COMPARISON OF PRODUCTIVITY AND ECONOMIC BENEFIT OF COMMERCIAL LOHMANN BROWN LITE LAYER'S ON FREE-RANGE AND CONVENTIONAL CAGE SYTEMS

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DECLARATION

I Maboneng Kgaditsi, declare that the dissertation entitled “Comparison of productivity and economic benefit of commercial Lohmann Brown Lite layer’s on free-range and conventional cage systems” hereby submitted by me to University of South Africa, is my own work and all the sources used and quoted have been indicated and acknowledged by means of complete references.

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ABSTRACT

The study was conducted in two different types of natural ventilated housing systems; one featured with conventional laying cages while other had free-range system features. The aim was to analyse productivity and economic benefit or loss of the Lohmann Brown Lite on different housing (Free-range system and Conventional cage system) with an evaluation of production cost. The total of 49 700 point of lay Lohmann Brown Lite layers pullets were placed in four natural ventilation free-range houses each consist of three rows of two tier conventional laying cages. The other 40 000 point of lay Lohmann Brown Lite layers pullets were place in four free-range houses each with placement of 10 000 chickens. The Cobb Douglas production model was used to determine the productivity of two different housing system by factoring the fixed cost and variable cost of the entire production process. The breakeven point tool was used to analyse the point where the total revenue equals the total variable and fixed expenses and the cost volume profit by measuring the profitability of each housing system (Nabil *et al.* 2014).

The results of the study revealed different productivity between conventional cage system (82.94%) and the free-range system (77.46%). These results led to the acceptance of hypothesis 1 that “the production of Lohmann Brown Lite is the same when they are kept on the free-range system or conventional cage system. The capital investment and operation on conventional cage system showed breakeven at 43 months while free-range system showed breakeven at 60 months. The economic benefit analysis shows that the free-range system has cost benefit of R0.29 and conventional cage system has a cost benefit of R0.26. It means for every rand spent, farmer may get R0.29 Rand as profit for free-range system and every rand spent for conventional cage system can get R0.26 Rand. The economic benefit to farmer is greater on free-range system that lead to acceptance of hypothesis 2 that the economic benefit of egg production is greater on the free-range system compared to conventional cage system. Free-range housing system remain the best alternative to replace the conventional cage housing system.

Keywords: Conventional cage system, Free-range system, Lohmann Brown Lite chicken breed, Egg production, Feed consumption, Production cost, and Economical benefits.

Table of Contents

List of Tables

List of Figures

List of Pictures

CHAPTER 1

1 INTRODUCTION

1.1 Background

Poultry plays an important role in agricultural industries in many countries. Moreover, eggs are the cheapest protein source for human consumption throughout the world. The commercial egg is the major index and it accounts for about 90% of income from the enterprise (Gow *et al.* 2011). The housing system is an external factor that influences the performance of hens and egg quality. Housing systems aim to maximize profit and offer increasingly new technological solutions which improve efficiency on labour activities and thus increase productivity. The welfare of animals is not only an ethical issue but also a practical issue, housing comfort translate into better weight gain, health, and productivity of the chickens (Sosnowka-Czajka *et al.* 2010). Egg production has an impact and benefits to the economy based on demand and market value.

The results from a study carried out by Dikmen *et al.* (2016) shown egg production in conventional cage system to be 87.1% and egg mass 56.8g while in free-range system production was 89.2% with egg mass of 59.7g. Hen day production and dirty eggs were similar in free-range and conventional cage systems while the feed conversion ratio for free-range system was higher than conventional cage system (Dikmen *et al.* 2016). The egg production ranged from 77.9 % to 91.2% in conventional cage system from the age 18 to 73 weeks. The laying period has been shown to affect egg weight and feed conversion ratio (Onbasilar e*t al.* 2015). Rouf *et al.* (2015) obtained 91.5% of hen day egg production with feed conversion ratio of 106g for conventional cage system. There was no difference on liveability between free-range system and conventional cage system. Campbell e*t al.* (2017) discovered that free-range system does not affect hen day production, however, it affect the quality of eggs. Performance of layers on egg production, crack egg, dirty eggs, mortality, body weight, and feed intake are influenced by housing systems (Moorthy *et al*. 2000; Singh *et al.* 2009). According to Muhittin *et al.* (2018), production performance of hens placed in free-range system at 30 weeks of age produce 95% of eggs, feed consumption of 113g with mortality of 0,7%. Free-range system hens at 18 weeks of age produce 8.31% for hen day production with feed consumption of 131.82g (Turker & Alkan 2017). According to Denli *et al.* (2016) the disease, poor housing and lack nutrition has negative on welfare of laying hens. Conventional cage system dominate the egg laying industry. Bartira de *et al.* (2018) found that free-range system had 3.4% mortality which was higher than conventional cage system, while conventional cage system had better external egg quality and egg production. Improving the welfare of layers is related to increasing occupational space. However decreasing the stocking density of a conventional cage system will result in high financial cost compared to the free-range system. Free-range system production increases energy requirement because of free movement (Bessei 2018). Matthews & Sumner (2015) reported the increase of production cost 135g of feed when increasing space that allows birds to move freely compared to conventional cage system.

1.2 Problem statement

The housing system is an external factor that influences both the performance of hens and the egg quality characteristics. Convention cage system is banned in European Union and layers are permitted in alternative systems, such as litter housings and free-range system to improve the welfare of hens. Better performance of layers is achieved in conventional cage systems, however, Australia is driving the increase of free-range system production because of consumer perceptions (Campbell *et al.* 2016). South Africa is following the international trend on poultry production system since it is imports or export some of the local poultry products, therefore, alternative production systems for laying such as free-range system is required to replace the conventional cage system. The concerns about the impact of using the conventional cage system on the environment and animal welfare of layer hens seem to drive change in poultry business. The impact of transitional change on production management and economic loss or benefit is unknown. Thus, leads to the need of conducting the current study by comparing the productivity and economic benefit of commercial Lohmann brown layers on free-range system and conventional cage system.

1.3 Aim of the study

The aim of the present study was to analyse productivity and economic benefit or loss of the Lohmann Brown Lite on different housing (Free-range system and Conventional cage system) with an evaluation of production cost.

1.4 Objectives of the study

The objectives of the study are to:

1. Determine the productivity of Lohmann Brown Lite layers on the free-range system and conventional cage system.
2. Analyse the economic benefit and viability of layers kept on the free-range system and conventional cage system.

1.5 Research question

In order to achieve the objectives, the study seeks to answer the following research questions:

1. How is the productivity of Lohmann Brown Lite layers in conventional cage system compared to the free-range system?
2. Does the economic benefits and viability of Lohmann Brown Lite layers in the free-range system differ from the conventional cage systems?

1.6 Hypothesis

It was hypothesis that:

1. The production of Lohmann Brown Lite is not the same when they are kept on the free-range system or conventional cage system.
2. The economic benefits and viability of egg production of Lohmann Brown Lite layers is greater on the free-range system compared to the conventional cage system.

1.7 Significance of the study

According to animal welfare, conventional cage systems limits the chickens to perform their natural behaviour. The free-range system needs more space and chickens have chance of getting diseases because they have access to contact with wild birds. The outcome of this research will assist farmers to select suitable adaptation strategies for transitional change from conventional cage system to free-range system with optimal profitable operation. The findings of the study will serve as basis for informed policy decisions aimed at improving productivity of emerging farmers in this system of production.

1.8 Limitation of the study

The findings of this study are not generalized to the Gauteng Province but seek to contribute to the discourse of housing system and level of understanding of the impact of alternative housing systems. The study focused on the key variables of production management like feeding, drinking, morbidity and mortality on alternative free-range system.

1.9 Summary

This chapter provided the background on the issue of housing system as important for hen welfare, egg productivity, and economic benefit of poultry business. Majority of medium scale and commercial farmers across the commercial layers that use the conventional cage system for efficient egg production are forced by animal welfare and consumers to allow the natural behaviour of hens for egg production. In Chapter 1, several literature studies show that egg production is influenced by housing systems. The next chapter describes and focuses on the theoretical and empirical studies relating to egg production.

CHAPTER 2

2. LITERATURE REVIEW

2.1 Introduction

Since the publication of Ruth Harrison's book "Animal Machines" in 1964, there has been widespread public pressure in Europe – supported by European institutions to "ban the battery (conventional) cage" and this is how Switzerland has completely banned eggs from cages (Matthews 2011; Gerzilov *et al.* 2012). Since the trade of poultry products is highly internationalized, welfare aspects have to be considered by all countries (Bessei 2018). Commercial layers can be kept in different housing system like open sided house with curtain on floor, free-ranging and conventional cage system. European Union (1991) emphases that welfare of laying hens should be improved by freeing them from cages to normal ranging behaviour. Housing systems influence productivity and economic benefit of commercial layers. Each laying systems and the technological solution is associated with certain problems such as social stress, the influence of feed consumption, chicken behaviours, eggs quality and productivity (Sosnowka-Czajka *et al.* 2010). The chapter presents relevant literature on productivity regarding egg production in different poultry systems.

2.2 Housing systems for layers

The farmers and investors should carefully consider animal welfare farming guidelines, health and safety of workers, effective health management of chickens, infrastructure capital cost, and production cost, user friendly environment whenever they choose a poultry house. The production performance between free-range system, conventional cage system and controlled environmental house system often differ significantly when compared (Daniel *et al.* 2008). In general, free-range housing system are characterized by space for a hen to move freely. More locomotion of the hen indicates more energy loss that needs to be supported by increasing feed intake (Lay *et al.* 2011). Housing systems for layers should be designed to balance the health and welfare of chickens with consumer preferences, the needs of the industry and the impact on the environment (Sosnowka-Czajka *et al.* 2010; Campbell *et al.* 2017).

2.2.1 Conventional cage system

Conventional cage system is the system whereby chickens do not have access to pasture and outdoor. The chickens perform under restricted confined environment. Most of the commercial eggs are produced under conventional cage system. Matthews & Sumner (2015) discovered that feed intake is the largest portion of overall production cost even in the conventional cage housing system. The height of cages are 40.6 cm with the floors slope and the size of the floor is highly variable. Some common floor sizes are indicated in table 2.1. Conventional cage system requires space of 450-672 cm² five hens (Widowski *et al.* 2016). Animal welfare is highly concerned about the restriction of hens to perform their natural behaviour throughout their entire lying lifespan at the interest of profit making.

Table 2.1 Common floor size for conventional cage system

Width cm	Multiple (X)	Depth cm
25	X	41
31	X	41
31	X	46
36	X	41
36	X	46
36	X	46
41	X	46
61	X	91
91	X	122

2.2.2 Free-range system

The free-range housing system allows chickens to have free movement between the indoor and outdoor. Chickens housed under free-range system have the opportunity to express their space through locomotion while performing their natural behaviour (Webster 2013; Pettersson *et al.* 2016). Free-range system is an enrichment for the hens and provide several advantages for chickens on pasture and outdoor (Campbell *et al.* 2017). Access to outdoors allows chickens to spread, have access to foraging naturally on space greater than 500 cm^2 per chicken to enable natural behaviour. The free-range housing system allows hens to spend most of their daily activity by foraging behaviour, searching, selecting, extracting and ingesting their preferred food (Savory *et al.* 2006; Campbell *et al.* 2017). European Union regulation demanded that eggs offered for sale as the free-range system must be from flocks that are kept in the following conditions; a) The hen must have continuous daytime access to open-air runs. b) The hens must have access to sufficient vegetation. c) The maximum stocking should not exceed 1000 chickens/hectare. d) The interior of the building must conform to the recommended standards of free-ranging house.

