UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA

EVALUATION OF DIFFERENT CHICKEN LAYER BREEDS FOR USE IN INTEGRATED AQUACULTURE–POULTRY PRODUCTION SYSTEMS IN GAUTENG, SOUTH AFRICA

By

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Submitted in partial fulfilment of the requirements for the degree
MSc. (Agric) Animal Science

in the

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January 2013

DECLARATION

I, Ikgadimeng Betty Motiang, declare that this thesis for the degree MSc (Agric) Animal Science degree at University of Pretoria, has not been submitted by me for a degree at any university.

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ACKNOWLEDGMENTS

My deepest gratitude goes to my supervisor Dr Christine Jansen van Rensburg of the University of Pretoria for her consistent invaluable advice, comments and follow-ups, constructive critiques and patience right from the start to the completion of my work. Thanks to my former mentor and co-supervisor at ARC, Dr Mary-Jane Thaela-Chimuka who extended her hand and went all out to make this study a success, for all the frustrations that she went through on this study, her guidance and valuable inputs throughout the experiment. I would also like to thank and appreciate Ms Thea Coetzee for her support and depth knowledge on technical work regarding poultry and not forgetting the general workers of ARC Poultry Nutrition Section for their hard work and willingness to give a helping hand at all the times, Mr Phillemon Tlhako, Mr Phanuel Motlhapi, Mr Koos Sejeng, Mr Jacobus Botlholo and Mr Matome Mokgerepi. My sincere thanks and appreciation is also extended to Tumelo Mahlangu from TUT also at ARC for her support, advises and assistance on the study and the laboratory work. I would also like to appreciate and thank Mr Jan Grobbelaar for his ever available time to help and all his inputs and efforts on the study and his in depth knowledge on South African the indigenous breeds.

I sincerely acknowledge the Department of Agriculture, Forestry and Fisheries for giving me this opportunity to study further. I would also like to extend my sincere gratitude to ARC for giving me the opportunity to be part of their students and benefit from their projects. My appreciation and thanks to the Gauteng Department of Agriculture and Rural Development for funding the study, without which this study would have not been a success. I appreciate time, patience and efforts put by Mr Roelf Coertze of University of Pretoria for statistical analysis.

Heartfelt thanks are extended to my family for their endless support and encouragement right from the beginning of my school life and to my husband Morake who always stood by me even in the worst periods and his support, thanks for your unfailing patience. Also my heartfelt thanks go to my two blessings from God, Malebogo and Rebaone for their love, tolerance for my absence from them during my study period.

To God be the glory! Let His name be glorified as He remains to be God almighty in my life in the midst of everything. Only through the Lord Almighty was this work done and successful because it was not by anyone’s might or power but by His spirit says the Lord. Amen.

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ABSTRACT

Hunger and malnutrition remain amongst the most devastating problems facing the world's poor and needy. About 80-90 million people have to be fed yearly and most of them are in developing countries in Africa. The majority of South African families live in poverty with a limited variety of foods available in their homes. Integrated aquaculture-poultry production systems can accommodate the demand for food. Integrated fish farming systems has been shown to can provide the vital animal protein necessary to relieve much of the prevailing problems of malnutrition in rural areas. Commercially orientated integrated aquaculture has been investigated in South Africa over the last two decades and intensive studies were done, yet little is known about the concept of aquaculture-agriculture systems in South African rural populations. Integrated fish-chicken farming has the potential to impact positively on the livelihood of rural populations because it can provide food, employment opportunities and recirculation of waste products for maximum utilization. The production from two farming enterprises integrated together, will therefore contribute much to poverty alleviation and provision of employment or income. The South African rural communities are more commonly involved in layer production with indigenous breeds which produce few eggs compared to commercial breeds. There is however a need to identify a suitable layer breed that can best perform when used in an integrated fish farming system. Since the purpose of promoting this system is to provide food security and regular sources of income to the poor, the best performing layer breed will be able to produce enough eggs for consumption and selling while the fish will be sold to increase profit. The spent hens will also provide meat and an income to the farmer at the end of the production cycle. Three hundred and twenty layer chickens of eight breeds were randomly assigned to either a conventional (control) layer house or a treatment house that was an open-sided layer house constructed over a dam (160 chickens/treatment). The eight layer breeds used were two lines of indigenous breeds (i.e. Potchefstroom Koekoek and Ovambo), dual purpose breeds (i.e. New Hampshire and Black Australorp) and commercial breeds (i.e. Hyline-Silver and Hyline-Brown; Lohmann-Silver and Lohmann-Brown). The design used for the study was a randomized block design. The houses were blocked in five blocks with one replicate per treatment (breed) in each of the blocks. Each replicate comprised of four hens, individually caged in adjacent cages. Parameters measured over the five month trial period were egg production, egg weight, feed intake, feed conversion ratio and hen day production %. Egg quality parameters were also measured i.e. egg shell strength, specific gravity, albumen height, Haugh unit and meat and blood spots. The mortality and economic efficiency of all the layer breeds was calculated over the five months trial period. The commercial breeds produced significantly more eggs, heavier eggs, had better FCR and higher hen day production % than the dual purpose and indigenous breeds in both the house that was constructed over a dam and a conventional house system. However, the feed intake of laying hens did not differ significantly in both the housing systems. The housing systems did not significantly affect egg quality parameters of laying hens. Mortality

per breed was higher in the conventional house than the dam house. The commercial breeds showed to be economically viable in an integrated chicken-fish farming system with a high profitability than the dual purpose and indigenous breeds.

CHAPTER 1

Introduction

There is a need for suitable agricultural systems to meet the increasing demand for food and also to maximize the utilisation of the available limited resources without much wastage. Hunger and malnutrition remain amongst the most devastating problems facing the world's poor and needy (FAO, 2002). About 80-90 million people have to be fed yearly and most of them are in developing countries in Africa. While the most reliable source of protein for many people is fish, millions of people who depend on fish are faced daily with the fear of food shortage (World Fish Center, 2003). In this regard, integrated fish farming systems can accommodate both the demand for food and utilisation of limited resources.

