.00^{a}
8hrs W	48	747.6^{b}	1721^{ab}	34.3^{a}	5.8^{a}	44.4^{b}	15.2^{a}	5.3^{a}	149.5^{a}	273.3^{a}	3.1^{a}	0.00^{a}
8hrs B	48	769.0^{b}	1685^{b}	22.4^{a}	7.8^{a}	51.4^{a}	15.6^{a}	5.4^{a}	177.1^{a}	294.3^{a}	3.3^{a}	0.00^{a}
SEM		19.1	17.0	8.5	11.3	1.2	1.4	0.2	26.7	7.6	0.8	0.28
Week		*	**	**	*	**	*	**	**	**	**	ns
FW		**	*	ns	ns	ns	ns	ns	ns	ns	ns	ns
ST		ns	**	ns	ns	**	ns	ns	ns	ns	ns	ns
FW*ST		ns	*	ns	ns`	*	ns	ns	ns	ns	ns	ns

N= number of observations. FI (g) = feed intake in grams. BWC (g) = body weight change in grams. FCRBWC = Feed conversion ratio for body weight change. EW (g) = egg weight in grams. FCREW = feed conversion ratio for average egg weight. EO = egg output. FCREO = feed conversion ratio for average egg output. EM (g) = egg mass. FCREM = feed conversion ratio for egg mass. MR= mortality rate. SEM = Standard error of the mean. FW (hrs) = Feed withdrawal in hours: 0hrs = No feed withdrawal, 4hrs = Four hours feed withdrawal, 8hrs = Eight hours feed withdrawal. ST = strain: W = White Hy-Line layers. B = Brown Hy-Line layers. FW*St = Feed withdrawal by Strain interaction. $^{A\ b\ c}$ = for a trait, means carrying different superscripts are significantly different. ns= not significant, ** = P<0.01 significantly different, * = P< 0.05 significantly different.

4.2 Effects of week, feed withdrawal, strain and feed withdrawal by strain interaction on external egg quality traits.

Table 3 shows that week had a significant (P<0.01) effect on median egg weight, egg height, egg width, egg shape index, egg shell weight, egg shell breaking force and average egg shell colour. Median egg weight, egg shape index and average egg shell colour at week one were lower and different from those observed in week two until week eight that were the same. Egg height and egg width at week one and three were comparably low and significantly different from the rest of the weeks that are also the same. The egg shell breaking force was high at week six and comparable with weeks two, seven and eight.

Feed withdrawal had insignificant effect (P>0.05) on external egg quality traits (median egg weight, egg height, egg width, egg shape index, egg shell weight, egg shell breaking force and on average egg shell colour.

Strain had a significant effect (P<0.01) on median egg weight, egg height and (P<0.05) on egg width and average egg shell colour. Brown Hy-Line layers had high median egg weight, egg height, egg width and average egg shell colour compared to White Hy-Line layers. Strain did not affect (P>0.05) egg shape index, egg shell weight and egg shell breaking force.

There was a significant feed withdrawal by strain interaction effect (P<0.05) observed on median egg weight and egg height. Eight hours feed withdrawn Brown Hy-Line layers had a high median egg weight and egg height than those of White Hy-Line layers under eight hours feed withdrawal. No significant feed withdrawal by strain interaction effects (P>0.05) were observed on egg width, egg shape index, egg shell weight, egg shell breaking force and average egg shell colour.

Table 3, Effects of week, feed withdrawal, strain and feed withdrawal by strain interaction on external egg quality traits

Week	N	MEW (g)	EH (mm)	EW (mm)	ESI	ESW (g)	ESBF (g/cm^2)	EGG SHELL COLOUR			AESC
								l*	a*	b*	
1	36	31.3^{c}	34.4^{b}	27.0^{b}	52.4^{b}	3.1^{c}	1910.7^{c}	34.7^{b}	10.2^{b}	16.3^{b}	39.7^{b}
2	36	48.5^{b}	50.7^{a}	39.7^{a}	76.4^{a}	9.5^{a}	2900.0^{ab}	51.1^{a}	16.2^{a}	23.8^{a}	58.9^{a}
3	36	49.7^{ab}	38.0^{b}	27.2^{b}	71.7^{a}	8.2^{ab}	2541.7^{bc}	51.7^{a}	16.4^{a}	23.6^{a}	59.3^{a}
4	36	51.2^{ab}	52.5^{a}	41.7^{a}	79.5^{a}	8.7^{ab}	2467.6^{bc}	50.5^{a}	17.7^{a}	25.5^{a}	59.4^{a}
5	36	52.1^{ab}	52.8^{a}	42.7^{a}	80.1^{a}	3.8^{c}	1878.1^{c}	52.1^{a}	17.1^{a}	26.9^{a}	61.5^{a}
6	36	53.8^{ab}	53.2^{a}	42.6^{a}	80.2^{a}	7.4^{b}	3337.5^{a}	50.3^{a}	17.4^{a}	25.8^{a}	59.3^{a}
7	36	54.1^{ab}	53.3^{a}	42.1^{a}	80.7^{a}	7.1^{b}	2980.2^{ab}	50.8^{a}	17.5^{a}	25.3^{a}	59.5^{a}
8	36	55.0^{a}	53.5^{a}	42.9^{a}	80.3^{a}	7.2^{b}	3050.8^{ab}	51.2^{a}	17.6^{a}	26.7^{a}	60.5^{a}
SEM		1.5	1.6	1.2	2.4	0.4	174.0	1.7	0.6	0.9	1.9
FW											
0hrs	96	49.3^{a}	47.9^{a}	37.8^{a}	73.7^{a}	6.9^{a}	2553.7^{a}	47.8^{a}	16.3^{a}	24.0^{a}	56.1^{a}
4hrs	96	49.5^{a}	48.8^{a}	38.8^{a}	76.7^{a}	7.0^{a}	2542.6^{a}	49.6^{a}	16.6^{a}	24.8^{a}	57.1^{a}
8hrs	96	49.8^{a}	48.8^{a}	38.5^{a}	75.4^{a}	7.0^{a}	2803.1^{a}	49.8^{a}	16.2^{a}	23.8^{a}	57.7^{a}
SEM		0.9	1	0.7	1.5	0.2	106.5	1	0.3	0.5	1.1
S											
W	144	47.5^{b}	47.0^{b}	37.4^{b}	74.5^{a}	6.7^{a}	2614.0^{a}	47.5^{b}	16.2^{a}	23.6^{b}	55.6^{b}
B	144	51.6^{a}	50.1^{a}	39.3^{a}	76.1^{a}	7.2^{a}	2652.8^{a}	50.7^{a}	16.5^{a}	24.9^{a}	58.9^{a}
SEM		0.7	0.8	0.6	1.2	0.2	87	0.8	0.3	0.4	0.9
FW*S											
0hrs W	48	48.6^{abc}	47.4^{ab}	37.8^{a}	74.3^{a}	6.7^{a}	2782.6^{ab}	46.7^{a}	16.6^{a}	23.9^{a}	55.1^{a}
0hrs B	48	50.0^{abc}	48.5^{ab}	37.9^{a}	73.0^{a}	7.1^{a}	2324.8^{b}	48.1^{a}	16.1^{a}	24.1^{a}	57.1^{a}
4hrs W	48	47.5^{bc}	47.5^{ab}	38.0^{a}	76.6^{a}	6.7^{a}	2505.7^{ab}	48.2^{a}	16.6^{a}	24.2^{a}	56.6^{a}
4hrs B	48	51.5^{ab}	50.2^{ab}	39.5^{a}	76.9^{a}	7.3^{a}	2579.4^{ab}	50.1^{a}	16.6^{a}	25.3^{a}	59.4^{a}
8hrs W	48	46.3^{c}	46.0^{b}	36.4^{a}	72.4^{a}	6.7^{a}	2553.7^{ab}	47.5^{a}	15.5^{a}	22.5^{a}	55.0^{a}
8hrs B	48	53.2^{a}	51.7^{a}	40.6^{a}	78.4^{a}	7.3^{a}	3054.3^{a}	52.1^{a}	16.9^{a}	25.1^{a}	60.4^{a}
SEM		1.3	1.3	1.1	2.1	0.3^{a}	150.7	1.4	0.5	0.8	1.6
Week		**	**	**	**	**	**	**	**	**	**
FW		ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
S		**	**	*	ns	ns	ns	**	ns	*	*
FW*S		*	*	ns	ns	ns	ns	ns	ns	ns	ns