Free-range eggs are more costly to produce and remain to be in high demand than eggs produced from conventional cage system since 2005 at United Kingdom where free-range system had only market share of 30% (Patterson *et al.* 2001; Kjarnes *et al.* 2009). In general, the free-range system can be characterized by more space for a hen that allows more locomotion of chicken. Sumner *et al.* (2011) reported that laying performance does not only depend on where the hens are kept but also on many other factors.

2.3 Behaviour of chickens on two housing systems

Housing system can affect the natural behaviour of chickens. The farmers who housed laying hens in a conventional cage system are not complying with animal welfare legislation, since cages system eliminate chickens natural behaviour due to confined space (Weeks & Nicol 2006; Widowski *et al.* 2016). Free-range system has nests dust-baths, which enables chickens to express natural behaviour such as nesting and bathing. Hens are raised outdoor to have a positive effect on their welfare by reducing the number of aggressive behaviour (Freire *et al.* 2003). If the free-range house does not meet the standard it can cause health problem on chickens (Hegelund *et al.* 2005; Campbell *et al.* 2016).

Dual-purpose breeds prefer outdoor area more frequently and show greater movement compared to other commercial layers (Nielsen *et al.* 2003). Dawkins *et al.*, (2003) found that chickens in free-range system preferred grasses and their welfare was improved by the presence of trees which provided the shade and protection against predators.

2.4 Animal welfare

The major concern of animal welfare is the limited movement of hens in the conventional cages that prohibits them to behave naturally at the expense of aggressive profit making (Hartcher & Jones 2017). This concern started in the past decades after animal welfare inspectors learned of serious challenging condition that a laying hen experience in the conventional laying cage. The continuous series of animal welfare assessments were done to put the egg producer under scrutiny while forcing egg industry to perform wide search for better housing system than conventional cage (Savory 2004). Good animal welfare cannot be achieved without chickens feeling comfort thus the heed to phase out the cage system (Meller & Beausoleil 2015). During 1999, the European Union passed the legislation that prohibits new investment in the conventional cage system beyond 2003 with complete ban of using conventional cage system by 01 January 2012 (EC 1999).

Concern over the welfare of hens raised in the cage system are, firstly that the cage prevents the performance of hen natural behaviour and, secondly the space in a cage imposes severe restrictions on movement (Savory 2004). From welfare viewpoint cage systems were burdened with a lack of space for laying hens, but ensured better health status of laying hens. However, Petermann (2003) recorded high mortality in the alternative systems. De Boer & Cornelissen (2002), considered conventional cages to be more favourable than other systems, particularly in stock economics and egg quality. Many factors can affect chickens welfare in the cage or in non-cage, the debate is now based on both livestock and producers (Sunstein & Nussbaum 2005; Widowski *et al.* 2016).

Growing success of markets for free-range eggs, legislation of banned conventional cage housing system for better chicken welfare is now a forefront discussion in agriculture (Campbell *et al.* 2016). According to Appleby *et al.* (2004), the conventional cage system does not give chickens freedom of movement and allow chicken to perform their natural behaviour which are the basis of animal welfare. Barnett *et al.* (2009), comparing conventional cage system and free-range housing system found that group size and living space had little effect on layer welfare, whereas cage equipment (perch, sand-bath, and nest) had no influence on chicken welfare as measured by physiological parameters, although it has a positive effect on bone strength.

The use of free-range housing system by laying chickens does not only boost their immunity but it helps to reduce the stress experienced during rearing (Bestman & Wagenaar 2003). The production system has a considerable effect on chicken welfare. It appears that free-range systems are best in providing layers with high welfare levels (Sosnowka-Czajka *et al.* 2010). Laying hens are perfectly adaptable to all types of housing systems, management must meet the standard of animal welfare of chickens in each system. The free-range housing system that have negative effect on laying hens are mainly a result of poor management (Lay *et al.* 2011).

2.5 Feeding of chickens

Feed remain the highest cost on overall egg production constituting more than 70% of total cost. Due to high energy requirement in feed, 94% of feed cost is used to meet energy and protein requirements, while 3% to 4% is use for major mineral, trace mineral, vitamin and last 1% to 2% for various feed additives (Asfaw 2016). De Persio *et al.* (2015) also emphases that laying hen diet should contain at least 85% of energy and other nutrients, to induce more egg production, sizeable egg weight and maintain constant body weight. To meet the animal welfare new legislation about layers, hens must be moved from the conventional cage system to free-range system of pasture based system and such move should be accompanied by adjustment of nutrients requirements since additional nutritional factors will be involved in egg production including egg quality (Horsted & Hermansen 2007; Plaimast *et al*. 2015). According to Hetland & Svihus (2007), hens have the ability and capacity to ingest large amount of their diet from forage after a period of about 6 to 7 weeks of adaptation on behavioural and digestive system. Therefore free-ranging and pastured hens are exposed to an opportunity to forage material which will affect their intake level digestibility and nutrient balance of their diet. A poultry diet is expected to contain three essential nutrients of protein, vitamins and minerals as well as provides adequate metabolizable energy (ME) (Almeida *et al*. 2012). The most easily available sources of energy are the carbohydrates contained in common grains, grain by-products and plants generally (Datch 2013).

2.6 Performance and health status

Housing system influence the performance characteristics of laying hens. Tauson (2005) reported better results were achieved in cages in terms of lower feed consumption with higher egg production. According to Tauson (2005), conventional cage performs better on egg production and have low mortality. Elson & Croxall (2006), discovered lower feed intake in free-range system compares to conventional cage system. However, Valkonen *et al.* (2008) did not find any effect on productivity and feed conversion ratio on the conventional cage system and free-range system. White flock perform high in free-range system compared to other genotypes (Hetland *et al.* 2004; Englmaierova *et al.* 2014). Free-range system layers have been reported to have higher mortality rate and challenges of salmonellosis infections (Van Overbeke *et al.* 2006). More eggs were laid in free-range system at 40 weeks compared to conventional caged because of considerable improvements in welfare levels (Cheng *et al.* 2009).

2.7 Light management

Light intensity and the length of the daily light period produce responses associated with egg production. The recommended lighting hours for layers range 11 hours to 16 hours depending on environmental in geographical area (North 1984; Jacome *et al.* 2014). Lighting is defined by source, intensity, wavelength spectrum and duration of photoperiod that affects chicken's behaviour and quality of egg production (Manser 2006; Liu *et al.* 2017). Effects on the duration of lighting and light intensity on chicken`s performance and behaviour are well documented for laying hens (Er *et al.* 2007). Long *et al.* (2016) reported that no differences in egg weight and egg production on lights hours and was supported by (Huth & Archer 2015).

2.7.1 Light effects during egg production

Light affects the growing chicken, but it stimulates the pituitary gland of layers to secrete the hormones necessary for egg production and chickens responded differently to light according to breeds (Ma *et al.* 2016). The hormonal secretions are activated once the length of the light is 11 to 12 hours. To increase the length of the day light in winter, artificial light must be used (North 1984). Light intensity during production can affect laying performance therefore, there is a need to supplement the natural day light by establishing lighting program in layer houses. Artificial light is provided to increase daylight hours and light intensity for egg production. Greatest light intensity has been achieved in conventional cage system through artificial light while natural daylight provide low light intensity (Yildiz *et al.* 2006).

2.7.2 Light treatment and production factors

The aim of artificial light is to control the length of daylight during growing and egg production period. Fewer hours of daylight affect the development of comb and results in fewer number of eggs during the laying period. Light controls physiological and behavioural processes on animal (Olanrewaje *et al.* 2006). Table 2.2 shows the influence of several different growing laying light programs on several production factors. Gradual reduction the length of the day light during the growing period was not effective unless the day light was reduced below the threshold of 11 to 12 hours. Light allows the chickens to establish rhythmicity, synchronize essential functions and influence the behaviour of chickens (Er *et al.* 2007).

Table 2.2 Influence of lighting treatment on sexual maturity, laying house mortality, and egg production in cages

Light treatment Growing period	Laying period	Days to reach 10% egg production	Days to reach 50% egg production	Laying house mortality%	Egg produced during 47 weeks of lay
Decreased from 22 hours (hrs) to 16 hrs	Increased from 16 to 22 hours	156	172	3.3	225
Decreased from 22 hrs to 9 hrs	Increased from 9hrs to 22hrs	172	186	3.3	220
Decreased from 16hrs to 9hrs	Increased from 9hrs to 16hrs	171	191	3.8	220
Decreased from 16hrs to 19hrs	Increased from 9hrs to 16hrs	163	176	5.0	230
Started on constant 16hrs then suddenly decreased to constant 9hrs	Increased from 9hrs to 16hrs	165	176	4.6	227
Constant 16hrs	Constant 16hrs	156	171	5.0	224

2.8 Egg production

The most important factors determining egg quality and safety are associated with the type of production system. Peric *et al.* (2016) states that although higher egg production has been determined in conventional housing system versus free-range system. The consumer choose of eggs produced have shown to be influenced by egg composition parameters. Free-range system production system is characterized by low productivity and low input. Productivity dependent on the genetics of stock, the effectiveness of disease control, quality of feeds supplement and the availability of pastures (Singh *et al.* 2009). Egg production fluctuates with a season under the free-range system because it controlled by follicle stimulating hormones (FSH) and luteinizing hormone (LH) produced by the pituitary gland in response to the photoperiod (Manser 2006).

Montero *et al.* (2011) reported no significant differences in egg production between the two housing systems but higher feed intake and egg weight were observed in conventional cage system compared to free-range system. Pavlik *et al.* (2007) found that egg production of hens housed in conventional cages was higher than those housed in alternative systems. Chickens in the conventional cage system at the age of 24 weeks produces 90.8% egg production and at 35 weeks produces 94.5% egg production (Gerzilov *et al.* 2012). The new standard of chicken welfare had additional costs to the farmers and farmers experience difficulties to recover additional cost (Patterson *et al*. 2001).

2.9 Egg quality

Egg quality plays an important role in egg industry for producers and consumers. The important factor affecting chicken egg quality is the production system. This is as a results of diseases, nutrition, genetics and technology (Sekeroglu *et al.* 2010). Peric *et al.* (2015a) reported that conventional cage system egg had low-fat content in yolks compared to other systems. Many consumers believe that free-range system and organic eggs are healthier compared to conventional cage eggs (Peric *et al.* 2015b).

2.9.1 Egg quality for conventional cage system and free-range system

Eggshell quality decreased at conventional cage system but in free-range system it fluctuated with age (Thomas & Ravindran 2005). Thomas & Ravindran (2005) observed that the housing system did not affect egg weight. Van Den *et al.* (2004) demonstrated that the weight of eggs from free-range layers was lower at an early age, but increased more with age than in the eggs from cages. Peric *et al.* (2015a; 2015b) reported that housing system affect egg quality. In addition, consumers are demanding more environmentally friendly and healthy products. Therefore, future sustainable egg production has a potential for expansion and development in contraposition on conventional cage system (Barrantes *et al.* 2006). Egg weight was not significantly affected by housing or genotype (Svobodova *et al.* 2014). Egg from cages was heavier than the free-range system, egg quality has a genetic basis and the parameters of egg quality vary between strains of hens. The age of hens and condition of environment resulted from housing system play an important role towards the egg quality (Singh *et al.* 2009).

Egg quality include both external (good eggshell) and internal (good albumen and yolk) measures which are critically important for entire egg production cycle for the economic viability of egg industry (Roberts 2004). Poor egg quality cost egg industry millions of dollars per year and take emerging egg farmers out of business at an early stage. Therefore is very important for egg farmers to study and understand factors that affect egg quality externally and internally (Roberts 2004). Layer production system has a considerable effect on the quality of eggs, including their physicochemical properties, which have been documented by many studies (Trziszka *et al.* 2004; Gianneanas *et al.* 2009; Matt *et al.* 2009). However, De Reu *et al.* (2009) observed no statistically significant differences in percentages of dirty eggs between conventional cage system and free-range system. According to Wall *et al.* (2008); conventional cage system and free-range system, found statistically significant differences in the enter-bacteria count on eggshells (12% in free-range system and 5.8% in conventional cage system).