Integrated fish farming systems are a diversified and coordinated way of farming, with fish as the main target along with other farm products (Ayinla, 2003). The integrated fish farming system focuses on an optimal waste or by-product utilisation efficiency in which the waste of one sub-system (livestock) becomes an input to a second sub-system (fish). In a livestock-fish integrated system, where the livestock (goats, pigs, chickens or ducks) are housed in pens constructed over the pond surface, for wastes to be deposited directly into the pond, space utilisation is improved (Edwards *et al.*, 1988), whilst land and labour are economised. The purposes of integrated farming systems on farms are: diversification, intensification, improved natural resource efficiency, increased productivity and sustainability (Lightfoot *et al.,* 1993; Prein *et al.,* 1995; Devendra, 1997; Dalsgaard and Prein, 1999; ICLARM, 2000).

Commercially orientated integrated aquaculture has been investigated in South Africa over the last two decades and intensive studies were done by Prinsloo *et al.* (1999) on the feasibility of duck-fish-vegetable integrated aquaculture-agriculture systems for developing areas, yet little is known about the concept of aquaculture in South African rural populations. It has, however, been shown that this integrated fish farming production system can provide the vital animal protein necessary to relieve much of the prevailing problems of malnutrition in rural areas (Steyn *et al.*, 1995).
The practice of intensive modern poultry production and processing tends to also focus on high quality by-products such as manure, with the intention of possible re-use of the by-products. The intensive poultry production system promotes the importance of poultry manure for integrated aquaculture systems because of their nutritional status. In addition, Knud-Hansen *et al.* (1991) indicated that among the different types of manure that could be used, chicken manure is preferred because it is readily soluble and has a high level of phosphorus concentrations. Furthermore, the manure from layer chickens has more nutritive value for fish systems than that from broilers per bird/day (Taiganides, 1979). Layers produce more calcium and phosphorus-rich excreta than broilers and the waste of replacement birds fed restricted diets high in fibre is correspondingly poorer than laying birds. Poultry raised on a balanced ration produce a higher quality, more nutrient dense waste than those fed a supplementary feed (Little and Satapornavit, 1995). However, the Agricultural and Aquatic Systems Program (AASP) (1996) reported that the relatively low nutrient density of wastes from scavenging poultry fed supplementary feeds explains the rationale for using them as partial inputs into fish culture. It has been reported that

soluble organic matter supplied to ponds by manure from layers stimulates phytoplankton growth and increases biomass of zooplankton and benthic organisms thus enhancing fish growth (Atay and Demir, 1998; Sevilleja *et al.,* 2001).

MOTIVATION

Integrated fish-chicken farming has the potential to impact positively on the livelihood of rural populations because it can provide food, employment opportunities and recirculation of waste products for maximum utilisation (Gabriel *et al*., 2007). The production from two farming enterprises integrated together, will therefore contribute much to poverty alleviation and provision of employment or income. There is however a need to identify a suitable layer breed that can best perform when used in an integrated fish farming system. Since the purpose of promoting this system is to provide food security and regular sources of income to the poor, the best performing layer breed will be able to produce enough eggs for consumption and selling while the fish will be sold to increase profit. The spent hens will also provide meat and an income to the farmer at the end of the production cycle. When compared to broilers, layers have more stable weights and produce fairly constant levels of waste and are easier to manage, while broilers' waste availability is cyclical. With an integrated livestock-fish farming system, the high feed costs of the livestock system will be compensated for by the low production costs and high returns of the fish. In addition, Ayinla (2003) indicated that integrated fish farming system reduces cost of inputs whilst achieving a diversified protein production of combined enterprises that improves profitability and farmer's socio-economic status. The products (manure) produced in an integrated fish farming system are used as either a source of feed or fertilizer (Chen, 1989).

PROBLEM STATEMENT

Although integrated aquaculture is perceived as a viable solution to South African problems of poverty alleviation, protein malnutrition and unemployment, little information is available on the dynamics of the system especially in the South African rural communities where it is needed most. These communities are more commonly involved in layer production with indigenous breeds which produce fewer eggs compared to commercial breeds. One of the most important factors affecting profit of layers is genotype. Wiener (1994) reported that most production traits tend to differ among animals of the same breed or strain. In addition, egg number and egg weight traits are heritable and vary with strain of birds (Akinokun and Dettmers, 1977). Hyline-Silver hens were found to be ideally suitable for their egg laying ability and survival in an integrated agriculture-aquaculture venture (Prinsloo *et al*., 1999). The Hyline-Silver breed is a commercial strain that might be costly for rural farmers to maintain for adequate production, hence there is a need to look at performance of other breeds (dual purpose and indigenous) under the same conditions. In addition, information on egg quality from the different breeds on integrated aquaculture systems is scarce. Likewise information on the comparative performance of different layer genotypes in the same ecological pattern, integrated with fish culture, is still limited. The aim of this study was to evaluate the different chicken layer breeds for use in integrated aquaculture-poultry production systems in Gauteng. For this purpose, different breeds were kept for five months in a cage system situated above a concrete dam filled with water and in a conventional cage system in a house. Various performance parameters were measured and compared between breeds.

HYPOTHESIS

The null hypothesis of this study was that the production performance of laying hens from different breeds and strains, kept in an integrated layer-fish farming system and conventional battery system will not differ. The alternative hypothesis is that one or more breeds/strains of chicken will be more suitable to be used in an integrated layer-fish farming system than others.

OBJECTIVES

The major objective of the study was to identify the best performing chicken layer breed for use in an integrated fish farming system.

The specific objectives were to:

- Compare the egg production, body weight, mortality rate, feed conversion ratio, feed intake and hen-day production (%) of different layer breeds kept in an integrated fish farming system with those kept in a conventional battery cage system.