N = number of observations. MEW (g) = median egg weight grams.EH (mm) = egg height in millimeters. EW (mm) = egg width in millimeters. ESI = egg shape index. ESW (g) = egg shell weight in grams. ESBF (g/cm^2) = egg shell breaking force in grams per square centimeter. AESC = average egg shell colour. SEM= standard error mean. FW (hrs) = feed withdrawal in hours.0hrs = zero hours feed withdrawal.4hrs = four hours feed withdrawal and 8hrs = eight hours feed withdrawal. W = white Hy-Line layers. B = brown Hy-Line layers. FW X ST = feed withdrawal by strain interaction. ns = not significant P>0.05. ** Significantly different P<0.01. * Significantly different P<0.05.

4.3 Effects of week, feed withdrawal, strain and feed withdrawal by strain interaction on internal egg quality traits.

Table 4 shows that week had a significant (P<0.01) effect on median egg weight, albumen weight, yolk weight, albumen height, yolk height and Haugh Units. Median egg weight, albumen height, yolk height and Haugh Unit were low and different in week one than on other weeks that were the same. Median egg weight and yolk weight increased with time. Albumen and yolk weight on the first week were different and the rest of the weeks were comparable.

Feed withdrawal had no significant effect (P>0.05) in all internal egg quality traits (median egg weight, albumen height, yolk height, albumen weight, yolk weight and Haugh Unit).

Strain had a significant effect (P<0.01) on median egg weight and albumen weight. High median egg weight and albumen weight were observed on Brown Hy-Line layers than on White Hy-Line layers. Strain had no significant effect (P>0.05) on albumen height, yolk height, yolk weight and Haugh Unit.

There was significant feed withdrawal by strain interaction effect (P<0.05) on median egg weight and albumen weight. The median egg weight was high for Brown Hy-Line layers than for White Hy-Line layers under eight hours feed withdrawal. Albumen weight was high for Brown Hy-Line than for White Hy-Line under both four hours and eight hours feed withdrawal. There was no significant feed withdrawal by strain effect (P>0.05) observed on albumen height, yolk height, yolk weight and Haugh unit.

Table 4, Effects of week, feed withdrawal, strain and feed withdrawal by strain on egg internal quality traits

Week	N	MEW (g)	AH (mm)	YH (mm)	AW (g)	YW (g)	HU
1	36	31.3[c]	2.6[b]	7.1[b]	19.8[d]	7.5[d]	47.0[b]
2	36	48.5[b]	4.1[a]	13.8[a]	29.4[c]	9.6[c]	70.9[a]
3	36	49.7[ab]	4.6[a]	13.9[a]	30.5[bc]	10.9[c]	68.9[a]
4	36	51.2[ab]	4.2[a]	14.7[a]	31.3[bc]	11.3[bc]	63.9[a]
5	36	52.1[ab]	4.4[a]	14.7[a]	36.2[a]	12.9[ab]	65.7[a]
6	36	53.8[ab]	4.0[a]	14.4[a]	32.7[abc]	13.4[a]	61.1[a]
7	36	54.1[ab]	4.5[a]	15.1[a]	33.5[abc]	13.5[a]	66.1[a]
8	36	55.0[a]	4.2[a]	14.4[a]	33.6[ab]	14.2[a]	62.4[a]
SEM		1.5	0.2	0.4	0.1	0.4	2.8
FW							
0hrs	96	49.3[a]	4.2[a]	13.3[a]	30.8[a]	11.6[a]	62.2[a]
4hrs	96	49.5[a]	4.2[a]	13.6[a]	30.6[a]	11.9[a]	63.8[a]
8hrs	96	49.8[a]	4.3[a]	13.7[a]	31.2[a]	11.5[a]	63.7[a]
SEM		0.9	0.1	0.3	0.6	0.3	1.7
S							
W	144	47.5[b]	4.2[a]	13.5[a]	28.1[b]	11.8[a]	63.5[a]
B	144	51.6[a]	4.2[a]	13.5[a]	32.8[a]	11.5[a]	62.1[a]
SEM		0.7	0.1	0.2	0.5	0.2	1.4
FW*S							
0hrs W	48	48.6[abc]	4.3[a]	13.5[a]	30.0[bcd]	11.9[a]	63.8[a]
0hrs B	48	50.0[abc]	4.0[a]	13.0[a]	31.7[abc]	11.2[a]	60.6[a]
4hrs W	48	47.5[bc]	4.0[a]	13.6[a]	28.8[cd]	11.1[a]	63.3[a]
4hrs B	48	51.5[ab]	4.3[a]	13.6[a]	32.4[ab]	11.8[a]	64.3[a]
8hrs W	48	46.3[c]	4.3[a]	13.4[a]	28.1[d]	11.5[a]	63.4[a]
8hrs B	48	53.2[a]	4.3[a]	13.9[a]	34.4[a]	11.6[a]	64.1[a]
SEM		1.3	0.2	0.4	0.8	0.4	3
Week		**	**	**	**	**	**
FW		ns	ns	ns	ns	ns	ns
S		**	ns	ns	**	ns	ns
FW*S		*	ns	ns	*	ns	ns

N= number of observations. MEW (g) = median egg weight grams. AH (mm) = albumen height in millimeters. YH (mm) = yolk height in millimeters. AW (g) = albumen weight in grams. YW (g) = yolk weight in grams. HU= Haugh Unit. SEM = standard error mean. FW (hrs) = feed withdrawal in hours.0hrs = zero hours feed withdrawal, 4hrs = four hours feed withdrawal and 8hrs = eight hours feed withdrawal. W = white Hy-Line layers. B = brown Hy-Line layers. FW X ST= feed withdrawal by strain interaction. ns = not significant P>0.05. ** Significantly different P<0.01. * Significantly different P<0.05.