2.9.2 External quality of eggs

Studies have shown free-range system eggs to be lower in cholesterol with shell that are lighter and thicker (Samman *et al.* 2009, Krawczyk *et al*. 2010, Tercic *et al.* 2012). Hidalgo *et al.* (2008) reported thicker egg shell on conventional cage system chickens. Thicker shell found in free-range system whereby effects can be sunlight on calcium metabolism (Barrantes *et al.* 2006). Many studies have shown that housing system can affect egg quality in commercial flocks (De Reu *et al.* 2005; Zemkova *et al.* 2007). Housing has been shown to affect the inner and outer content of eggs (Peric *et al.* 2016). Leyendecker *et al.* (2001) reported that eggshell thickness was higher in the intensive free-range system for Lohmann LSL and Lohmann Tradition. The greater has been observed in layers raised in conventional cages (Hidalgo *et al.* 2008). In conventional cage production system and shell quality decreased with the age while there factors remained constant or increased in free-range system (Van Den *et al.* 2004).

Eggshell thickness, in contrast with eggshell strength or eggshell weight were not affected by a housing system, and no significant interaction between housing and genotype was found. Van Den *et al.* (2004) obtained greater eggshell thickness and strength in eggs from outdoor layers disagree. However, Lichovnikova *et al.* (2008) reported higher eggshell strength in eggs from conventional cage system. Shell thickness value was the lowest in eggs produced in cages, while free-range system and barn eggs presented the highest values (Svobodova *et al.* 2014).

2.9.3 Internal egg quality

Eggs from free-range system layers have been shown to be lower in weight from the onset of production until 50 weeks of age with crude protein content of 9.40% compared to 8.32% in conventional cage system. Crude fat for free-range was 0.34%, while conventional cage system was 0.16% (Van Den *et al.* 2004; Peric *et al.* 2016). Breaking of bone has been shown to be caused by feeding 2775Kcal/kg metabolic energy and 16% crude protein (Hassan *et al.* 2013).

2.10 Economic cost benefit of egg production

Egg industries sustainability encompasses positive contributions to the economy. According to Scanes (2007), the poultry industry is the largest segment of the South African agricultural sector, contributing more than 16% of its share of gross domestic product and it provides employment directly and indirectly. Egg industry in South Africa and worldwide reflecting the levels of investment required to improve efficiencies and produce competitively. Egg weight is one of the most important economic parameters of egg production and the effect of different factors on egg weight would, therefore, influence the economics of egg production on a farm (Svobodova *et al.* 2014). Changing production systems may have implications on the cost of production, product characteristics and market prices among other economic and market variables. Besides affecting costs in relation to egg markets, hen housing and other conditions are contributing factors that affect the flock (Sumner *et al.* 2011; Watnick 2015).

Farmers also raise a concern that complying with discard of conventional cage system by replacing with alternative housing will require sizable capital investment and raise marginal production cost (Fisseha *et al*. 2010). Shifts from conventional cage system to free-range housing system would likely cause farm level cost increases of about 40% per dozen (Sumner *et al.* 2011). Daniel *et al.* (2008) reported that production cost for free-range system recorded 20% higher than conventional cage system. As a result of the higher production cost, the retail price for free-range system eggs were 25% above eggs from conventional cage system. Historically large companies rely on the benefits of integrated supply chain to reduce production cost while gaining dominance in market share to maintain sustainable large economy. Due to political challenges in Africa, there are limited investment in some countries with investment in others resulting in poor growth of poultry industry and general socio-economic aspects in the continent (Scanes 2007).

CHAPTER 3

3. MATERIAL AND METHODS

3.1 Study area

This chapter presents the study area, materials and methods of the study. The study was conducted at Nulaid laying farms Gauteng province in South Africa. The farms are apart from one another for bio-security reasons since they differ with housing structures. The farms practicing conventional cage system are situated at Krugersdorp near Talton area (-26.134728, 27.607415 coordinate) in Gauteng province and those practicing free-range system are situated at Western Cape Province at Atlantis area (latitude: 33.57°S and longitude: 18.48°E). The study area compares the level of productivity and economic benefits of commercial layers on conventional cage system and free-range system. This study will assists in evaluating how the farmer in the egg business can choose between conventional cage system and free-range system for production.

3.2 Research design

The researcher adopted a quantitative approach, using an exploratory and descriptive assessment to examine the impact of the housing system on egg production. Quantitative research is one of the research approaches used in empirical investigations and quantitative research was defined differently by authors (Leedy & Ormrod 2010).

3.3 Chicken breed used in the study

The total of four conventional cage houses and four free-range houses were used in the study. The Lohmann Brown Lite chicken breed has lite brown feathers, produce golden brown eggs, which are bigger eggs as compared to other chickens. Picture 3.1 shows a Lohmann Brown Lite breed.

Picture 3.1 Lohmann Brown Lite breed (own picture)

3.4 Types of laying houses

Two types of layer house systems namely conventional cage system and free-range system were used in the current study to compare egg production. The purpose of using two housing systems is to seek adaptive strategies that can be used on free-ranging house as the future alternative housing to replace conventional cage system. Pullets were purchased from the internal commercial rearing farm and transfer to experimental sites and kept in conventional cage system and free-range housing systems. Table 3.1 show list of activities and features of two housing systems.

Table 3.1 Activities and features of two-layer houses

Activities	Free-range system	Conventional cage system
Freedom of locomotion	Yes	Restricted
Nest box	Yes	No
Laying floor	Sawdust	Wire mesh
Egg collection systems	Manual (hand) collection	Manual (hand) collection
Egg collection time	08:30 and 14:30	08:30 and 14:30
Manure collection	Manual	Manual

Feeding system	Automatic chain feeder	Guntry feeding (hand)
Water system	Bell drinkers	Nipples
Lights	15 watts bulbs	15 watts bulbs
Number of feedings day	Three times	Five times

3.4.1 Conventional cage housing system

The use of laying cages for the housing of commercial layers has been a popular alternative to floor systems. Three houses of conventional cage house system placed 12 384 point of lay and one house placed up to 12 549 point of lay. The total number of chickens were placed on the conventional cage system was 49 701. Chicken were placed at point of lay pullets in conventional cage system at the age of 18 weeks until depopulation. The conventional cage system was fitted with three rows of two tiers of back to back cages. Table 3.2 indicates the cage equipment and size.

Table 3.2 Conventional cage house equipment and size

Equipment	Size
House width (m)	10m
Total number of units	81
Number of units per row	27
Total number of followers	78
House height (m)	2.5m
Total number of starters	3
Number of tiers	2 tiers
House length (m)	73.6
Number of chickens	12380
Number of rows	3

Conventional cage system consist of one 5 litres header tank and float valve per tier, one nipple, drinker and drip cup, scissors cross braces, level height adjustors, horizontal sliding gate. The dimension of the cage involve 7-degree floor slope and 451 centimetres square per chicken with built-in 0.8mm feed trough under the cage gates. The wall of the conventional cage system is built with white painted pane land have isolated roofing. The 16-ton feed bin is outside with a cross auger distributing the feed inside the house.

The big water tank with the capacity of 5 000 litres is installed outside, connected with 25mm pipe sending water to the header tank inside the house. These cages are made of wire and have sloping floors that cause the eggs to roll to the front of the cages and a typical conventional cage houses system place five to eight hens per cage. Most wire cages used for laying hens have a height of 15 to 16 inches at the rear of the cages and are slightly higher at the front of the cage. The floor space varies from 12 by 18 inches to 24 by 20 inches. Picture 3.2 shows the layers in cages whereby hen, where placed five per cage as part of animal welfare and Picture 3.3 shows the conventional cage system outside.

Picture 3.2 Layers in conventional cage system

Picture 3.3 Conventional cage system outside

3.4.2 Free-range housing system

There are many different types of equipment systems for layers houses, in order to reduce investment costs, one of other layers houses is free-range system. Four free-range housing system each placed 10 000 point of lay, total amount of 40 000 chickens was placed on the free-range system. The free-range system allow laying hens to have access to outdoor during the day. The outdoor has surrounding or fence that all free movement of chickens within it. Inside the fence there feature of pasture, feeders and the nest box. Picture 3.4 shows the free-range house system inside and Picture 3.5 shows free-range chicken house outside.

Picture 3.4 Picture of the free-range house system with chickens inside

Picture 3.5 Picture of free-range house system outside

Equipment of free-range house system differ with equipment of conventional cage house system. Table 3.3 indicates equipment and size of the free-range house system.

Table 3.3 Equipment and size for free-range house system

Equipment	Size or number
House width (m)	15m
House height (m)	100m
Number of bell drinkers	80
Feeder tube	200
House length (m)	2.5
Number of chickens	10 000
Nest box	30

One of the most important equipment in the free-range house is nest boxes, water system and feeder system. It is mentioned that chickens prefer to lay an egg in nest boxes than other equipment. The total number of 40 000 Lohmann Brown Lite (LBL) point of laying placed at the age of 18 weeks until depopulation. Pullets of the same age were purchased from commercial rearing site within the company. Standard Operating Procedure (SOP) for transfer of chicken between the rearing and laying were followed to deliver the chickens into two sites conventional cage system and free-range system.

The total number of pullets placed in the chicken house were calculated to ensure that the proper production cost for each house was calculated. The chicken were bought from the rearing farm at the live head unit price. The budget of feed and costing of other operational activities differed between two housing system. To determine the cost of dozen per house, all monthly cost factors were included and divided by total number of dozen eggs produced on that particular month.

3.5 Data collection

Data collection method for the two housing system differ due to farm operational procedure of each system. Table 3.4 presents the fixed and variable cost used for data analysis. The daily data collection included eggs, mortality, feed added, farm consumables, occasional medication and other like vaccine which were converted to weekly, monthly and entire cycle for appropriate comparisons between two farming system. The stock, production input and other variable data were analysed per flock cycle against the initial capital investment and repayment period for type housing system. The analysis allowed calculation of itemized costs per dozen eggs for each housing system. The data were collected from 18 weeks to 70 weeks of age. Standard record form was used to capture data at the chicken house then later transferred to the Microsoft Excel spreadsheet at the end of day seven (every Thursday). Annexure A shows daily production record while Annexure B shows weekly production records; this is the total eggs produced, feed consumed and mortality for that week.

Table 3.4 Fixed and variable cost per farm housing system

Fixed and variable costs	Frequency measurement
Fixed capital cost	
Farm cost	Monthly
Development of farm infrastructure	Monthly
Cost of erected house	Monthly

Equipment fitted in the house	Monthly
Insurances	Monthly
Loan interest cost	Monthly
Security	Monthly
Stock	
Total cost of pullet placed	Cycle split to monthly
Labour cost	
Managerial position cost	Monthly
Administration post cost	Monthly
General worker posts cost	Monthly
Maintenance and repairs	
General maintenance and repairs	Monthly
Production input	
Layer feed	Monthly
Supplement mix feed	Monthly
Vaccine	Monthly
Medication	Monthly
Veterinary costs	Monthly
Health monitoring sample cost	Monthly
Packaging cost	Monthly
Transport cost	
Deiseal cost	Monthly
Vehicles maintenance	Monthly
Distribution cost	Monthly
Electricity	
Farm electrical consumption cost	Monthly

3.6 Feed program

Feed program designed to supply adequate nutrients for egg production, maintenance egg mass and shell quality. The feed was bought from quantum feeds, a reputable poultry feed supplier of balance nutrients requirements according to animal species. Since the cost of feeding hens is usually in excess of 60% of the total costs of producing an egg, it is necessary to ensure optimum economic utilization of the feed. Feed comprise of the correct ratio of energy, protein, vitamins and minerals that are supplied at different production phases. Both conventional cage system and free-range system used layer mash. The feed was automatically supplied three times per day at the free-range system and five times a day for the conventional cage system. Both experimental farms purchased feed ingredients in bulk each week, the feed formulation for two farms differed according to nutrients requirements as influenced by farm housing system.