- Compare the egg size, albumen height, Haugh unit, shell strength, specific gravity and the amount of meat and blood spots of eggs from different identical layer breeds kept in an integrated fish farming system with those kept in a conventional battery system.

- Determine the economic efficiency of the different chicken layer breeds in the two different housing systems.

CHAPTER 2

Literature review

2.1. Defining integrated fish farming system (IFFS)

A variety of definitions of integrated fish farming systems (IFFS) exist. They include: practices which link two normally separate farming systems, whereby outputs (usually by-products) of one production sub-system (livestock) are used as inputs by another sub-system (fish) (Edwards *et al.,* 1988; Edwards, 1998); or diversifications of agriculture towards linkages between sub-systems (Prein, 2002); or systems of producing fish in combination with other agricultural/livestock farming operations centered on the fish pond (Rahman *et al*., 1992).

Little and Edwards (1999) argued that IFFS are commonly and narrowly equated with the direct use of fresh livestock manure in fish culture. However, there is an existing broader and better definition that illustrates potential linkages between IFFS whereby fish is produced at separate locations by different people and yet still integrated (Little and Edwards, 2003). In other cases the livestock can be housed over or adjacent to fish ponds, facilitating the loading of wastes. Little and Edwards (2003), stated that a wider definition includes manures obtained from off-farm and transported in bags, e.g. poultry manure, or as a slurry in tanks, such as for pig and large ruminant manure.

Integrated farming involving fish is defined broadly as the concurrent or sequential linkage between two or more human activity systems, of which at least one is aquaculture. Furthermore, the linkages between aquaculture and human activities involve not only agriculture (i.e. crops, livestock, irrigation dams canals) but also include roles in sanitation (nightsoil, septage or other forms of human excreta re-use, sewage treatment), nutrient recovery (hydroponic–fish, breweries) and energy recovery (culture in heated effluents of power plants, dairies, etc) (Prein, 2002). In contrast, theoreticians used to differentiate IFFS from mixed farming, in which production sub-systems of a farm are not mutually supportive and do not depend on each other (Csavas, 1992).

2.2. Origin of integrated fish farming system

IFFS also called Agropisciculture or integrated agriculture–aquaculture have a long history in Asia, dating back to more than 1500 years in India (Coche, 1967) and more than 2400 years in China (Willman *et al.,* 1998). Rana *et al.* (1998) indicated that the extended practice of IFFS in China resulted from the fact that more than 60% of the world's total aquaculture production comes from China. Moreover, Csavas (1992) reported that in China, integrated livestock fish systems were documented since the Ming dynasty (14-17th century) and they were thought to be developed to alleviate the pressure of high population densities and limited resources. In Asia, a wide range of integrated agriculture–aquaculture systems are in use and are mainly practiced in Bangladesh, Indonesia, Malaysia, Thailand, and Vietnam (Pullin and Shahadeh, 1980; Little and Muir, 1987; NACA, 1989; IIRR and ICLARM, 1992; Symoens and Micha, 1995; Mathias *et al.,* 1998; FAO 2000). According to Nnaji *et al.* (2011), IFFS has been practiced in African countries such as Nigeria, Benin, Madagascar, Zambia, Cameroon and Malawi but mainly at subsistence level. In addition, Brown (1983) reported that the use of large areas of land in Hungary, Czech Republic and Slovakia is predominantly for animal–fish farming. Willman *et al*. (1998) indicated that on the American continent, rice–fish farming is carried out at low levels in the United States, Argentina, Brazil, Haiti, Panama and Peru.

2.3. Rationale of integrated fish farming systems

The rationale behind integrated fish-livestock farming is to minimise waste from various sub-systems on the farm. Wastes or by-products from each sub-system are used as inputs to other sub-systems to improve the productivity and lower the cost of outputs for the various sub-systems (Edward *et al.,* 1986). IFFS play a major role in increasing employment opportunities, nutrition and income for rural populations and has received considerable attention in recent years. It is generally considered relevant particularly to benefit the rural poor in different countries. Furthermore, Vincke (1992) elaborated that in Asia fish farming has been a part-time activity of peasant farmers, who developed it as an efficient means of utilising farm resources to the maximum capacity. With a global emphasis on ecologically sustainable management of natural resources, it is logical to integrate where possible, appropriate farming practices to enhance farm productivity and water-use efficiency. Long term sustainability factors and water management costs to the industry and community at large indicate that farmers will need to diversify and increase total farm productivity and profitability as well as conserve water (Gooley, 2000). For example, water is currently under-utilised in irrigated farming systems in Australia as a result of routine, single-use only (Ingram *et al*., 2000).

2.4 Benefits of integrated livestock-fish farming systems to the rural poor

In recent years, a number of studies on the impact of rural livestock-fish farming systems on household nutrition have been conducted. These show that considerable benefits result either from direct consumption of fish by the producing households or from gains in income resulting in the purchasing of other cheaper foods, which lead to improved household food consumption (Ruddle and Prein, 1998; Ahmed and Lorica, 1999; Thilsted and Roos 1999; Thompson *et al*., 1999; Prein and Ahmed, 2000; Sultana, 2000).

FAO (1979) listed the benefits of integrated fish farming in a community in China to include:

- the provision of a cheap feedstuff;
- organic manure for pond fertilization, without any use of supplementary feeds;
- cost reduction of inorganic fertilizers and commercial feed;
- 30-40% increase in profit;
- self-sufficiency and self-reliance for communities due to production of grains, vegetables, fish and livestock from integrated fish farming systems;
- use of silt (rich water) from fish ponds for fertilizing crops which lead to reduction of chemical fertilizers.

Having fish production in ponds and livestock (duck, chicken or pig) reared over or besides the pond simultaneously, constitutes an organic fertilization of the pond which increases the efficiency of both livestock farming and fish culture through the profitable utilization of animal and feed wastes (Vincke, 1988).