4.4 Effects of week, feed withdrawal, strain and feed withdrawal by strain interaction on number of egg's grade (%).

Week had significant effect (P<0.01) on percentage of extra small, small, medium, large and extra-large graded eggs (P<0.05). Week two had high percentage of extra small graded eggs percentage and in other weeks it was comparable. Whereas week one had higher percentage which differed from low percentages observed from weeks five to eight. Weeks two to week five small graded eggs percentage were comparable and high, weeks five to eight are comparable and week one and eight are low and comparable. Week seven and eight had high percentage of medium eggs which differed from percentages observed in weeks one to six, with week two having the smallest percentage of medium eggs which differ from percentages observed in other weeks except in week three. Week one had had higher percentage of large graded eggs which differ from other weeks. The percentage of extra-large graded eggs was higher in week six and differed from low percentages observed in weeks two and four, but both weeks were comparable to the rest of the weeks. Jumbo graded eggs percentage showed no week significant (P>0.05) difference.

Feed withdrawal had a significant effect (P<0.01) on percentage of small and extra-large graded eggs. Hens under four hours feed withdrawal had higher percentage of small graded eggs than hens under eight hours feed withdrawal and *ad libitum* fed hens, and hens under *ad libitum* had higher percentage of extra-large eggs, intermediate on eight hours feed withdrawn hens and lower on four hours feed withdrawn hens. There was no feed withdrawal significant effect (P>0.05) observed on percentage of extra small, medium, large, and jumbo graded eggs.

Strain had a significant effect (P<0.01) on percentage of extra small, small, medium and large graded eggs. White Hy-Line layers had high percentage of extra small and small graded eggs and Brown Hy-Line layers had high percentage medium and large graded eggs. There was no strain significant effect (P>0.05) observed on percentage of extra-large and jumbo graded eggs.

There was feed withdrawal by strain interaction effect observed on small and large (P<0.05) and on medium (P<0.01) graded eggs percentage. In all feed withdrawal regimes, White Hy-Line had high percentage of small graded eggs and Brown Hy-Line had high percentage of medium grade eggs. Brown Hy-Line had higher percentage of large graded eggs than White Hy-Line under eight hours feed withdrawal. There was no feed withdrawal by strain interaction effect

(P>0.05) observed on percentage of extra small, extra-large and jumbo graded eggs percentage.

Table 5, Effects of week, feed withdrawal, strain and feed withdrawal by strain on egg grade average percentage

Week	N	Extra small (%)	Small (%)	Medium (%)	Large (%)	Extra-large (%)	Jumbo (%)
1	36	9.1[b]	23.7[e]	27.1[ef]	8.9[a]	0.7[ab]	0.0[a]
2	36	18.7[a]	67.6[ab]	8.6[g]	2.3[b]	0.0[b]	0.0[a]
3	36	4.8[bc]	72.3[a]	20.3[fg]	2.3[b]	0.6[ab]	0.0[a]
4	36	1.9[bc]	60.7[ab]	34.1[de]	1.1[b]	0.4[b]	0.0[a]
5	36	1.5[c]	53.7[bc]	42.6[cd]	1.5[b]	0.7[ab]	0.2[a]
6	36	0.9[c]	43.1[cd]	51.8[bc]	0.9[b]	2.3[a]	0.0[a]
7	36	0.3[c]	40.5[cd]	56.4[ab]	1.8[b]	1.1[ab]	0.0[a]
8	36	0.8[c]	29.8[de]	67.2[a]	1.4[b]	0.7[ab]	0.3[a]
SEM		1.2	3.6	3.2	1	0.4	0.1
FW (hrs)							
0hrs	96	4.1[a]	45.3[b]	40.6[a]	2.5[a]	1.3[a]	0.1[a]
4hrs	96	4.1[a]	54.5[a]	35.3[a]	2.6[a]	0.4[b]	0.0[a]
8hrs	96	5.1[a]	47.2[ab]	39.1[a]	2.6[a]	0.8[ab]	0.1[a]
SEM		1.1	2.2	1.9	0.6	0.3	0.1
ST							
W	144	6.9[a]	59.1[a]	26.3[b]	1.5[b]	0.7[a]	0.0[a]
B	144	2.6[b]	38.9[b]	50.1[a]	3.7[a]	0.9[a]	0.1[a]
SEM		0.9	1.8	1.6	0.5	0.3	0.04
FW*ST							
0hrs W	48	7.3[a]	52.1[bc]	33.6[b]	1.9[ab]	1.0[a]	0.0[a]
0hrs B	48	2.7[a]	38.5[d]	47.5[a]	3.3[ab]	1.5[a]	0.2[a]
4hrs W	48	6.5[a]	67.1[a]	18.8[c]	2.1[ab]	0.4[a]	0.0[a]
4hrs B	48	1.7[a]	41.1[cd]	51.7[a]	3.1[ab]	0.4[a]	0.0[a]
8hrs W	48	6.1[a]	57.1[ab]	26.3[bc]	0.6[b]	0.6[a]	0.0[a]
8hrs B	48	3.4[a]	37.3[d]	53.7[a]	4.7[a]	0.9[a]	0.1[a]
SEM		1.5	3.1	2.7	0.9	0.4	0.1
Week		**	**	**	**	*	ns
FW		ns	**	ns	ns	**	ns
ST		**	**	**	**	ns	ns
FW*ST		ns	*	**	*	ns	ns

N = number of observations. SEM = standard error of the mean. FW (hrs) = feed withdrawal in hours: 0hrs = no feed withdrawal, 4hrs = four hours feed withdrawal and 8hrs = eight hours feed withdrawal. ST= strain: W = white Hy-Line layers. B = brown Hy-Line layers. FW*ST = feed withdrawal by strain interaction. ns = not significant $P>0.05$. ** Significantly different $P<0.01$. * Significantly different $P<0.05$.