3.6.1 Feeding program for conventional cage system

Since egg production varies with age, two-phase feeding was applied in conventional cage system during the experiment. From point of lay to 45 weeks, chickens fed phase I and from 46 weeks to depopulation fed phase II. Feed specifications for phase I and phase II are indicated in Table 3.5.

Table 3.5 Layer phase I and phase II for conventional cage system

	Phase I	Phase II
AME (MJ/kg)	11.5	11.5
Protein %	15.0	14.5
Avl Methionine %	0.36	0.33
Calcium %	3.7	3.82
Avl Phosphorous %	0.35	0.31
Sodium %	0.18	0.18
Linoleic acid %	1.5	1.0

3.6.2 Feeding program for free-range system

In the free-range system, chickens were fed three different diet, free-range I, free-range II and free-range III, which is indicated in Table 3.6. Calcium on three phase feeding was adjusted to meet chickens requirements since calcium is decreasing on the bloodstream as it get older.

Table 3.6 Nutrient level for layer diets free-range system

Nutrients	Units	Free-range I	Free-range II	Free-range III
Metabolisable	MJ/Kg	11.60	11.41	11.20
Energy	Kcal/kg	2675	2660	2560
Crude protein	Percent	19.80	17.50	17.00
Lysine	Percent	1.02	0.93	0.89
Methionine	Percent	0.51	0.46	0.41
Linoleic acid	Percent	1.10	1.60	1.60
Calcium	Percent	4.10	4.25	4.30
Phosphorous	Percent	0.48	0.40	0.36

3.7 Micro nutrients

Micro nutrients required in the layer diet include, copper, iodine, iron, manganese, selenium and zinc. Fat-soluble vitamins that are essential in the diet of a laying hen include A, D3, E, and K, water-soluble requirements include B12, biotin, and choline. Fats and oils are feed sources high in energy and can be added to a poultry diet to provide energy and in turn, improve productivity and efficiency. The application period of the different feed types in weeks can be slightly modified depending on the production development of a flock. Table 3.7 show micro minerals specification.

Table 3.7 Micro nutrients specification

Supplements per kg feed	Layer	Supplements per kg feed	Layer
Vitamin A	10000	Nicotinic Acid	30
Vitamin D	2500	Biotin	50
Vitamin E	15-30**	Choline	400
Vitamin B_1	1	Antioxidant	100-150**
Vitamin B_2	4	Folic Acid	0.5
Vitamin B_{12}	25	Manganese*	100
Pantothenic acid	10	Zinc*	60

Iron	25	Iodine	0.5
Copper*	5	Selenium*	0.2

* So-called "organic sources" should be considered with higher bioavailability.

** According to the fat addition

Table 3.8 shows a continuous supply of fine and coarse limestone, whereby phase II diet has a high percentage of coarse limestone.

Table 3.8 Continuous supply of fine and coarse limestone

Feed type	Fine limestone 0-0.5 mm	Coarse limestone 1.5-3.5mm*
Layer phase I	30%	70%
Layer phase 2	25%	75%

3.8 Macro nutrients

Macro nutrients that are required in the diet of a laying hen include calcium, chlorine, magnesium, phosphorus, potassium and sodium. Two macro nutrients that are important in the diet for laying hen are calcium and phosphorus. The hens with outstanding production require higher calcium and lower phosphorus levels based on their age, which is a key aspect when changing feeds.

3.8.1 Calcium on diet

Calcium is the most important mineral in the structure of bone and the formation of eggshell and 99% of calcium in the body form part of the skeletal system. The amounts of calcium required in the diet for laying hens, as recommended by the NRC (1994), are 4.06, 3.25 and 2.71% for 80, 100 or 120 grams of feed intake respectively. Calcium plays important role in the eggshell quality and maintenance of bone health (De Vries *et al.* 2010). Calcium constitutes approximately 1.5% of a hen body, 40% of eggshell weight and calcium is deposited in the medullary bone where eggshell formation develops (Bolukbasi *et al.* 2005; Kim *et al.* 2012). Increasing calcium from 35 to

40mg/kg and increasing limestone particle size can course breaking in laying hens at 72 weeks (Koutoulis *et al.* 2009).

3.8.2 Phosphorus on diet

Phosphorus is an element of the bones found together with calcium in the form of phosphate ions in bones. Other additional feeds and supplements were added to the ration with permission of veterinarian but had relatively extra costs. The average egg cost were calculated by using the fixed cost and variable cost like daily, weekly, monthly and yearly.

3.9 Measurement of laying performance

The performance parameter such as hen-day egg production, feed conversion ratio, average egg weight was recorded daily and data were calculated weekly. Feed conversion ratio (FCR) was determined by the ratio between egg weight and weight of consumed feed. The total number of eggs produced were recorded daily with subtraction of broken and cracked eggs. To measure salmonella contamination of eggshell, 12 eggs from each house were tested at 30 and 45 weeks.

3.10 Samples and vaccination programmes

Due to the presence of poultry disease in South Africa, the company vet (specialized poultry vet) had design vaccination program in (appendix C) to prevent infection and protect chickens against the diseases. The company applied the principle of prevention is better than cure. Health monitoring samples were collected at different ages: 20 weeks, 41 weeks and 62 weeks of age whereby 8 hens were randomly selected for blood sample collection.

3.11 Data analysis

3.11.1 Productivity

Productivity is a function of production inputs. A production function approach was used to summarize the production process of all inputs into outputs. The production function on the current study used the fixed cost like the cost of the house and cost of equipment in the house. The productivity of two systems indicate the number of eggs produced per house. The production of eggs on different poultry houses used fixed cost such as house and its equipment or features, chicken cost, labour per house and variable cost like feeds, vaccine, medication, packaging cost, and others.

$E = f(H, F_1, E, L, F_2, O_v)$.

- E: Dozen of eggs
- H: Housing system
- F_1: Features in the chicken house
- E: Equipment
- L: Labour
- F_2: Feed
- O_v: Other variables:

Free-range system: Maintenance (bell drinkers and feed through), packaging materials, grass maintenance, spare parts, lights, broom, feather dust, disinfection chemicals, sani-gel, Lab-samples, egg tray, saw-dust

Conventional cage system: Maintenance (feed through, cages and nipples), packaging materials, spare parts, manure plates, broom, feather dust, disinfection chemicals, sani-gel, Lab-samples, egg tray,

The production function employed to model the production of two types of poultry houses was as follow;

$P(L, K) –bL^{\alpha} K^{\beta}$

Where:

P = Total production (the monetary value of eggs produced in the production cycle)

L = Labour input (the total number of person-hours worked per production cycle)

K = Capital input (the monetary worth of (fixed cost) houses, equipment, extra features, pullet cost, vehicles (variable cost) maintenance cost, feed cost and other variables)

b = total factor productivity

α and β are the output elasticity of labour and capital, respectively. These values are constants determined by available technology.

The economic benefit was determined by comparing housing fixed cost, maintenance, feed costs, labour costs, pullet costs, calculated energy costs, capital costs, miscellaneous operating costs, and the sum of all available costs across the two housing systems. Economic benefits (profit) is calculated by total production cost to produce a dozen eggs.

The comparison of productivity and economic efficiency performed in two different types of houses.

Comparison model:

House 1, (conventional cages system)

P1 = b(L_1)(K_1)

and,

House 2, (free-range system)

P2 = b(L2)(K2),

A further comparative analysis on the investment of two types of housing systems was performed by using a complement of the Net Present Value (NPV) and Internal Rate of Return (IRR). Both analysis is derived from the time value of money equation (TVM) expressed as follows:

$$\boldsymbol{NPV} = -\boldsymbol{I_0} + \sum_{1}^{n} \frac{\boldsymbol{C_i}}{(\mathbf{1} + \boldsymbol{r})^{i}}$$

NPV is net present value; I_0 is the initial investment in period zero, the minus sign indicates that money is paid away; C_i represents the cash flows in the periods I = 1to *n* and *r* is the cost of capital and *n* is the number of periods.

$$\boldsymbol{IRR} = -\boldsymbol{I_0} + \sum_{1}^{n} \frac{\boldsymbol{C_i}}{(\mathbf{1} + \boldsymbol{R})^{i}}$$

The NPV by definition computes the present value of all future cash flows whilst excluding the project lifespan, on the other hand, the IRR is accurate with cash flows whether negative or positive. The study will use annual estimates for both analyses since by definition the production of sugarcane is expressed on annual basis.

3.11.2 Statistical Analysis

The multi-comparison of egg production equivalence or differences from both housing system (free-range house system and conventional cage house system) was tested hypothetically on productivity and economic benefit or loss. The two hypothetical tests were model as follow for the analysis:

H_0: $\beta_1 + \beta_2 = 1$

H_1: $\beta_1 + \beta_2 \neq 1$

The Microsoft excel and SPSS was used to analyse the data and the statistical outcome from applied analyses methods such as tables and figures were used to summarize and present the results. Data analysis was conducted to reduce, organize and give meaning to the data. Data analysis usually begins together with data collection. Data was broken into smaller categories and coded.

Two hypothetical statements were tested by SPSS Version 24, General Linear Model using univariate to test the production variation between two housing system. Tukey Honestly Significant Difference (HSD) was use to compare the production data from two housing systems (SPSS, 2017). The production range with *k* and *r* degrees of freedom is the range of set of *k* independent estimate (with *r* degrees of freedom) of standard deviation of that normal distribution.

Hypothesis 1; the production of Lohmann Brown Lite is not the same when they are kept on the free-range system or conventional cage system (Complete null hypothesis) x_{cc} and x_{fr} are conventional cage (cc) and free-range (fr) production means are the respective housing system.

$$(X_{fr} - X_{cc}) / \sqrt{\left(\frac{MSE}{2}\right)\left(\frac{1}{N_{fr}} + \frac{1}{N_{cc}}\right)}$$

Then followed the production range distribution with *I* and *N – I* degree of freedom (N is the total sample size). Critical values for *q* then was appropriate for comparing production of x_{cc} and x_{fr}. Although other pairs of means do not actually represent the range of the observed production samples (they differ by less than -), *q* critical values also are used for comparing the production performance in a conservative procedure. A (1-α) CI for (μ_i - μ_j) is

$$(X_i - X_j) \pm q_1, N - 1, 1 - \alpha\sqrt{\left(\frac{MSE}{2}\right)\left(\frac{1}{n_i} + \frac{1}{n_j}\right)}$$

Hypothesis 2, the economic benefits (profit) and viability of egg production in Lohmann Brown Lite layers is greater in the free-range system compared to conventional cage system.

H1: Return - / = / < f(H, F_1, E, L, F_2, O_v). = (-) loss or (+) profit in house 1

H2: Return - / ≠ / < f(H, F_1, E, L, F_2, O_v). = (-) loss or (+) profit in house 2

The SPSS, General Linear Model with Univariate procedure was performed to analyse the production data of two different types of chicken houses. The production data of two different houses was analysed by means of crossover design (H_1H_2/H_2H_1).

3.12 Ethic clearance

The research proposal for the current study was approved by the University of South Africa Ethics Committee prior to the start of data collection under this reference number: 2017/CAES/046. The research was carried out in Republic of South Africa at Nu-laid farms, Conventional cage system in Gauteng and Free-range system in Western Cape. The study followed the rules and policy of animal welfare during the research at the conventional cage system and free-range system.