2.4.1 Poverty alleviation

Numerous examples exist in which aquaculture has been suggested as a tool for poverty alleviation and sustainable rural livelihoods. Earlier, stand-alone fish farm designs and 'simple' two component packaged systems with unidirectional flow of wastes (e.g chicken-fish and pig-fish in pens above or adjacent to the ponds), were targeted to benefit poor farmers, but these failed in large scale development attempts after external support was withdrawn (Prein, 2002). These systems required operation of the manure-providing enterprise at such high levels of productivity and inputs, that they were neither affordable nor manageable by poor smallholders. Nevertheless, the important role of IFFS is under-valued and their potential for enhancement usually overlooked in favour of large-scale commercial ventures, which are more attractive for support by development institutions and policy makers (Edwards, 2000; Haylor, 2000). In integrated-poultry fish farming systems, fish, meat and eggs could be produced which are excellent sources of nutrients crucially required by many households to meet the recommended dietary requirements of the family. These products supply amino acids, vitamins, macro- and trace-minerals and energy essential for the wellbeing of the population. The products of the integrated poultry-fish farming system thus provide food security and raise the nutritional status by providing important complementary ingredients for better nutrition particularly in developing regions such as Africa where the diet may be heavily dependent on root crops such as cassava or cereals such as maize (Qureshi, 1996). A further benefit of the products produced in the integrated poultry-fish farming system is the additional income, which enables the farmer to buy other foodstuffs which are not being produced by the family thus further increasing access to food, raising the standard of nutrition and ensuring a secure food supply for all members of the family. In this way co-prosperity is achieved and peaceful coexistence enhanced in the community (Smith and Yoshida., 2011).

2.4.2 Economic benefits

According to Edwards (2000), further direct benefits from rural integrated aquaculture, besides increased household nutrition and income are:

- local availability of fresh fish
- the provision of employment for household members

Furthermore, the indirect benefits are:

- the increased availability of fish to local and urban markets that may lead to a reduction of prices;

- increased employment benefits through development of an industry providing work on fish farms and in related services;

- the sharing of investment in community-managed common-pool resources such as water bodies, cages, settled/attached species (e.g. freshwater and marine invertebrates and seaweeds)

Bedford and Mowbray (1998) stated that the benefits of aquaculture for poor women in rural Bangladesh have been shown to be considerable. In numerous cases, women headed households have been able to obtain income and achieve tangible levels of relative prosperity. Furthermore, the importance of integrating aquaculture into future rural development programs has been underlined by NACA/FAO (2000).

The economic benefit of IFF cannot be over-emphasised since the integration is varied and diversified in nature providing the farmer with a steady source of income all year round; which comes from various farm products. For example, in poultry-cum fish farming, the farmer can sell the eggs throughout the year, before the fish can be harvested. Nnaji *et al.* (2003) reported that IFFS is more profitable than the unitary system of fish farming (monoculture) while Tipraqsa *et al.* (2007) stated that an integrated chicken-fish farming system creates a higher economic return (profit selling of old chickens + eggs and fish). This is one of the most practical, reliable/consistent and profitable systems of any farming enterprise. It contributes to the economic empowerment of many families especially in the rural communities, enabling the farmer to be productive all year round and to fully maximize its production (Gabriel *et al.*, 2007). Integration of ducks and fish enterprises in Thailand resulted in farmers being able to earn a net profit of US$ 1.850 ha^{-1} of which 87% came from fish yields of 3.5 t ha^{-1} (Tokrishna, 1992).

2.4.3 Food security

The high nutritional value of fish, particularly for vulnerable groups such as pre-school children, pregnant and lactating women is widely known (Edwards, 2000) and some societies target specific species of fish as food for these categories (Thilsted and Roos, 1999) due to its high quality. With the prevailing economic situation in developing countries, there is a need for farmers to engage in a result-oriented farming system that will guarantee and sustain adequate food security (Gabriel *et al.*, 2007). Since there is a demand for protein rich foods in the developing countries and its supply is extremely expensive for the rural poor, this problem needs to be attended seriously considering available limited resources. IFF offers a big opportunity and hope of life, as it serves as a food–production base that combines cultivation of crops, rearing of livestock and fish farming. IFFS will not only supply enough manure to produce a large quantity of fish, but also produce meat, milk, eggs and vegetables (Gabriel *et al.*, 2007). The study by Tipraqsa *et al.* (2007) showed that the integrated farming system outperforms the commercial farming system in all its dimensions of multifunctional agriculture as it gives a more secure supply of food and also better matches the social needs for agriculture as a supplier of materials for food, economic and environmental functions.

According to Ayinla (2003), IFFS are more suitable for poor farmers with remarkably low or no capital expenditure patterns for self-sufficiency. Furthermore, they can lead to continuous low spending for food and other dietary requirements for the household. Huazhu and Botany (1989) further elaborated that the varied nature of IFFS contribute to more farming activities being available than in unitary fish farming systems. Throughout the year, the farmers become engaged in one or the other farming activity, thus making it self-reliant and productive all year round.