Chapter 5: Discussion

5.1 Effect of week on laying performance, egg quality and egg grading percentage.

Results showed that week had a significant (P<0.01) effect on feed intake, body weight, body weight change, egg output, feed conversion ratio for egg output, egg weight, egg mass and feed conversion ratio for egg mass, and feed conversion ratio for body weight change (P<0.05), see table 2. Rayan *et al* (2013) supports that age had a significant effect on laying performance. Feed intake was different between week two and six and they are both comparable to the rest of the weeks. Body weight was increasing with hens age increase. Body weight change on the first five weeks was comparable and the last three were low, and the sudden decrease in body gain must have been caused by an increase in egg production and egg weight. Egg weight was increasing with time throughout the investigation. Hani *et al.* (1999) agree with an increase in egg weight as the hen age increased. Egg weight increased with the hen's age (Zita *et al*., 2008).Rizzi and Chiericato (2005) reported a significant (P<0.01) increase of egg weight as hens age increased. Osman *et al.* (2010) investigated the effects of strain and treatment weekly and by looking at their results the laying performances and egg quality traits were different weekly throughout their investigation, the egg output, egg mass and egg weight was increasing with an increase in hen's age and the current study found the same results. Premavalli and Viswanangthan (2004) also reported an increase of egg weight as hen's age increased. Feed intake was decreased with an increase in hen's age (Osman *et al*., 2010). Osman *et al*. (2010) results also show that week had a significant effect on feed conversion ratio as well as in the current study. Baumgartner *et al*. (2007) reported a significant effect of age on egg weight in the Leghorn type hens.

Week showed a difference on median egg weight, egg height, egg width, egg shape index, egg shell weight, egg shell breaking force and on average egg shell colour. Osman *et al*. (2010) reported a significant week effect on egg shell breaking force and egg shape index where they were increasing with hen's age. The current study found the same results, but the difference on egg shell weight was observed on the first week and on the rest of the weeks the difference was comparable. Hasnath (2002) reported an increase in egg shell colour and egg shape index as hen's shape increased, the same occurred in the current study (Table 3). Premavalli and Viswanamgthan (2004) reported a significant increase in egg shape index as hen's age increased, but egg shell breaking force was significantly decreased. Egg shell percentage decreased with age increase, eggshell thickness and strength improved with age (Zita *et al*., 2008).

Osman *et al*. (2010) reported that egg quality (yolk index, Haugh Units, albumen and shell strength) reduced with an increase in hen's age. Egg height and egg width increased with hen's age and these results corresponded to an increase in egg weight as hen's age increase. The age effect on egg quality was correlated to the difference that was observed on egg weight that increased with time and egg weight is dominated by the egg yolk and albumen weight, correlated differences are expected. Rizzi and Chiericato (2005) also reported a significant (P<0.01) decrease of Haugh Unit as age increased and the current study agree with this report, on table 4 Haugh Unit was decreasing with hen's age increase, but the differences were comparable except on first week. Haugh (1937) also indicated that egg shell quality reduced with hen's age. Albumen index, yolk index and Haugh Unit were reported to be significantly decreasing with hen's age (Premavalli and Viswanangthan, 2004). Yolk weight, Haugh Unit increased with the hen's age, but albumen weight improved with age increase (Zita *et al*., 2008). Egg weight influences the weight of its components, the correlations between the egg weight and the albumen weight, yolk weight, egg shell weight are high (Zhang *et al*., 2005).

Week had significant effect (P<0.01) on percentage of extra small, small, medium, large and extra-large sized eggs (P<0.05). Since week showed a significant effect on egg output (number of eggs produced) its effect is expected on the percentage of egg grades since egg grades percentages were determined from the same egg count. Rizzi and Chiericato (2005) and many more studies reported a significant (P<0.01) increase of egg weight as hens age increased. Also in this study extra small and small graded eggs percentage decreased as hens age increased and medium, large and extra-large graded eggs percentage increased as hens age increased. Jumbo graded eggs percentage showed no week significant (P>0.05) difference, see table 5.

5.2 Effect of feed withdrawal on laying performance, egg quality and egg grade percentage.

High significant (P<0.01) feed intake was observed on *ad libitum* fed hens, whereas four hours and eight hours feed withdrawn hens feed intake was comparable. Olawumi (2014) support that feed withdrawal reduced feed intake. Crounch *et al.* (2002) support the reduction of feed consumption due to an increase in feed withdrawal period. Lebbie *et al.* (2008) also reported a significant decrease in feed consumption with an increase in feed withdrawal level. Significant (P<0.05) high body weight was observed on *ad libitum* fed hens, intermediate on eight hours feed withdrawn hens and lower on four hours feed withdrawn hens. Feed restriction decreased body weight and hen-day egg production relatively to the feed withdrawal level (Oyedeji *et al*., 2007). Quantitative feed restriction reduced body weight and feed consumption without reducing egg production (Crounch *et al.,* 2002) and the current study agree with this report, but egg production were not affected though the means of feed intake were low and those of egg output were high on feed withdrawn hens. Osman *et al.* (2010) reported that feed intake reduced as feed withdrawal level increased. Body weight change, feed conversion ratio for body weight change, egg output, feed conversion ratio for egg output, egg weight, feed conversion ratio for egg weight, egg mass and on feed conversion ratio egg mass did not show a difference based on feeding regime (Table 2). The laying performance of these hens did not show a significant difference towards feed withdrawal since their feed intake was comparable on four and eight hours feed withdrawn hens, but on *ad libitum* hens it was high together with body weight change and less feed efficiency was observed. Similar to this study (Table 2), it was reported that feed withdrawal had no significant effect on egg number, egg weight, egg mass, hen day egg production and egg quality (Table 3 and 4) (Osman *et al*., 2010). The insignificant high egg weight, egg output and egg mass were observed on eight hours feed withdrawn hens and Osman et al. (2010) results also reported an insignificant high egg mass on eight hours feed withdrawn hens. The insignificant egg mass is due to comparable egg weights in all feed withdrawal levels. Nofal and Hassan (2004) reported that feed withdrawn hens showed an insignificant better conversion ratio than *ad libitum* fed hens and the current study found the same results (Table 2).