CHAPTER 4

4. RESULTS AND DISCUSSION

In this chapter the results are presented in the form of table and graphs. The overall egg production per hen each day was significantly ($p < 0.05$) different between the two systems (conventional cage system and free-range system). Egg production records started at 18 weeks of age in both systems and production was terminated at the same age to ensure a fair comparison. Housing systems affect production, feed conversion ratio, mortality and economic benefits.

4.1 Egg production

Free-range system production was higher at the age of 18 to 19 weeks compared to conventional cage system, however, from week 20 to 70 production was higher in conventional cage system compared to free-range system. Conventional cage system production reached peak production of 96.15% at the age of 28 weeks and free-range system reached peak production of 91.84% at the age of 33 weeks. The difference between the two systems was less than 5%, which shows the competitiveness of free-range system as suitable alternative to conventional cage system.

Continuous production on free-range system will lead to adaptable operational strategy for day to day activities and specialised production input like feeds. These results were better compared to those of Krawczyk & Gornowicz (2009) who found Polish hybrid layers to have 87% egg production at peak production on the free-range system. The results from the present study are at supported by those of Tactacan *et al.* (2009), who achieved 95% peak production from Shaver White kept under conventional cage system. Table 4.1 shows the production, mortality, feed consumption of both conventional cage system and free-range system. The results indicate that the conventional cage system has high production with lower average feed intake compared to free-range system. Free-range housing system had better mortality rate compared to the conventional cage system.

Table 4.1 Production parameters for the conventional cage (CC) and free-range (FR) from 18 to 70 weeks

Age in weeks	Production %		Mortality %		Average daily Feed intake / hen / week	
	CC	FR	CC	FR	CC	FR
18	0.36	4.78	0,02	0,19	57	67
19	7.03	13.06	0,20	0,32	65	99
20	34.06	26.98	0,45	0,58	98	108
21	66.52	51.70	0,70	0,68	89	111
22	83.55	69.20	0,92	0,78	92	126
23	90.05	83.30	1,17	0,89	113	129
24	93.08	88.76	1,39	0,98	111	130
25	94.34	90.99	1,61	1,10	122	130
26	95.78	90.90	1,87	1,19	105	129
27	95.90	91.22	2,04	1,29	103	131
28	96.15	90.39	2,25	1,35	105	131
29	95.65	91.30	2,43	1,40	108	131
30	95.50	90.82	2,58	1,44	113	130
31	95.60	91.02	2,75	1,51	114	130
32	95.74	91.12	2,89	1,55	116	132
33	95.65	91.84	3,04	1,60	119	130
34	95.39	90.67	3,15	1,67	117	125
35	95.31	90.25	3,31	1,72	112	128
36	94.98	91.27	3,46	1,81	115	132
37	94.11	89.75	3,61	1,85	116	130
38	93.41	89.19	3,77	1,89	118	133
39	94.19	88.47	3,88	1,95	119	129
40	94.97	87.89	4,03	1,99	120	125
41	95.10	87.08	4,22	2,08	125	130
42	94.63	87.20	4,32	2,19	127	130

43	94.31	86.51	4,46	2,26	128	128
44	94.02	86.58	4,63	2,36	128	121
45	93.89	86.88	4,78	2,44	132	132
46	93.86	86.95	4,94	2,49	120	128
47	93.54	86.27	5,11	2,56	122	133
48	93.03	85.29	5,29	2,66	122	128
49	92.79	84.50	5,46	2,77	118	129
50	92.67	84.63	5,63	2,86	125	132
51	92.77	84.00	5,80	3,00	125	126
52	92.52	83.18	5,97	3,16	116	129
53	91.87	82.47	6,14	3,38	126	130
54	91.29	81.94	6,30	3,49	121	128
55	90.92	82.29	6,48	3,64	122	129
56	90.11	82.45	6,66	3,83	119	131
57	89.77	81.18	6,84	4,01	122	131
58	89.92	80.21	7,05	4,20	119	128
59	88.49	79.37	7,45	4,39	122	116
60	87.31	79.28	7,87	4,61	15	119
61	87.31	79.21	8,24	5,01	109	112
62	86.52	77.74	8,62	5,17	111	122
63	86.71	76.34	9,03	5,36	106	115
64	86.12	76.37	9,44	5,54	106	112
65	85.55	75.68	9,82	5,74	117	112
66	85.61	79.04	10,24	5,90	125	116
67	84.58	78.49	10,61	6,05	120	127
68	84.74	78.48	10,95	6,14	127	126
69	84.61	75.23	11,44	6,29	104	130
70	62.19	74.33	11,95	6,42	112	126

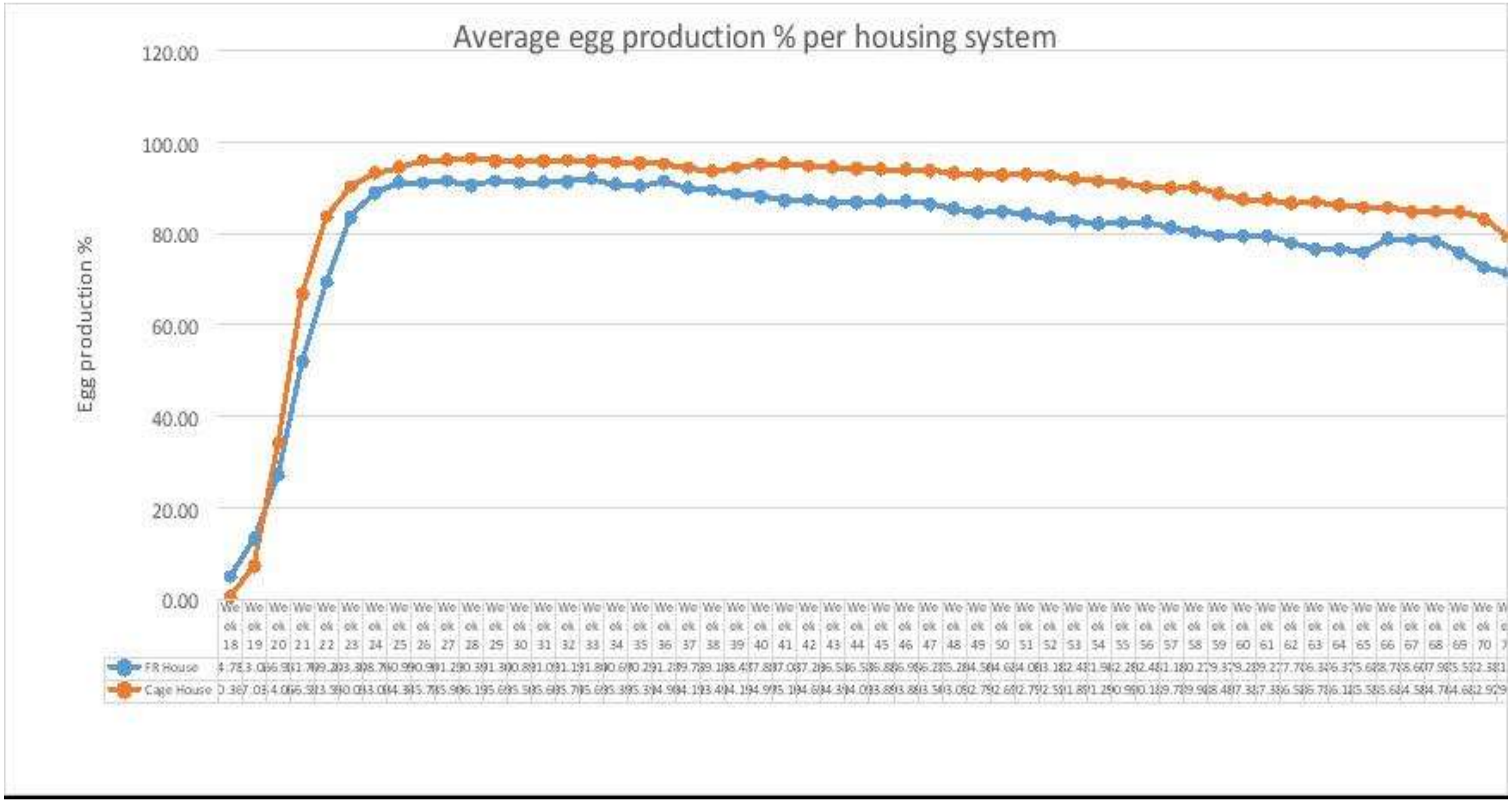

Figure 4.1 The productivity of Lohmann Brown Lite layers on the free-range system and conventional cage system

Egg production results are shown in Table 4.1 and illustrate in Figure 4.1. The conventional cage house system had better egg production compared to the free-range system. The conventional cage system achieved 36.0% of egg production while the free-range system was 24.9% at the age of 20 weeks. However, better results were reported by Dikmen *et al.* (2016), where egg production from the conventional cage system was 69.1% while free-range system produced slightly higher by achieving 69.6% at the age of 20 weeks. Singh *et al.* (2009) reported that chickens at conventional cage system lay 90.8% from 20 weeks up to 30 weeks, from 31 weeks to 45 weeks lay 89.2% each week, 72.1% egg production at the age of 46 up to 50 weeks. Tactacan *et al.* (2009) reported low egg production of 88.6% in the period of 21 to 61 weeks on conventional cage system compared to the current study that has achieved 96.1% on conventional cage system at the age of 28 weeks.

Layers kept in conventional cage system manage to reach 90% egg production at 23 weeks of age, while free-range system reach 83.3% at the same age of 23 weeks. Dikmen *et al.* (2016) found at the age of 50 weeks birds where at 90% at conventional cage system and at the age of 60 weeks birds still producing 90% at free-range system. The current study reveals that the rate of peak production age is related to the rate of production decline age. The layers reached peak production at 28 weeks of age with 96.1% egg production from conventional cage system, and free-range layers have reached peak production at the age of 32 weeks with 91.8%. The layers at the age of 70 weeks at conventional cage system were on 72.1% and free-range system at 74.3%. Similar results were attain by (Gerzilov *et al.* 2012) where layers in conventional cage system were decreasing egg production and reached 74.1% at the age of 70 weeks.

Egg per hen house from 18 to 70 weeks was 304.36 eggs at conventional cage system and these results are comparable to results obtained by (Neijat *et al.* 2011 and Ahmmed *et al.* 2014). However, Karcher *et al.* (2015) achieved high production of 97% with a total number of 352 eggs per house on conventional cage system from 18 to 70 weeks, compare to free-range system eggs per hen which recorded 340 eggs. Peric *et al.* (2007) found that 303 eggs per hen house were obtained from 20 to 72 weeks of age. Sumner *et al.* (2011) reported that laying period, from 18 to 76 weeks of age the average egg-laying capacity of the layers kept in conventional cage system was 361.1 eggs. The commercial layers produce 300 or more eggs per hen house in a period of a year (Isidahomen *et al.* 2013). Conventional cage system achieve an average of 87.10% between 20 to 60 weeks and free-range system achieve 89.27% at the same age (Dikmen *et al.* 2016). Less production of eggs on layer breeds can be influenced by presents of disease, poor feeding, housing and other environmental factors (Blackie 2014).

4.2 Mortality

The mortality rate may rise due to disease, prolapse during peak production, cannibalism and high temperature. Mortality rate between 18 weeks and depopulation (70 weeks) was 11.9% for conventional cage system and 6.93% for free-range system. In this study, mortality for the free-range system was higher (0.25%) than mortality at conventional cage at the age of 18 weeks and dropped to 0.12% at the age of 19 weeks. Gerzilov e*t al.* (2012) reported that high mortality (0.65%) was observed in conventional cage system at the age of 23 weeks and increased to 3.2% at the age of 73 weeks. Lack of protein and vitamins can cause high mortality at the early age of laying and during peak production (Gunaratne 2013). Weeks *et al.* (2015) found 8.4% mortality at the age of 72 weeks for free-range system. Commercial layers encountered a problem with high mortality during summer season if the temperature is above 30°C inside chicken house (Rahman & Samad 2003).