2.4.4 Quality of manure

Manure contains considerable quantities of nutrients for fish production with ranges of between 10 and 30% for protein, 0.46-5.86MJ/kg for energy, as well as high levels of soluble vitamins (Pratt, 1975; Tuleum, 1992). It also contains non-digested feed, metabolic excretory products and residues resulting from microbial synthesis, which can be utilised to replace reasonable quantities of feedstuffs used in conventional fish-feed thereby reducing production costs (Falayi, 1998; Fashakin *et al.,* 2000). Yingzue *et al.* (1986) reported that the quality of manure produced in an IFFS depends on the species of the animal involved (Table 2.1). The manure of ruminants contains less nutrients than that of poultry and pigs, especially when it is collected from the field after being dried and or leached out (Csavas, 1992). Nnaji *et al.* (2003) also reported that the conversion ratios of animal manure to fish (i.e kg of fresh manure/kg of increase in fish weight) are as follows: cattle 35-45; pig 20-30; chicken 15-25 and duck 15-25. Chicken and duck have better conversion ratios for fish growth than pig and cattle. The intensive nature of modern poultry production and processing tends to concentrate on high quality byproducts, and this has stimulated their re-use, thus making it more important for integrated aquaculture because of their nutritional status. In addition, Knud-Hansen *et al.* (1991) stated that among manure used from different species, chicken manure was preferred because of its high solubility and high level of phosphorus concentrations. Poultry layer wastes have a higher nutrient availability (being between 72-79% of dietary nitrogen, 71-87% of potassium and 82-92% phosphorous) (Taiganides, 1978). Soluble organic matter supplied to ponds by using manure (layer waste) stimulates phytoplankton growth (Sevilleja *et al*., 2001) and moreover it increases biomass of zooplankton and benthic organisms (Atay and Demir, 1998), thus enhancing fish growth.

It has been observed that the manure added to fish ponds gave better results than fertilizing the pond (Ansa and Jiya, 2002). According to Otubusin (1983), manure loading required by fish is directly related to the number of farm animals involved. The quantity and composition of the resulting organic matter varies with feed, age and total live weight of the farm animal (Gabriel *et al.,* 2007). The benefit of manure loading in fish production is the stimulation of growth of benthic organisms (small living creatures and plants) in the pond.

Table 2.1. Matrix of livestock waste qualities and suitability for use in aquaculture (Little and Satapornavit, 1995)

Livestock Type	Factors increasing relative suitability for aquaculture				
	Collectability	**Acceptability**	**Nutrient density**	**Low opportunity cost**	**Lack of deleterious compounds**
Poultry					
Feedlot	***	***	***	*	***
Scavenging	*	**	**	**	**
Pigs					
Feedlot	***	*	**	**	***
Scavenging	*	*	*	**	**
Ruminants					
Feedlot	***	**	**	**	**
Scavenging	*	**	*	**	*

(*** = high; ** = medium; * = low)

2.4.5 Nutrient re-cycling

Integrated fish farming systems reduce waste disposal by re-cycling organic wastes from chicken culture, thus promoting environmental cleanliness and also provide economic benefits. This is important to sustainable aquaculture and also reduces expenses on feed and fertilizer to a large extent (Gabriel *et al.*, 2007). For effective cycling of nutrients in an integrated fish farm, the farm must be well managed, taking into consideration the type and level of integration involved. In aquaculture, animal waste has been recycled as fertilizer for centuries with the aim of promoting pond productivity of phytoplankton and zooplankton (Velasquez, 1980). In integrated poultry-cum fish farming, the protein rich chicken droppings are made available to the fish either directly or indirectly via the primary producers in the aquatic food web (Oladosu *et al.*, 1990), which in most cases reflects the productive capacity of the ponds.

The unsystematic use of manure in fish ponds may instead of improving the pond productivity, lead to pollution (Otubusin, 1986; Asala, 1994). This can result in a lack of dissolved oxygen thus killing the fish. Therefore, it is necessary to know the standard doses of these wastes which would keep the physicochemical parameters of pond water in a favourable range required for the survival and growth of fish. In addition, Pearl and Turker (1995) indicated that poorly managed integrated systems usually have high nutrient loading leading to poisonous effects of cyanobacterial bloom. Osuji *et al.* (2003) emphasised that cyanobacterial bloom is undesirable in aquatic ponds because:

- they are relatively poor aquatic food base;
- they are poor oxygenators of pond waters with undesirable growth habits;
- some species produce odorous metabolites;

- they impact undesirable flavours to the cultured fish species while others produce compounds that are toxic to aquatic animals.

The above mentioned call for serious attention to the ecological sustainability of integrated fish farming

2.5. Types of integrated poultry-fish farming systems

Poultry-fish farming is the integration of poultry, such as chickens, ducks and geese with fish farming. The poultry house can be constructed over the pond or adjacent to the pond. In both cases the excreta from the birds can serve as feed, which fertilizes the pond or the fish can feed on the excreta directly.

2.5.1 Direct integrated model

It is more ideal when the poultry houses are constructed over the ponds to allow direct flow of manure to ponds and thereby maximizing the usage of the land. A poultry house constructed over the pond will reduce labour requirements and costs, as the excreta falls directly to the pond resulting in good hygienic environment for hens. The nutritive value of applied fresh chicken manure is much higher in direct integrated poultry-fish farming system than dry manure collected from a different place (indirect integration). In direct integrated poultry fish farming system, no transportation costs or additional labour are involved and there is a higher production of animal protein from the same area, increasing the overall farm productivity and income (Rahman *et al.,* 1992).

2.5.2 Indirect integrated model

The house can also be constructed alongside the pond or in another place. In such cases additional land will be required for the integrated system. Furthermore, more labour will be required for manure collection and transportation, which will increase production costs. However, this model has an advantage of curbing potential transmission of diseases from chickens to fish during outbreaks. Better control on the amount of manure applied to the pond is possible to eliminate chances of pollution.

2.6 Effects of poultry and aquaculture integration on production systems

The use of poultry in an integrated production system with fish has several benefits such as low digestibility due to the size of the digestive tract resulting in nutrient rich manure and subsequent low input integration, as well as the apparent synergistic relationship between the two production systems under integration.

2.6.1 Quality of chicken manure

Poultry manure can be used fresh, or after processing, to enhance natural food production in sun-lit tropical ponds. Although some nutrition may be derived directly from the waste, natural feed produced on the nutrients released from the wastes is more important. The quality of poultry wastes used in fish culture varies greatly. High levels of spilt feed, for example, increase direct feeding value. Nutrient composition may be a useful guide to value but the availability or release of nutrients to the food web may be more important (Little and Satapornavit, 1995). Conventional feed ingredients have been 'replaced' with dried poultry wastes of various types, but low metabolisable energy and digestible protein levels limit their usefulness (Wohlfarth and Schroeder, 1979). In addition to being more nutrient dense than other livestock waste (Table 2.1), poultry waste contains less moisture, fibre and compounds such as tannins that discolour water when used as fish pond fertilizers (Little and Satapornvanit, 1995). Poultry manure is a “complete” fertilizer with characteristics of both organic and inorganic fertilizers, which can be used without resorting to the addition of supplementary feed (Banerjee *et al.,* 1979; FAO 2003).