Feed withdrawal did not show significant differences on external egg quality traits (median egg weight, egg height, egg width, egg shape index, egg shell weight, egg shell breaking force and on average egg shell colour) on table 3 and on all egg internal quality traits, median egg weight, albumen height, yolk height, albumen weight, yolk weight and Haugh unit. Hens on restricted feeding exhibited no significant effects on egg weight and shell thickness (Lebbie *et al.,* 2008). Osman *et al.* (2010) agree with insignificant effect (P>0.05) of feed withdrawal on egg weight, egg shell breaking force results of the current study. Feed withdrawal had a significant effect on egg shape index and egg shell weight, yolk quality, Haugh Units Osman *et al.* (2010). Osman *et al.* (2010) support the current results that egg shell weight was insignificantly higher on eight hours feed withdrawn hens than on other treatments. Hasnath (2002) reported the insignificant differences in egg shape index, egg shell thickness, albumen index and Haugh Unit between *ad libitum* fed hens and hens fed 80% of *ad libitum*. The external and internal egg quality traits did not show a significant effect of feed withdrawal since the median egg weight in all feeding regimes were the same and egg quality traits were measured and determined from the same median eggs.

High percentage of small eggs was observed on four hours feed withdrawn hens, intermediate on eight hours feed withdrawn hens and lower on *ad libitum* fed hens. This results show that *ad libitum* feeding can be replaced by feed withdrawal since eight hours feed withdrawal resulted to comparable small graded eggs percentage and it also showed that hens under those treatments used comparable feed in egg production. The percentages of extra small, medium, large, and jumbo graded eggs were the same in all treatments (feeding regime). Egg grading results correspond with the egg weight results on table 2, 3 and 4 which shows that egg weight was comparably high on eight hours feed withdrawn hens. The results also showed that more feed was used in egg production since the body weight change on eight hours feed withdrawn hens was comparably low, also the egg output was comparably high. The current author did not manage to acquire previous studies which studied the effects of feed withdrawal on egg grades of White and Brown Hy-Line layers.

5.3 Effect of strain on laying performance, egg quality and egg grading.

Strain had a significant effect (P<0.01) on body weight and egg weight. White Hy-Line layers had high body weight than Brown Hy-Line layers. Brown Hy-Line layers egg weight was higher (49.4g) than that of White Hy-Line layers (45.1g). Benyi *et al.* (2006) also reported significant effect (P<0.05) of strain on egg weight. Anderson (2002) reported that egg weight of Brown Hy-line was greater than that of White Hy-line. Strain showed no difference on feed intake, body weight change, feed conversion ratio for body weight change, egg output, feed conversion ratio for egg output, feed conversion ratio for egg weight, egg mass and on feed conversion ratio for egg mass, (Table 2). Osman *et al*. (2010) reported that Hi-sex Brown strain consumed higher (P<0.05) cumulative feed than Bovans white strain at all production periods. Badawe *et al*. (2005) showed that, feed consumption of Brown egg strains was higher than that of White egg strains. Rayan *et al.* (2013) support insignificant effect of strain on egg production (egg output). Osman *et al.* (2010) reported that Hi-sex Brown strain produced more (P<0.05) eggs than

Bovans White strain and Hi-sex Brown strain produced insignificant heavy eggs than Bovans White strains. The current results agree with findings by Riczu *et al*. (2004) that eggs laid by Brown Hy-line were heavier than White Hy-Line layers. Rizzi and Chiericato (2005) found that egg weight of Brown Hy-Line was higher (P<0.01) than that of White Hy-Line layers. Silversides *et al*. (2006) reported that ISA-brown hens produced heavier eggs than Babcock hens. Contrary to the findings on feed intake, Ragheb *et al.* (2013) reported significant difference on feed intake between strains. Oyedeji *et al.* (2007) support the current results of comparable feed intake between strains. Hens with low body weight produced more eggs compared to hens of high body weight (Falconer and Mackay, 1996), the current study results shows that hens with high body weight change produced less number of eggs than hens with low body weight change. These results and literature suggest that heavier strains use feed to produce fewer heavier eggs whereas lighter strains use feed to produce more of lighter eggs. On contrary, Al-Khalifa *et al.* (2013) reported that egg production and efficiency for Brown Hy-line hens was greater than that of White Hy-line ones.

Ragheb *et al.* (2013) reported a significantly higher egg weight, egg production and egg mass on Brown Hy-Line layers. Ragheb *et al*. (2013) also reported that strain had no effect on body weight change which supports the current study result, but Brown Hy-Line had high body weight change than White Hy-Line layers (Table 2). The body weight change insignificance results corresponds with feed intake insignificance difference between the two strains and it also implies that differences in body weights between strains remained constant over time. Grobas *et al*. (2001) who found that, egg mass produced by ISA-Brown was more than that from White strain and the current study agree with those results. Also Badawe *et al*. (2005) found that, Brown Hy-line strain produced higher egg mass than White Hy-line strain. Feed conversion efficiency differences between strains occurred due to the differences in production performance of the two strains. Osman *et al*. (2010) revealed that Hi-sex Brown strain recorded better (P<0.05) cumulative feed conversion ratio than Bovans white strain. The little effect of strain on feed conversion ratio in spite of its significant effect on both egg mass and feed intake could be attributed to the fact that, as feed intake increased, egg mass also increased with the same level and vice versa (Osman *et al*., 2010). Grobas *et al*. (2001) reported that ISA- Brown hens had better feed efficiency than Dekalb white strain. Also Al-Nasser *et al*. (2006) found that feed efficiency of Brown egg strain was better than that for white egg strain.

Strain effect was observed on median egg weight, egg height, egg width and average egg shell colour. Brown Hy-Line layers had high median egg weight, egg height, egg width and average egg shell colour compared to White Hy-Line layers. Vits *et al.* (2005) support high egg weight on Brown Hy-Line layers over White Hy-Line layers. Monira *et al.* (2003) also support the significant difference between strain on egg weight, egg height and egg width. The egg shape index, egg shell weight and egg shell breaking force were high on Brown Hy-Line layers than White Hy-Line layers though their difference was not significant because the significant high median egg weight was observed on Brown Hy-Line layers. Duman *et al.* (2016) also reported a correlation between egg shape index and egg shell strength and it was stated that egg quality depend on egg weight and size. The egg shape index of brown eggs was significantly higher than white eggs and insignificant egg shell breaking force was reported (Badawe *et al*., 2005). The results also showed that the external egg quality of Brown Hy-Line layers was better than that of White Hy-Line layers. Osman *et al.* (2010) found the insignificant effect of strain egg shape index, but on the later stage (62-72 weeks of age) of egg production and high egg shape index was observed on Hi-sex Brown strain. Osman *et al.* (2010) reported lower (P>0.05) egg shell strength and lower (P<0.05) egg shell weight on Hi-sex Brown strain than on Bovans White strain. Riczu *et al*. (2004) reported that eggs laid by Brown Hy-line had high egg shell weight than White Hy-Line layers and the current study found outcome, but the effect was insignificant. Hassanein and Toson (2005) found that, Hi-sex Brown eggs were superior in egg shape index, shell percentage than those recorded for Bovans white eggs and Bovans white eggs were higher in shell strength than that of Hi-sex Brown eggs.