At the age of 20 weeks mortality increased again. Figure 4.2 shows the graph of mortality from 18 weeks until depopulation, but from 21 weeks to 53 weeks, mortality was below 0.17% which was acceptable. The average temperature of 32°C it course high mortality more especially when chickens are over 50 weeks. Poor production and high mortality for layers and their crossbred was mainly due to poor nutrition, environmental stresses and diseases (Marwa *et al.* 2016). At the age of 60 weeks both housing systems where less than 1% on accumulative mortality. Conventional cage was 0.45% while free-range was lower with 0.23%. Mortality results on conventional cage system was less compared to mortality obtained by Tactacan *et al.* (2009), who reported mortality rate at 5.6% at the end of 61 weeks. However, the worst mortality rate of 10.41% was observed on free-range system by (Peric *et al.* 2007). Gerzilov *et* *al.* (2012) reported low mortality of 0.05% on free-range housing system at the age of 23 weeks and 0.15% at the age of 73 weeks. Mortality percentages for conventional cage system was reported to be at 4.7% and 11.5% for free-range system (Karcher *et al.* 2015). The overall mortality percentage was significantly different ($p < 0.05$) between free-range system and conventional cage system at the age of 69 weeks.

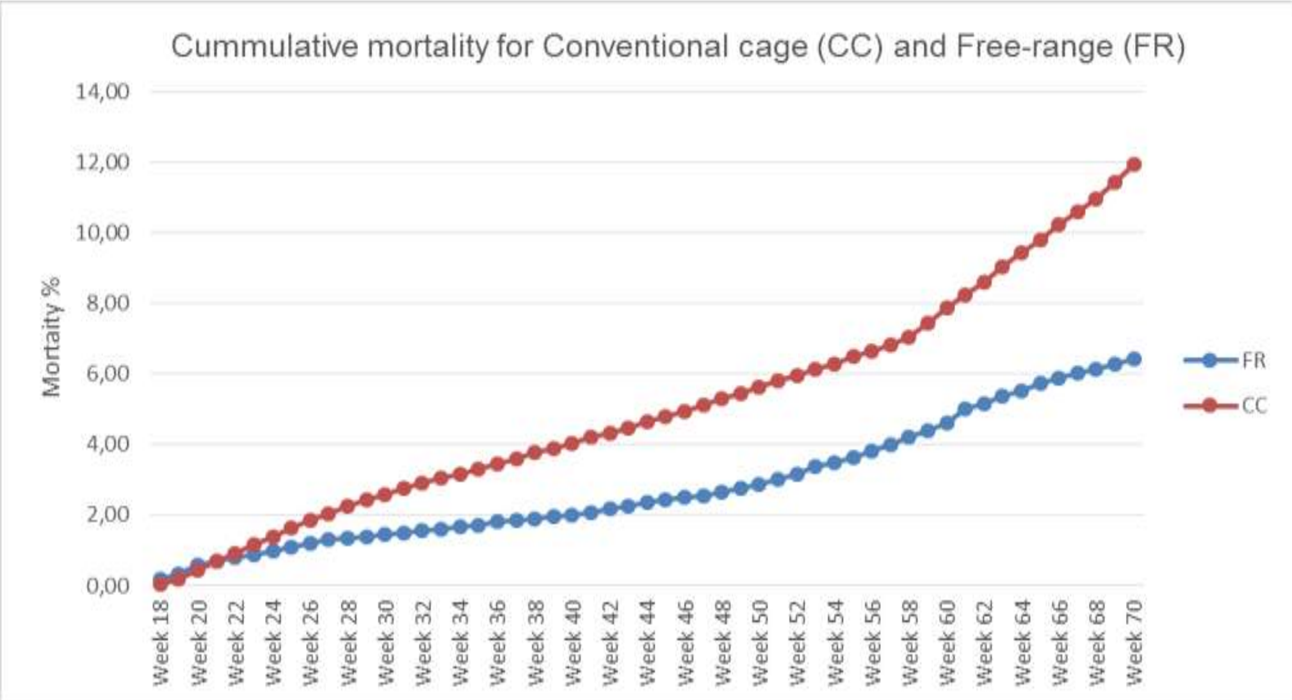

Figure 4.2 Mortality graph for the conventional cage system and free-range system

4.3 Feed consumption

Feed is the largest cost item in egg production, it accounts of 70% or more of the total cost and it affects feed cost per dozen eggs produced. Ravindran (2013) also confirm that feed cost contributes higher percentage in poultry production. There are three main factors that egg producer must be concerned about which includes feed cost, the number of eggs produced and egg quality for a profitable business. Feed is the most significant input for poultry production. It is important for the farmer to work out the total amount of feed consumed by hen to produce a dozen eggs to better understanding the sales price determination.

The nutritional value of conventional cage system and free-range system differs. The layer diets are formulated to optimize egg production in terms of egg numbers, egg size and egg mass. The feeds used in the current study did not show any nutritional deficiency but fulfilment of the nutrients requirements that has manage to maintain the optimal health and induce adequate egg production from both systems. Total energy used, expressed in MJ per kg egg, was 20.7 for conventional cages and 23.1 to 23.8 for free-range system. Poultry diets are formulated from a mixture of different ingredients such as cereal grains, cereal by-products, fats, plant protein sources and vitamin. The production cost, nutrients in feed and additives or medication influence the feed cost in a study by Ravindran *et al.* (2012).

Housing system also has an impact on feed conversion ratio (FCR) on free-range and conventional cage system. The results indicate that the chickens raised in conventional cage system consumes less as compared to the free-range system. Free-range system daily feed intake from 22 to 70 weeks range between 126g to 133g, while conventional cage system range between 92g to 128g. Dikmen *et al.* (2016) reported that free-range system feed intake range between 120g to 127g at the age of 20 to 60 weeks and conventional cage system range between 96g to 126g feed intake at the same age. At the age of 20 to 50 weeks, Muzaffer *et al.* (2018) obtained that Lohmann Brown in conventional cage system feed intake range between 98g to 112g.

At the age of 45 weeks, chickens consumed more at conventional cage system due to low temperature. Free-range system chickens consume more because they have access to move around which lead to the loss of energy thus needing replacement from the feed. At the age of 44 weeks, free-range system feed consumption dropped due to the high average temperature recorded that week. Peric *et al.* (2007) discovered the average daily feed consumption of 121g per hen at age of 50 weeks, while Englmaierova *et al.* (2014) obtained 131g per hen per day in the free-range system same age. At the age of 60 weeks, conventional cage system feed consumption dropped due to feed changes. Matthews & Sumner (2015) reported that feed cost per dozen of the egg in conventional cage system was higher compared to other systems by 0.51g. Peric *et al.* (2007) obtained average daily feed consumption of 127g per day for conventional cage system at the age of 60 weeks. Plaimast *et al.*

(2015) state that the including of calcium and vitamin D_3 in chicken ration did not affect their feed intake, egg weight and egg production, however egg shell quality was affected.

4.4 Feed consumed to produce a dozen eggs

In this study, the results indicate that low feed was consumed to produce a dozen in conventional cage system compared to the free-range system. At the age of 28 weeks (peak production), conventional cage system hens each consumed an average of 1.32kg to produce a dozen eggs. Free-range system hens consumed an average of 1.68kg to produce the dozen of eggs during peak production (33 weeks). The average conventional cage system feed per dozen was 1.54kg per dozen from 20 weeks to 70 weeks and free-range system use 1.87kg per dozen as an average from 20 weeks to 70 weeks. Karcher *et al.* (2015) obtained 1.44kg feed per dozen for conventional cage house and 1.49kg per dozens for the free-range house system. Horsted & Hermansen (2007) obtain high feed of 2.11kg per dozen in conventional cage system. The production cycles must be managed effectively and efficiently especially on feed in order to produce maximum output and profitability. The average cumulative dozens per hen per housing system presented in Figure 4.3, indicating that free-range system had lower dozens per hen house. Conventional cage system had higher dozens per hen housing as compared to the free-range system.

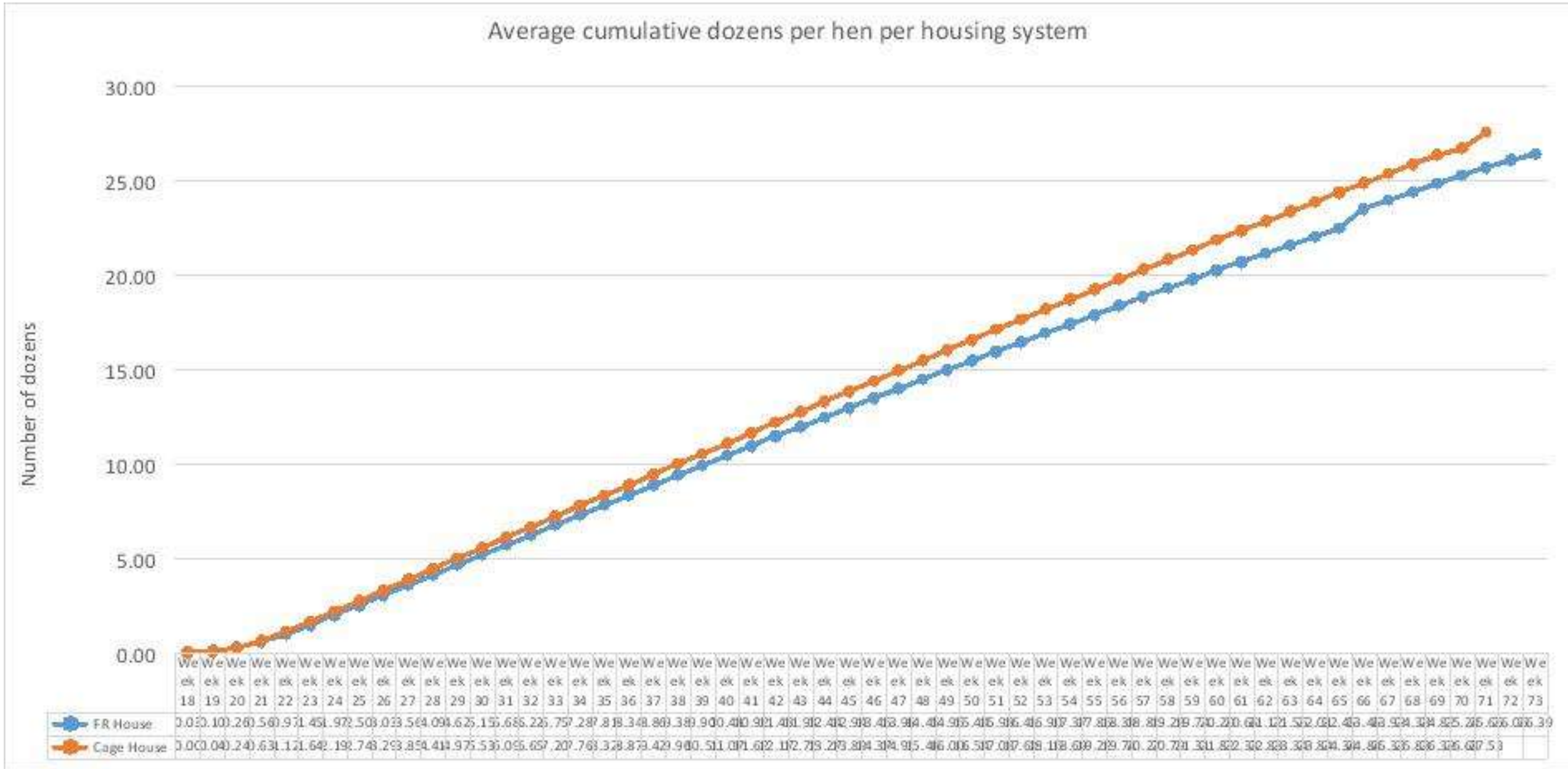

Figure 4.3 Average cumulative dozen per hen per housing systems

4.5 Production cost for free-range and conventional cage system

Accurate production costs are very important for the determination of financial benefit or loss after the sales of products. The economically most important parameter is the gross margin, which is revenue from eggs sales less fixed cost and operational cost involved in the production of eggs. Production cost for conventional cage system in this study is less compare to the free-range system due to high production and egg per hen housed.