2.6.2 Type of poultry production system

The most valuable poultry production systems for use in fish production have been reported to be those producing nutrient-rich and collectable waste; unlike chickens receiving a poor quality supplementary feed or only restricted to overnight confinement (Little and Sataporvanit, 1995).

Taiganides (1978) reported that although the egg-laying hen from a feedlot can produce manure which contains dietary nitrogen between 72-79 %, phosphorous between 61-87% and potassium between 82-92%, the variability in terms of nutrients available (g/bird/day) from different poultry production systems can be much greater. According to Little and Satapornvanit (1995) layers produce more calcium and phosphorous-rich excreta than broilers and the waste of replacement birds fed restricted diets high in fibre is correspondingly poorer than laying birds. They also indicated that the fish yield will be influenced by the nutritive value of manure from different types of poultry production system used (Table 2.2).

Table 2.2. Input and output of poultry waste fed-aquaculture (Little and Satapornvanit, 1995)

Systems	Input (g/m²/day) Poultry waste Dry Matter	N	P	Other Dry Matter	N	P	Systems	Output Fish	g/fish/m²/day
Feedlot									
Egg laying ducks	6.71	0.3	0.07	-	-	-	200m² pond, 6mths (Edwards *et al*, 1986)	Tilapia	2.82
Broiler chickens	10.0	0.4	0.46	-	-	-	400m² pond, 3mths (Hopkinz & Cruz, 1982)	Tilapia, common carp	2.87
Layer chickens	14.3	0.4	0.3	-	-	-	1,000m² ponds, 5mths (Green *et al*, 1994)	Tilapia	1.33
Layer chickens	1.07	0.03	0.08	-	0.47	0.23	220m² ponds, 5 mths (Knud-Hansen *et al*,1991)	Tilapia	2.75
Scavenging									
Muscovy ducks	9.7	0.15	0.10	-	-	-	5m² tanks, 3mths ; ducks fed 75% *ad lib* (AFE,1992)	Tilapia	1.38
Egg laying ducks	3.0	0.23	0.03	-	0.17	-	200m² ponds, 4mths (AASP, 1996) rice bran	Tilapia	1.21
Egg laying ducks	1.24	0.20	0.01	-	0.17	-	200m² ponds, 4mths (AASP, 1996) paddy rice	Tilapia	0.53

2.6.3 Economic efficiency of integrated fish-laying systems

With integrated fish-laying systems the farmer can double his or her income from the whole system because eggs from laying hens, old hens and the fish can be sold compared to when farmed with fish or chicken alone. Gabriel *et al.* (2007) emphasised that IFF provides a farmer with a steady income all year round by selling various farm products. For example, in poultry-cum fish farming before the harvesting of fish, which may take some months, the farmer can sell the eggs which will generate the money for some time.

In addition, Hopkins (1982) and Otubusin (1986) emphasized that other advantages of integrated fish farming with poultry include: increased utilisation of resources including labour, feed, landspace; income generation; family food source and employment opportunities.

2.7 Importance of poultry production in rural livelihood

According to Moreki (2001) family-kept chickens are rarely the sole means of livelihood for the family but are one of a number of integrated and complementary farming activities contributing to the overall well-being of the household. The local chicken sector constitutes a significant contribution to human livelihood and contributes significantly to food security of poor households and can be considered an initiative enterprise owing to its low cost (Gondwe, 2004; Abdelqader, 2007). Poultry and poultry by-products can be sold to provide an income. Eating poultry meat and eggs is important especially for children and expectant mothers. Poultry can make a significant contribution in areas where child malnutrition is common. Enhanced nutrition improves growth, mental development, school performance and labour productivity and reduces the likelihood of illness. In many countries, poultry farming is regarded as the responsibility of the women. Women produce poultry to care for their families by selling chickens and eggs to buy other food.

In addition, rural poultry that scavenge for their feed can help to control pests such as cattle ticks while chicken manure can be used to fertilize crops and vegetables. Poultry projects are underway in South Africa to assist families affected by HIV/ AIDS (FAO, 2004). Households which lost loved ones from this disease and afterwards headed by children or elderly people raise poultry for sale and home consumption. In general, rural poultry plays a significant role in cultural and social life of rural people in the following ways: as gifts for relatives and for religious ceremonies, cocks as alarm clocks, to cure a sick person, starting capital for youth and a treat for special guests (Muhiye, 2007).

2.7.1 History of egg production

The development of high producing laying hens intensified in the late 1940s when producers sought to attain higher return on capital and labour by focusing on high average egg production from housed hens (Robinson, 1948). To date through intensive breeding and research, egg production by modern layer hybrids averages between 260 and 300 eggs per hen per year. Shalev (1995) reported a higher average egg production for hens that lay white-shelled eggs than those laying brown-shelled eggs. This study reported an average production of between 275.3 and 302.5 for white shelled eggs and between 267.3 and 295 for brown shelled eggs.

The Leghorn types are the most common commercial egg production breed with laying capacity of 250-300 eggs per year under proper management (Grobbelaar, 2009). The egg laying test in South Africa from 1945-1962 had shown that the Leghorn hen produces 269-286 eggs in 336 days (du Plessis, 1945). On average, egg production per hen over a 336 days egg laying test period increased by 90 from 176.5 in 1965 to 267.7 in 1982 (Gregorowski, 1984).