Strain had a significant (P<0.01) effect on median egg weight and albumen weight. High median egg weight and albumen weight were observed on Brown Hy-Line layers than on White Hy-Line layers. Since the high percentage of egg weight is on albumen, high or low corresponding results of egg and albumen egg weight are expected on a specific strain. Badawe *et al*. (2005) also reported a significant (P<0.01) high albumin weight percentage on Brown Hy-line layers than that of white Hy-line layers and strain did not affect egg yolk percentage . There was no significant strain effect (P>0.05) observed on albumen height, yolk height, yolk weight and Haugh unit, (Table 4). Since Haugh unit is determined by the albumen height the same effect on both traits should be expected as it appears on table 4 that they are both not affected by strain. Olawumi *(*2014) reported no strain significant effect (P>0.05) on measured internal and external quality traits except for albumen height and Haugh unit, so current results are in agreement of no strain effect on egg shell weight, egg shape index, yolk weight, albumen weight and yolk height (Table 3 and 4). Wall *et al.* (2010) and Ragheb *et al*. (2013) found that the difference between the two strains on Haugh unit was not significant and the current study found the same results. Ragheb *et al*. (2013) also reported that the yolk weight of the White Hy-Line layers was higher than that of Brown Hy-Line layers, but the difference was not significant (P>0.05). El-attar and Rayan (2016) reported that Brown Hy line showed high mortality compared to White Hy-line hens. No mortality occurred throughout the investigation of this study. The Hi-sex Brown strain produced eggs of higher quality than the Bovans white strain based on yolk index and Haugh units (Osman *et al*., 2010), the current study disagree with high Haugh units, yolk weight, and egg shell breaking force were observed on White Hy-Line layers though the difference was not significant. Vits *et al.* (2005) stated that percentage egg output, egg weight, shell thickness, shell breaking strength of Brown Hy-line were high compared to those of White Hy-line hens, this report support the current study based on Brown Hy-Line high egg weight and egg shell breaking force only. Al-Khalifa *et al.* (2013) observed insignificant low overall average yolk weight and percentage in eggs laid by Brown Hy-line than that of eggs laid by White Hy-line, and the current study agree with this outcome (Table 4). The overall albumen weight and albumen percentage of the eggs laid by Brown Hy-line eggs was greater than that of White Hy-line eggs which was reported by Al-Khalifa *et al.* (2013), the current study also agree with this results. Hassanein and Toson. (2005) found that, Hi-sex Brown eggs were superior in yolk index and albumin percentage than those recorded for Bovans white eggs and Bovans white eggs had high yolk percentage than that of Hi-sex Brown eggs.

White Hy-Line layers had high percentage of extra small and small graded eggs than Brown Hy-Line layers. Brown Hy-Line layers had high percentage of medium and large graded eggs than White Hy-Line layers, extra-large and jumbo graded eggs percentage did not show significant difference. Current results correspond with significant high average egg weight on Brown Hy-Line, but the grades did not show a significant difference. The insignificance might be the results of comparable egg output and egg mass since the egg grading percentage was determined from number of eggs of certain egg weights. There are no previous studies done on the effect of strain on egg grading.

5.4 Effect of feed withdrawal by strain interaction on laying performance, egg quality and egg grading.

The interaction effect (P<0.05) was observed on body weight and average egg weight. White Hy-Line layers had high body weight than Brown Hy-Line layers under *ad libitum*. High average egg weight was observed on Brown Hy-Line than White Hy-Line layers. The interaction also caused a difference on median egg weight and egg height. The effect of interaction between strain and feed restriction on cumulative egg mass was not significant (Osman *et al*., 2010).

Eight hours feed withdrawn Brown Hy-Line had high egg weight, median egg weight and egg height than White Hy-Line layers. These traits did not show a difference of feed withdrawal by strain interaction effect (feed intake, body weight change, feed conversion ratio for body weight change, egg output, feed conversion ratio for egg output, feed conversion ratio for egg weight, egg mass, egg width, egg shape index, egg shell weight, average egg shell colour and on feed conversion ratio for egg mass). The interaction between feed restriction (*ad libitum,* 4hours and 8hours) and strain (Hisex Brown and Bovans White) had insignificant effect on egg weight (Osman *et al.,* 2010). Osman *et al*. (2010) agree with this study result of no significant effect of the interaction between feed restriction and strain on cumulative feed intake

Albumen weight was affected by interaction, (Table 4). Brown Hy-Lines had high albumen weight than White Hy-Lines under four and eight hours and in *ad libitum* the albumen weight was comparable. There was no interaction effect observed on albumen height, yolk height, yolk weight and Haugh unit. The interaction affected small, large and medium graded eggs percentage. High percentage of small graded eggs was observed on White Hy-Line layers under all feeding regimes. High percentage of medium graded eggs was observed on Brown Hy-Line layers under all feeding regimes. Brown Hy-Line layers had high percentage of large graded eggs than White Hy-Line layers under eight hours feed withdrawal. Extra small, extra-large and jumbo graded eggs percentages were not affected by interaction.

Chapter 6: Conclusions and recommendations

6.1 Conclusions

Feed withdrawal had no significant effect on laying performance (egg output and average egg weight), body weight change, mortality rate and external and internal egg quality of the two strains. Feed withdrawal had a significant effect on feed intake, body weight and on egg grading (small and large graded eggs). Strain had a significant effect on body weight, average egg weight and some of internal and external egg quality traits (median egg weight, albumen weight, egg height, egg width and average egg shell colour) and on egg grading (extra small, small, medium and large graded eggs percentage). Strain did not affect feed intake, body weight change, egg output, egg mass, feed conversion ratio, mortality rate, some of internal and external egg quality (albumen height, yolk height, yolk weight and Haugh Unit and egg shape index, egg shell weight, egg shell breaking force) and on extra-large and jumbo graded eggs percentage. Feed withdrawal by strain interaction effect was observed on body weight, average egg weight, median egg weight, egg height and on albumen egg weight, egg grades percentages (small, medium and large graded eggs percentage), but not on feed intake and mortality rate.

6.2 Recommendations

The current study recommend the use of eight hours feed withdrawal since the laying performance and productivity of hens under this treatment were comparable to hens under *ad libitum* and their egg quality traits were better than those hens on *ad libitum* and four hours feed withdrawal. White Hy-Line layers are recommended for high production of small graded eggs of good external quality. Brown Hy-Line layers appears to be economically productive based on comparable low feed intake, low body weight, comparable high body weight change, comparable egg output and better egg quality, high egg weight and more of high grades of eggs. White Hy-Line layers are recommended for comparable high feed intake, comparable high egg output of low weight. Feed intake difference between *ad libitum* hens and eight hours feed withdrawn hens was 129.0g, between *ad libitum* hens and four hours feed withdrawn hens was 108.5g and between four and eight hours feed withdrawn hens was comparable with 18g difference. It was observed that eight hours feed withdrawal reduced amount of feed laying hens require for maintenance and production. Eight hours feed withdrawal by Brown Hy-Line layers interaction effect is recommended based on reduced feed intake, well maintained body weight and comparable laying performance.