The study indicates that from 18 to 70 weeks, conventional cage system produced 1 260 601 dozen eggs per cycle. The total variable and fixed cost for the first year of production cost R15, 55 to produce a dozen eggs in the conventional cage system. The free-range system produces 939 913 dozens of eggs per cycle. The total variable and fixed cost for the first year of production cost R15, 90 to produce the dozen of eggs for the free-range system. Production costs per dozen of eggs produced in free-range system were R0, 35 higher compared to conventional cage system. According to Matthews & Sumner (2015), the free-range housing system produced 3.3% above the conventional cage system production with 2.7% lower pullet cost per dozen produced due to lower mortality in free-range system compared to laying cage. Production costs were lower in conventional cage systems, while free-range systems had the highest cost due to large occupational space and high level energy requirements resulting from free movement. Daniel *et al.* (2008) reported that free-range system cost of production was 20% higher than the conventional cage system. In the current study the conventional cage system had a fixed cost of R13 887 279, 80 and variable cost of R13 995 439, 69. Free-range system fixed cost was R11 247 421, 27 with the variable cost of R14 945 128, 24.

4.6 Financial benefit for free-range and conventional cage system

Economic benefit or loss from the free-range system were compared to common conventional cage system. The study results showed that cost for conventional cage system was higher when compared to free-range systems. Total cost for the conventional cage system was R27 882 719, 49 and R26 192 549, 52 for the free-range system. According to Sumner *et al.* (2011), conventional cage system require high capital investment but resulted in high egg production with low effective cost due to less labour in long a run. Free-range system income was lower than the conventional cage system income. Due to the equipment and structure for the first year the cost is expected to be higher with low income for both systems. Figure 4.4 shows the graph that indicates average production cost and income for laying cage and free-range house during the first year. Economically, conventional cage system has benefits compare to the free-range system.

This study, indicates that average production cost and income for the conventional cage system and free-range system differ. The production cost in conventional cage system was higher than the free-range system. The Net Present Value for building and equipment for conventional cage system cost R13 144 699.80 while it cost R10 310 309.07. Conventional cage system cost was higher compared to the free-range system by R2 834 390.73. The cost benefit ratio for free range housing system was 1,21 while conventional cage stand at cost benefit ration 2.08. The internal rate of return for free range was 0.9996 and 1.000 for conventional cage housing system.

In conventional cage system chickens where at rich peak production of more than 95% between 32 and 36 weeks of age, while free-range system rich peak production of 90% at the same age of 32 and 36 weeks. The free-range system started dropping production slowly after peak. Similar trend were reported at the age of 32 to 36 weeks on free-range system where production was 87% and dropped to 73.8% at the ages of 52-56 weeks (Krawczyk & Gornowicz 2009). Conventional cage system from the age of 21 to 40 weeks, hen housed production was at the average of 88,8% and from 41 to 60 weeks production drop to 87.9%. Free-range system production from 21 to 40 weeks was 87.1% and from 41 to 60 weeks dropped to 85,5% (Ahammed *et al.* 2014).

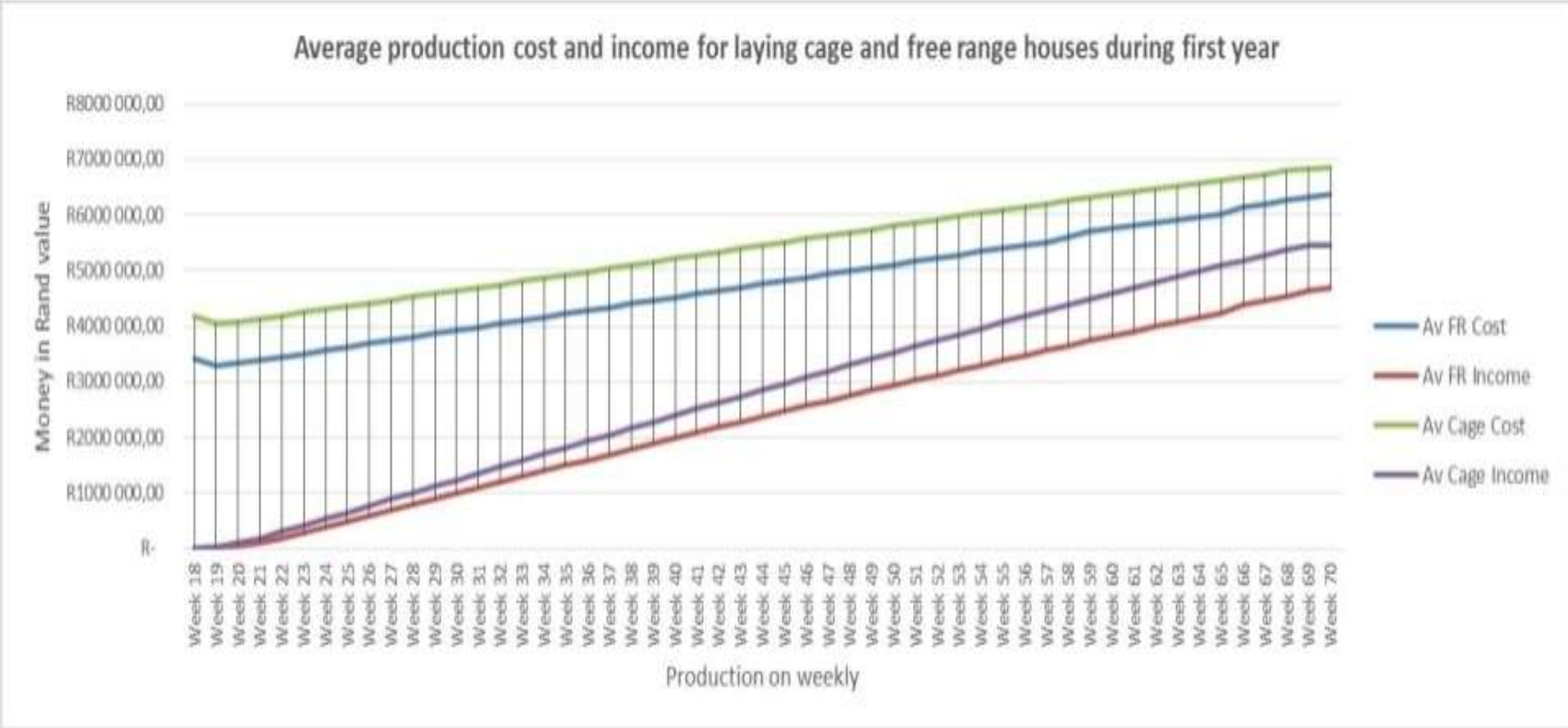

Figure 4.4 Average production cost and income for laying conventional cage system and free-range system house during the first year

4.7 The breakeven point for conventional cage and free-range systems

The first twelve months of production cost was higher due to the initial capital of building and equipment. At sixty months of production to fifteen months, income became higher than cost, figure 4.5 presents the break-even point for the free-range system. The results of breakeven point in the conventional cage system shows high cost for the first year compared to income. Breakeven point on sale for conventional cage system was at 46 months. Figure 4.6 shows the breakeven point for the conventional cage system. Cost for the first year was higher compare to income and from 46 months to 180 months income should be higher than cost both system. The breakeven point is a challenge for egg business, whereby the money it makes from sales of eggs is just enough to cover the cost of the production, but not enough to make a profit. The breakeven point is the tool used to analysis the cost volume profit by measuring the profitability in business (Nabil *et al.* 2014). It is a point where the total revenue equals the total variable and fixed expenses. Cost volume profit is important for planning of budget and forecast profit over a certain period or quantity of products produced (Horngren *et al.* 2014).

Free-range system have net profit value of R88 527 517.65, benefit cost ratio of R1.22 and breakeven point of sixty months. Conventional cage system has net profit value of R164 654 496.00, benefit cost ratio of R2.23 and breakeven point of 43 months. According to Nabil *et al.* (2014), knowledge of breakeven point outcomes should be extended and uses to employees in order to achieve maximum benefit. In the current study the breakeven point was done on fixed and operation cost only not extended to the employees.