2.8 Selection criteria of laying hens

Selection for increased egg production in laying hens is generally based on cumulative part records for up to about 40 weeks of age (Ayyagari *et al*., 1980; Ibe *et al.,* 1982; Gowe and Fairfull 1985; Poggenpoel *et al*., 1996), which is positively correlated to response in the full record. Selection for increased egg production and other economic traits from various breeds, environments and selection methods also contributed many estimates of genetic and phenotypic parameters (Anang *et al.*, 2000).

However, there are only few studies that used monthly records for genetic improvement of laying hens. Liljedahl *et al*. (1984) found that the estimates of genetic variances increased along with the age of hens, but the environmental variation also had an impact. Results published by Von Preisinger and Savas (1997) and Savas *et al*. (1998) showed low heritability estimates for monthly egg production and low genetic correlations between early monthly egg productions and the full record, increasing gradually towards the end of production. Van Vleck and Doolittle (1964) noted that selection based on a single month of egg production would not be satisfactory unless the month chosen was one in the latter part of the laying year.

Indigenous chickens are said to produce less eggs and their production performance can improve when there is proper management and feeding. In practice, annual egg production per bird ranges between 20 and 100 eggs with an average weight ranging from 30 to 50g under village conditions (Guèye, 1998). With improved feeding and husbandry, egg production rate of 100 eggs per hen was achieved in Cameroon (Ngou Ngoupayou, 1990), while a rate of over 150 eggs per hen was achieved in Tanzania (Kabatange and Katule, 1989). However, Adetayo and Babafunso (2001) reported that the Nigerian indigenous chickens kept in cages and fed commercial feed produced 80 to 90 eggs per hen in a period of 280 days with a mean egg weight of 36.8g. In Ethiopia, the indigenous chickens produce between 40 eggs under extensive conditions and 99 eggs per year with an average egg weight of 40 g under more intensive systems (Yami, 1995). Exotic breeds characterized by high productivity and hardiness such as Rhode Island Red, New Hampshire and Plymouth Rock are generally used to genetically improve the village chickens (Anonymous, 1987). Guèye and Bessi (1997) stated that the frequency of egg collection plays an important role in determining egg production; as this collection of eggs postpones broodiness and thus leads to higher egg production.

2.9 Factors affecting egg production

Egg production is affected by physiological factors, environmental factors, mortality, housing as well as nutrition (Viljoen, 1979).

2.9.1. Physiological factors

All female poultry have physiologically a juvenile period before the onset of egg production (Rose, 1997). Generally, it is believed that weight and age of the hen contribute to the hen's sexual maturity. Robinson and Renema (2008) reported that the hen only has one functional ovary and oviduct which is under-developed and stays in this state during the juvenile period until it reaches sexual maturity. In some of the breeds, the hen reaches sexual maturity earlier when fed *ad libitum* and thus reaching a target weight at an earlier age. According to North and Bell (1990), by the time the hen reaches sexual maturity the ovary and oviduct had undergone drastic changes, whereby 11 days before the hen starts to lay her first egg, a sequence of hormonal activities takes place. In contrast, other breeds will not reach sexual maturity before they reach the correct age even if they are enhanced by feeding them *ad libitum* to reach their target body weight earlier (Grobbelaar, 2009).

Hens typically begin producing eggs in their twentieth or twenty-first weeks of age and continue production for slightly over a year. Eggs tend to increase in size until the end of the egg production cycle (FAO, 2003). Furthermore, the annual average egg weight is correlated to the age at which the pullet lays her first eggs (North and Bell, 1990). The age at start of laying may be manipulated by lighting programs; increasing or decreasing the feed intake, and also the management program. According to Jacob *et al*. (1998), chickens can live for many years and continue to lay eggs for many of these years. However, after two or three years many hens significantly decline in productivity. Good layers will lay for 50 to 60 weeks and have a rest period called molt.

In general, optimum body weight during the laying period should be around 1.5 kg, although this varies according to breed. Underweight as well as overweight birds lay eggs at a lower rate. Therefore, proper management and nutrition are necessary to achieve optimum body weight (Dandapat, 2009).

2.9.2 Environmental factors

2.9.2.1 Temperature

Arad *et al*. (1981) stated that the response to environmental temperature varies considerably in different genetic strains and the adaptation process also varies accordingly. The report by Dandapat (2009) indicated that the optimum temperature for laying hens is between 11 and 26°C whilst relative humidity above 75 % reduces egg laying. An increase in temperature above 28°C results in decreased production and quality of eggs. Kekeocha (1985) indicates that feed intake of hens reduces when temperature rises above 26-28°C. The rise in temperature of 28-32°C suppresses feed intake of the hen, thus resulting in a decreased availability of calcium and phosphorous for shell deposition and formation leading to thin shelled eggs (Gerber, 2006).

Moreover, Koelkebeck (1999) indicated that laying hens will try to overcome heat stress by panting during high temperatures. However, this causes a decrease in the amount of carbon dioxide (CO_2) in the hen's blood, a condition known as respiratory alkalosis (Koelkebeck, 1999). As egg shells are made up of 95% of calcium carbonate ($CaCO_3$), this decrease in blood calcium levels, combined with the increase in blood pH and a subsequent decrease in Ca_{2+} ions for shell formation leads to an increase in the number of thin or soft shelled eggs. Environmental temperature and its effects on egg production, mentioned by Kekeocha (1985) are shown in Table 2.3 below.

Table 2.3. Temperature and its effects on egg production (Kekeocha, 1985)

Temperature	**Effects**
11-26	Good production
26-28	Some reduction in feed intake
28-32	Feed consumption reduced and water intake increased; eggs of reduced size and thin shell
32-35	Slight panting
35-40	Heat prostration sets in; measures to cool the house must be taken
40 and above	Mortality due to heat stress

2.9.2.2 Laying house

Laying hens are able to adjust to a wide range of environmental conditions but they perform well at any temperature up to 30°C in a dry, well-ventilated house free from ammonia, dust and air-borne pathogens. The laying house should be built according to local climatic conditions and the farmer's finances. A good house protects laying birds from theft, predation, direct sunlight, rain, excessive wind, heat and cold, as well as sudden changes in temperature and excessive dust. For example, if the climate is hot and humid, the use of an open house construction will enable ventilation (Dandapat, 2009).