References

1. Al-Khalifa, H, Ragheb, .G. 2013. Enhancing diversity of poultry products by producing high quality brown eggs. European Scientific Journal, 24: 1857-7881.
2. Al-Nasser A., A. Al-Saffar, M. Mashaly, H. Al-Khalaifa, F. Khalil M. Albaho and A. Al-Haddad, 2006.A comparative study on production efficiency of brown and white pullets. World's Poultry. Sci. 62: 296-307.
3. Altan, O., S. Ozkan, A. Altan, Y. Akbas, V. Ayhan, and K. Ozkan. 2000. Effects of short-term fasting and midnight lighting on egg production traits of laying hens during summer season. Archiv-fur-Geflugelkunde, 64: 85-89.
4. Amos, T.T. 2006. Analysis of backyard poultry production in Ondo State, Nigeria. International Journal of Poultry Science, 5: 247-250.
5. Anderson, K.E. 2002. First cycle report. North Carolina layer performance and management test, 34:1-35.
6. Anderson, K.E, Tharrington. J.B, Curtis. P.A and Jones. FT. 2004. Shell characteristics of eggs from historic strains of single comb white leghorn chickens and relationship of egg shape to shell strength. Department of poultry Science.
7. Badawe, M. I., E. F. Abd El-Hameid, M. M. Fathi, and A. Zein El-Dein, 2005. Prediction of feed intake and residual feed consumption in laying hen chickens. Egypt. Poultry. Sci. 25: 1003-1016.
8. Baumgartner J, Benková J, Peškovicová D 2007: Effect of line, age and individuality on yolk cholesterol content and some other egg quality traits in Leghorn type yolk cholesterol selected hens. XVIII European Symposium on the quality of poultry meat and XII European Symposium on the quality of eggs and egg products, 2 - 5: 35-36.
9. Bell, D. D., and W. D. Weaver, 2002. Commercial Chicken Meat and Egg Production.5thed.Cambridge, Massachusetts. Kluwer Academic Publisher.
10. Benyi, K. Norris, D. and Tsatsinyane, P.M. 2006. Effects of stocking density and group size on the performance of white and brown Hy-line layers in semi-arid conditions. Trop Animal Health Production, 38:619-624.
11. Bruggeman, V. Onagbesan. O, D'Hondt. E, Buys. N, Safi. M, Vanmontfort. D, Beghman. L, Vandesande. F and Decuypere. E. 1999. Effects of timing and duration of feed restriction during rearing on reproductive characteristics, in layer breeder females. Poultry Science, 78:1424-1434.
12. Coutts, J. A. and Wilson, G.C., 1990. Egg Quality Handbook. Queensland Department of Primary Industries, Australia.

13. Crouch, A.N., Grimes, J.L., Christensen, V.L. and Krueger, K.K., 2002. Effect of physical feed restriction during rearing on large white turkey breeder hens: 2. Reproductive performance. Poultry science, 81(1), pp.16-22.
14. Duman, M. Sekeroglu, A. Yildirim, A. Eleroglu, H. and O Camci.2016. Relation between egg shape index and egg quality characteristics. University of Nigde. European poultry science, 80, 1-9.
15. El-Attar, A.H and Rayan, G.N. 2016. Eggshell and bone quality in two different genetic groups of aged layer breeders. Department of Poultry Production, Faculty of Agriculture, Ain Shams University, Cairo, Egypt. 831, 16, 5.
16. Fairful, R. and Gowe, R.S. 1990. Genetics of egg production in chickens. In R.D. Crawford (ed), poultry breeding and genetics, Elsevier, Amsterdam, 705-709.
17. Falconer, D.S and Mackay, T.F.C. 1996. Introduction to Quantitative Genetics, 4th edition (Pearson educational Limited, Harlow, England), 314-315.
18. Grobas, S., J., Mendez, R. de Lazaro, C. Blas, and G. G. Mateos, 2001. Influence of source and percentage of fat added to diet on performance and fatty acid composition of egg yolks of two strains of laying hens. Poult. Sci 80:1171-1179.
19. Hani, M.S, Henry. R.W, Robert. H.H, Charles. J.W. 1999. Genetic parameters for egg and related characteristics of white leghorn in a subtropical environment. Genetic and molecular biology, 22, 2, 183-186.
20. Hasnath, R., 2002. Effect of feeding systems on the egg production of Fayoumi hens of model breeding units under PLDP programme in Bangladesh. M. Sc. Thesis, Department of Animal Science and Animal Health and Network for Smallholder Poultry Developmnet, Bangladesh.
21. Hassanein, H. H. and M. A. Toson, 2005. Effect of strain and storage period on egg quality of chicken. Minia J. of Agric. Res. & Develop. 25: 281-294.
22. Haugh, R.R. 1937. The Haugh unit for measuring egg quality.US Egg Poultry. Mgt. 43:552–555, 572–573.
23. Hussain, S. Ahmed, Z. Khan, M.N. Khan, T.A. 2013. A study on quality traits of chicken eggs collected from different areas of Karachi. Poultry Research Laboratory, Department of Physiology, University of Karachi, Karachi - Pakistan. Sarhad J. Agric, 29, 2.
24. Ingram, D.R., L.F. Hatten, K.D. Homan, 2008: A study on relationship between eggshell color and eggshell quality in commercial broiler breeders. International Journal of Poultry Science, 7(7), 700-703.