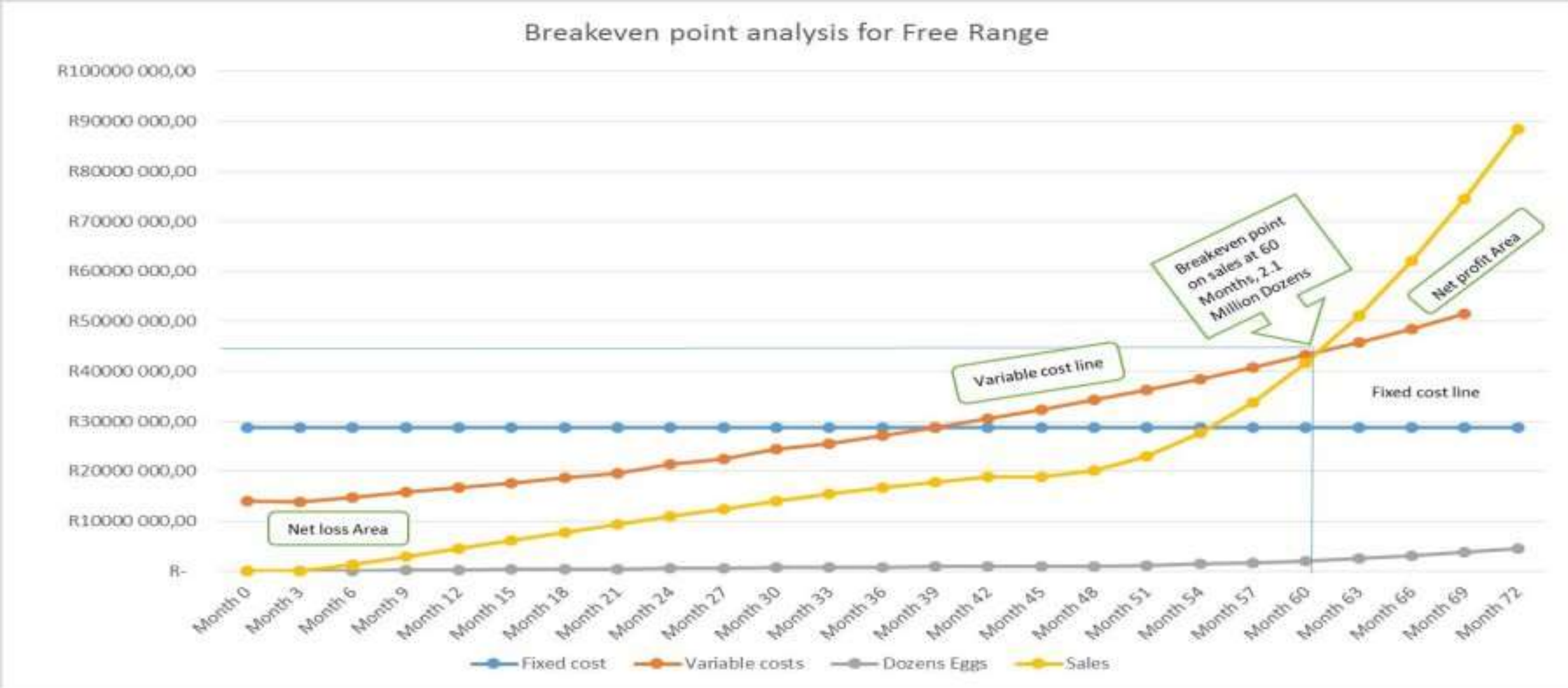

Figure 4.5 Break-even point for the free-range system

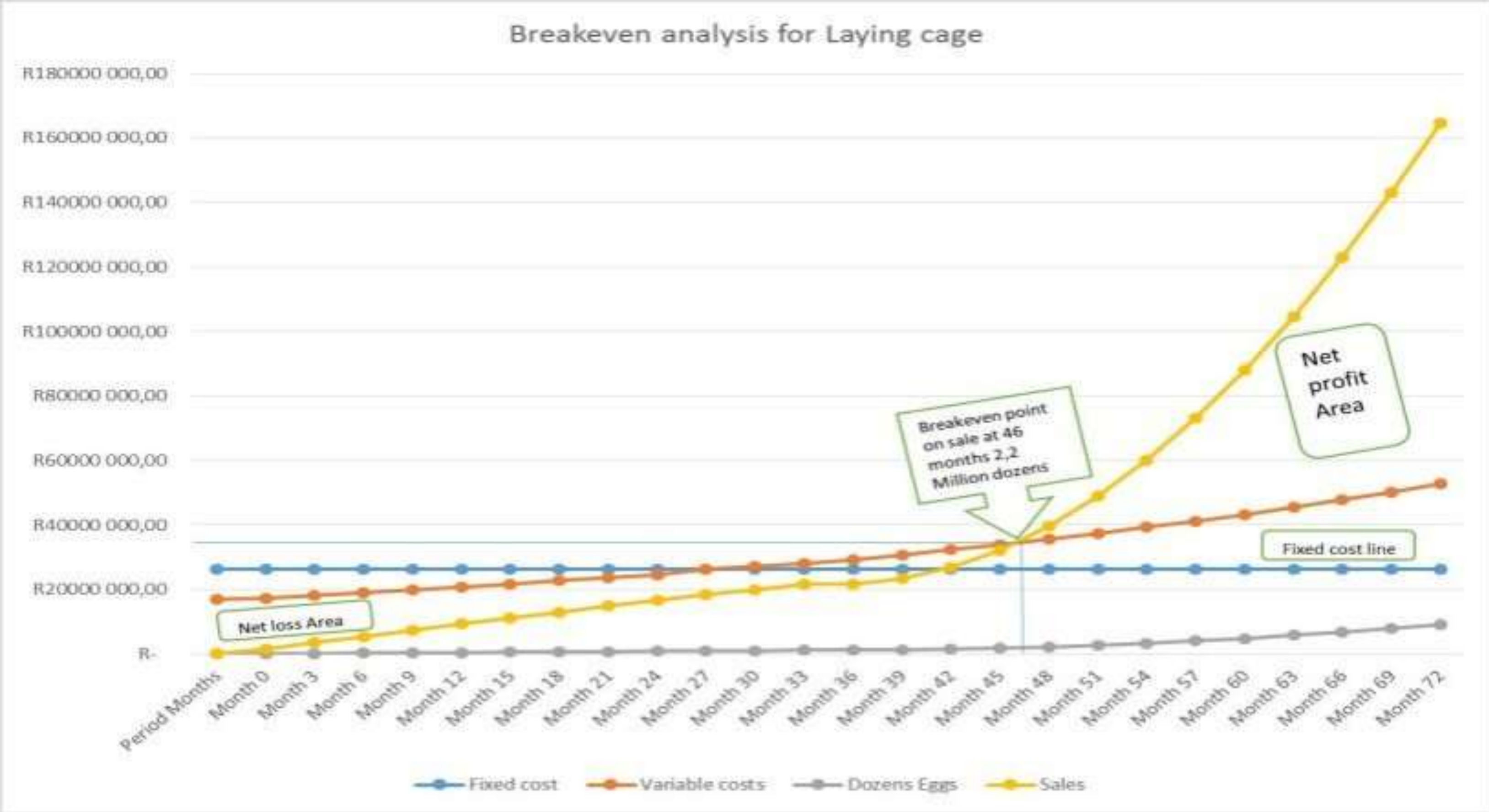

Figure 4.6 Break-even point for conventional cage system

4.7 Production challenges

The control of temperature is natural ventilation is difficult and challenging to keep required temperature by chickens for constant optimal production. Another challenge that has an impact on production is manual manure removal that increases cost during removal and causes ammonia inside the house. In free-range system operations, pasture became contaminated with manure Williams *et al.* (2006) also observe such contamination which makes pasture management a critical issue in the environment. The contaminated pasture especially during disease out breaks will lead to continuous problem since the new coming flock had to range and eat on contaminated pasture.

CHAPTER 5

5. CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

The study was concluded on the set hypothesis by establishing if the attained results lead to acceptance or rejection of a particular hypothesis. The outcome of the study revealed that egg production in free-range housing system was slightly lower than conventional cage housing system. Conventional cage system was higher by 22.39 eggs per hen compared to free-range system and mortality from the conventional cage was also higher by 5.5% compared to the free-range system. Conventional cage system had a higher egg production and economically beneficial compared to the free-range system. The consumption of feed by chickens from free-range system was higher compared to the conventional cage system.

Hypothesis 1: There is an influence of housing system on productivities of Lohmann Brown Lite kept in both free-range system and convention cage system. The outcomes of the study has shown that housing system had influence on egg production since chickens in conventional cage system has produced more eggs per hen house than chickens in free-range system, this lead to the acceptance of hypothesis 1. Although conventional cage system produce more eggs than free-ranging with significant ($p < 0.05$) between the two housing system, free-range system remain the best alternative to replace the conventional laying cage due to the pressure of animal welfare about the conventional cage system. The niche market of free-range system eggs as driven by consumer will make free-ranging housing system successful. The results show significant ($p < 0.000$) on mortality and feed intake between conventional cage system and free-range system.

Hypothesis 2: There was different economic benefit or loss of egg production on conventional cage system compared to the free-range system. The outcome for the economic benefit measure revealed that the gross margin for conventional cage system was 26% and differed slightly from the free-range system which was 29%. The economic benefit shows that the farmer who uses conventional cage system can get R0.26 cents while free-range system get R0.29 cents as profit every rand spend on input. The chickens placed in the conventional cage system had high productivity compared to chickens in free-range housing system but the return on free-range system is higher than return in conventional cage system due to the niche market price of free-range eggs. The difference on economic benefit between two housing system lead to the acceptance of hypothesis 2.

5.2 Recommendations

Results of this study have shown that Lohmann Brown Lite breed perform better in conventional cage system compare to the free-range system. Housing system plays an important role on production, mortality, feed convention ratio and also economically. Free-range system have low mortality with high feed consumption and acceptable production that is sustainable. This study recommend free-range housing system as the best alternative for replacement of conventional cage house to allow natural behaviour and locomotion of chickens as required by animal welfare and production free-range eggs to satisfy the consumer needs.

5.3 Future research suggestion

The future research should focus at the adaptation strategies for different layer breeds management of free ranging housing system to improve productivity. The chicken breeders should shift their breeding research to focus on development of genotypes that will perform under free-ranging system. The developed genotypes should be accompanied by nutrition research and effective management of free-ranging areas. It is important to get the right nutritional requirements for those breeds at different production stages to enable all poultry farmers to shift smoothly to free-range housing system to allow continuous sustainable poultry business operation at optimal profit.

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APPENDICES

APPENDIX A: Daily stock take

Daily Sheet			Site			Week no.		Week end date				
Water meter	Date	House	1	2	3	4	Total		Good eggs	Cracks	Dirties	Whites
		Prev. Prod						O/Stock				
		O/stock						Production				
		Cracks						Sales				
		Dirties						Transfer				
		White eggs										
		Destroy eggs						C/Stock				
		Good eggs						Actual				
		Total prod						Theo				
		Prod. %						Variance				
		Mortality										
		Transfer IN										
		Transfer OUT										
		Egg weight										

APPENDIX B: Weekly stock take

							Point of lay			Egg Transfer/sales		
Site		**Week no**			**Week end Date**		**Invoice No**	**Quantity**	**Supplier**	**Invoice No**	**Quantity**	**Customer**
	House 1	House 2	House 3	House 4	Total							
Hen O/stock												
Hen In/Out							Total P.O.L					
Mortality										Total Prod.		
C/ Stock										Staff Sales		
Cracks										Invoice	Dozen	
Dirties							Egg Del No	Dozens	Del. To			
Whites												
Destroyed												
Good eggs												
Total eggs							ITD Slip	Dozens	Liquid			
Age					Egg Movement							
O/Feed					Opening stock							
Feed Del					Production							
C/Feed					Egg sales							
					Destroyed							
Feed Cons												
Mortality					**Theoretical**							
Prod %					**Actual**							

APPENDIX C: Vaccination programme

VETERINARY CONTROL DOCUMENT

VACCINATION PROGRAM

COMMERCIAL LAYING

Age	01-08-2018	Vaccine / Medication	Supplier	Route/Dose	Expiry date	No. of doses	Monitoring	Test Code	Date (completed)
Week 20	01-08-2018	E coli (Poulvac E.coli)	Zoetis	Stihl/Herbi-4 or Spraycart spray (Full dose)			Salmonella: 3 x pooled swabs from manure belt/pit (or 200g dropping	BAK/4	
		HIPRAVIAR S	Hipra				1 x 500g feed	BAK/25	
		IB (Poulvac IB QX)	Zoetis						
Week 24	29-08-2018	NCD/IB (VH+IBH120)	Phibro AH	Stihl/Herbi-4 or Spraycart spray (Full dose)				See week 20	
		POULVAC E.COLI	ZOETIS	Stihl/Herbi-4 or Spraycart spray (Full dose)					
Week 29	03-10-2018	IB (Tabic IB Var)	Phibro AH	Stihl/Herbi-4 or Spraycart spray (Full dose)					
		POULVAC E.COLI	Zoetis						
Week 32	24-10-2018	NCD (ND Clone 30)	MSD	Stihl/Herbi-4 or Spraycart spray (Full dose)				See week 20	
		IB (Poulvac IB QX)	Zoetis						
Week 38	05-12-2018	ND/IB HIPRACLON/H120	Hipra	Stihl/Herbi-4 or Spraycart spray (Full dose)				See week 20	
Week 41	26-12-2018	IB (Tabic IB Var)	Phibro AH	Stihl/Herbi-4 or Spraycart spray (Full dose)			Blood: 8 sera per house if < 30 000 and 16 sera per house if > 30 000		
							(NCD, IB, MG)	EK/2	
Week 44	16-01-2019	HIPRAVIAR S	Hipra	Stihl/Herbi-4 or Spraycart spray (Full dose)				See week 20	
		IB (Poulvac IB QX)	Zoetis						
Week 50	27-02-2019	NCD/IB (VH+IBH120)	Phibro AH	Stihl/Herbi-4 or Spraycart spray (Full dose)				See week 20	
Week 56	10-04-2019	NCD (ND Clone 30)	MSD	Stihl/Herbi-4 or Spraycart spray (Full dose)				See week 20	
		IB (Tabic IB Var)	Phibro AH						
Week 62	22-05-2019			Stihl/Herbi-4 or Spraycart spray (Full dose)				See week 20	
		HIPRACLON/H120	Hipra				Blood: 8 sera per house if < 30 000 and 16 sera per house if >		
							(NCD, IB, MG, AI) **All farms**	EK/2, ELI/46	
Week 68	03-07-2019			Stihl/Herbi-4 or Spraycart spray (Full dose)				See week 20	
		IB (Poulvac IB QX)	Zoetis						
Week 72	31-07-2019								