25. Jacob, J. P., Miles, R. D. and Mather, F. B., 2000. Egg Quality. University of Florida, 24: 112-117.
26. Jones, D. R. 2006. Conserving and Monitoring Shell Egg Quality. Proceedings of the 18th Annual Australian Poultry Science Symposium, pp. 157 - 165.
27. Kostal, L., Savory, C.J. and Hughes, B.O., 1992. Diurnal and individual variation in behavior of restricted-fed broiler breeders. Applied Animal Behavior Science, 32(4): 361-374.
28. Lebbie, S.H.B, Benyi .K and Ademosun .A.A. 2008. The effects of feeding regime and stocking rate on the performance of medium-bodied layers in the humid tropics. British poultry science, 22(5): 415-421.
29. Magdelaine, P., Spiess, M.P. and Valceschini, E., 2008. Poultry meat consumption trends in Europe. World's Poultry Science Journal, 64(1): 53-64.
30. Mausa, F. 2008. The poultry industry in the world present and future, 43:44.
31. Minitab, 2014. Minitab 16 statistical software. Minitab Inc., state collage, Pennsyvania, USA.
32. Monira, K.N., Salahuddin, M. and Miah, G., 2003. Effect of breed and holding period on egg quality characteristics of chicken. International Journal of Poultry Science, 2(4): 261-263.
33. Mutaf, S., Seber Kahraman, N. and Firat, M.Z. 2009. Intermittent partial surface wetting and its effect on body-surface temperatures and egg production of white and brown domestic laying hens in Antalya (Turkey). British poultry science, 50(1): 33-38.
34. Mzezewa, J and Gwata, E.T. 2012. The nature of rainfall at a typical Semi-Arid Tropical Ecotope in Southern Africa and Options for Sustainable Crop Production. University of Venda South Africa.
35. Nofal, M. E. and I. I. Hassan, 2004. Duration of fertility and productive performance of Mamourah laying hens as influenced by feeding system during the last period of the first year production. Egypt. Poult. Sci. 24: 719-735.
36. Ogunlade, I and S.A. Adebayo. 2009. Socio- Economic status of women in rural poultry production in selected areas of Kwara state, Nigeria. International Journal of Poultry Science, 8(1): 55-59.
37. Olawumi, S.O. 2014. Effect of short-term feed restriction on production traits of brown and black plumage commercial layer strains at late phase of egg production. American Journal of Agriculture and Forestry, 2(2): 33-38.

38. Osman, A.M.A, Toson A.M; Abdel-Latif S.A; Hassanien H.H.M. 2010. Effect of fasting on reproductive performance of laying hens. Egypt. Poultry Science, 30(4): 1031-1057.
39. Oyedeji, J.O. A.M. Orheruata and M. Omatsuli. 2007. Effects of feed rationing on the laying performance of 40 – weeks in lay hens. Journal of food, Agriculture and Environment, 5: 301-303.
40. Premavalli, K and K. Viswanangthan. 2004. Influence of age on the egg quality characteristics of commercial white leghorn chickens. Indian vet. 81:1243-1247.
41. Ragheb, G., Al-Nasser, A.E., Abdullah, F.K., Al-Bahouh, M.E., Al-Saffar, A., Al-Khalifa, H. and Mashaly, M.M., 2013. Comparative study on production efficiency of two strains of brown and white egg laying hens in Kuwait. International Journal of Poultry Science, 12(7): 383-389.
42. Rayan, G.N, Mahrous M.Y, Galal .A, and El-Attar A.H.2013. Study of some productive performance and egg quality traits in two commercial layer strains. Department of Poultry Production, Faculty of Agriculture, Ain Shams Univ., Cairo. Egypt. Poultry. Science, 33(II): 357-369.
43. Reddy, P.M, Reddy V.R, Reddy C.V. and Rap P.S.P. 1979. Egg weight, shape index and hatch ability in Khaki Campbell duck egg. Poultry Science, 14:26-31.
44. Riczu, C. M., Saunders-Blades. J.L, Yngvesson. A.K, Robinson. F.E and Korver. D.R, 2004. End-of-cycle bone quality in white-and brown-egg laying hens. Poultry Science, 83: 375-383.
45. Rizzi, C. and G. M. Chiericato, 2005. Effect of genotype and storage on some egg quality parameters of laying hens reared according to organic farming production. Poult. Sci. 78: 922-928.
46. Robinson, D., G. Horsnell and P.J. McMahon. 1978. Restricted feeding of egg strain chickens during growth and throughout an extended laying period. Australian Journal of Experimental Agriculture and Animal Husbandry, 18: 658-666.
47. Scott, T.A, Silversides .F.G, Tietge. D and Swift M.L. 1999. Effect of feed form, formulation and restriction on the performance of laying hens. Canadian journal of animal science, 79 (2), 171-178.
48. Scott, T.A and F.G Silversides, 2000. The effect of storage and strain of hen on egg quality. Poultry Science, 79:1725-1729.
49. Silversides, D. Korver, R and Budgell K.L. 2006. Effect of strain of layers and age of photo stimulation on egg production, egg quality and bone strength. Poultry Science, 85: 1136-1144.

50. Silversides, F.G., 2010. Laying performance of six pure lines of chickens and four commercial hybrids at the Agassiz Research Centre. Canadian journal of animal science, 90(3): 341-347.
51. Singh, R., Cheng, K.M. and Silversides, F.G., 2009. Production performance and egg quality of four strains of laying hens kept in conventional cages and floor pens. Poultry science, 88(2): 256-264.
52. Summers, J.D. and Robinson, F.E., 1995. Comparative feeding programs for poultry reproduction. World Animal Science C, 9: 319-434.
53. Vits, A., D. Weitzenburger, H. Hamann, and O. Distl. 2005. Production, egg quality, bone strength, claw length, and keel bone deformities of laying hens housed in furnished cages with different group sizes. Poultry Science, 84: 1511-1519.
54. Wall, H. Jonsson, L and Johansson, L. 2010. Effect on egg quality traits of genotypes and diets with mussel meal wheat-distillers dried grains with soluble. Poultry Science, 89: 745-751.

55. Wilson, K.J and Beyer, R.S. 2000.poultry nutrition information for the small flock. Kansas state Uni Agric Exp Stat Coop Ext Service.

56. Zhang LC, Ning ZH, Xu GY, Hou ZC, Yang N. 2005. Heritability and genetic and phenotypic correlations of egg quality traits in brown-egg dwarf layers. Poult Sci 84: 1209-1213

57. Zita, L. Tumova, E and Stolc, L. 2008. Effects of genotype, age and their interaction on egg quality in Brown-egg laying hens. Animal husbandry. 78: 85-91.

Appendices

Figure 1. Layer house

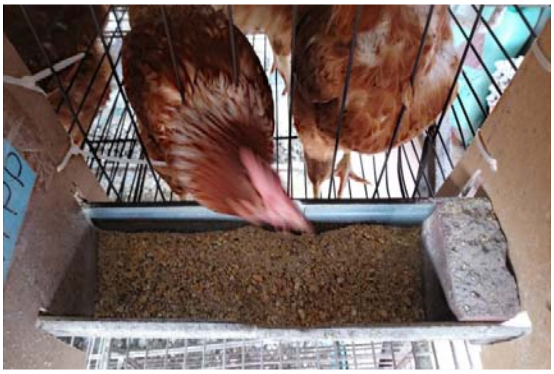

Figure 2 Feeder

On figure 2, during feed withdrawal time a wooden plank was put on top of the feeder to prevent hens from feeding.

Figure 3. White Hy-Line layers

Figure 4. Brown Hy-Line layers