2.9.2.3 Lighting

Before the process of the ovulatory cycle commences, the retinal cells of a hen's eye absorb a light stimulus from the environment. Fitzsimmons (1971) suggested that by maintaining the ovulatory cycle, ovulation would occur because of two Luteinizing-hormone (LH) peaks following each other. The first LH peak would be the result of the onset of a light stimulus and a second LH peak occurred 18h after the preceding ovulation and would be stimulated by the ruptured follicle. According to Rose (1997), birds use day lengths and changes in day length as the primary factors for synchronizing their seasonal breeding patterns.

2.9.4 Mortality during egg production

Excessive mortality during the laying period is an expensive management failure (North and Bell, 1990). Some strains of bird have a low incidence of mortality. The general average mortality rate of 20 to 25 percent per year was reported (FAO, 2003). In contrast, North and Bell (1990) reported that some studies of large cage laying farms in southern California reported that monthly average death losses have been from 0.5 % to 2%. However, individual flocks have had mortality as low as 0.3 % per month.

2.9.5 Nutrition

It is very important to provide laying hens with a constant supply of nutritionally balanced layer feed to sustain their maximum egg production over time. Inadequate nutrition can cause hens to stop laying eggs because of inadequate levels of energy, protein and calcium, which can also cause oviduct prolapse (Jacob *et al*., 1998).

2.10 Egg production performance in South Africa

Between 2001 and 2011 egg production increased by 37.6% or 5 296 900 cases of 30 dozen eggs per case. The average compounded growth in egg production over the ten year period was 3.37% per annum. Most of the expansion in the egg industry occurred after 2004 when egg production increased by 28.6% over the period of three years to 2007. The excessive growth over this short period was activated by a persistent increase in demand for eggs and good profit margins. After 2007 the economic downswing resulted in a decreased demand for eggs and severe pressure was put on egg prices. As a result egg production was decreased in 2008 and 2009 and egg prices subsequently increased by up to 20%, year to year, leading to high profit margins. In response egg production was increased in 2010 and 2011 which resulted in an oversupply of eggs and severe pressure on egg price (SAPA, 2011). Despite a relatively weak position in the livestock market, preference for poultry is growing in South Africa. In 2000 the national demand for poultry products exceeded the domestic production by an estimated 22%. It was expected to increase to 92 per cent by 2010 and by 192 % by 2020 (National Department of Agriculture, 2002).

2.11 Importance of eggs in human diet

The value of eating eggs has long been recognized. An egg is one of the most complete and versatile foods available. It is an inexpensive but nutritious component within the human diet. It is one of the few most consumed foods, which is healthy and safe for human beings. It's also a nutrient-rich food, being a natural source of at least 13 variable vitamins and minerals (Table 2.4), in addition to high quality protein and essential fatty acids (Anon, 1989). Among the most complete, yet the least expensive protein foods, an egg can be consumed by every sector of the population. This is due to its nutritional value, low caloric content, blandness and high digestibility (Lomanika and Mínoková, 2006). A typical egg would contribute 3-4% of an adult's average energy requirement per day and it contains approximately 6.5 g of protein (Sparks, 2006). About 12% of an egg is a shell, which is not eaten. The remainder is a mix of protein, energy, minerals and vitamins, which form part of a good mixed nutritious diet. Some producers have marketed specialty eggs which are fat modified with high omega-3 fatty acids by feeding hens on a specially selected diet (PoultryHub, 2009).

Eggs are also a good source of lutein, and zeaxanthin which has been linked with the reduced risk of age-related eye disease such as muscular degeneration (Hasler, 2000). A study in the United States indicated that egg consumers have higher intakes of vitamins A, E, B_{12} and folate compared to non-egg consumers (Song and Kerver, 2000). Consequently, the egg is considered to make a significant contribution to increase a population's daily nutrient intakes.

Apart from recent suspicions of it promoting high cholesterol levels in consumers (Applegate, 2000), nutritionists now agree that moderate egg consumption has little or no negative effects on cholesterol levels (Davis and Reeves, 2002). The nutritional value of eggs helps in building good immunity, strong vision, and treatment of muscular degeneration, cataract treatment, skin care, nervous system, strong bones, and for blood formation (Evans, 2007). The overview of South African egg industry for 2007 revealed an 11.2% increase in production with about 546 million dozen eggs sold through various channels (Maree, 2008). The report indicated that per capita consumption for 2010 was 132 eggs/ person/ annum representing an increase of 2% in comparison with 2009 of 130 egg/annum. The nutritive value of eggs is outlined below in Table 2.4.

Table 2.4. Nutritive value of egg/100g (Srilakshmi, 2003)

Nutrient	**Amount**
Energy (KJ)	724
Protein (g)	13.3
Fat (g)	13.3
Calcium (mg)	60.0
Phosphorus (mg)	220.0
Iron (mg)	2.1
Carotene (µg)	600
Thiamine (mg)	0.1
Riboflavin (mg)	0.4

Niacin (mg)	0.1
Folic acid (µg)	78.3
Vitamin B_{12} (µg)	0.2

2.12 The formation of an egg

The major contents of an egg are the yolk, albumen, membrane and the egg shell (Figure 2.1). The yolk develops in the functional left ovary of the hen as an ovum largely during the final 10 days before release. After ovulation or release, fully developed ovum or yolk is engulfed in the oviduct where a gel of albumin or egg white is secreted to surround the yolk for a few hours. Finally, the shell membranes and the calcareous shell are deposited in the oviduct for nearly 16 hours before the egg is laid.

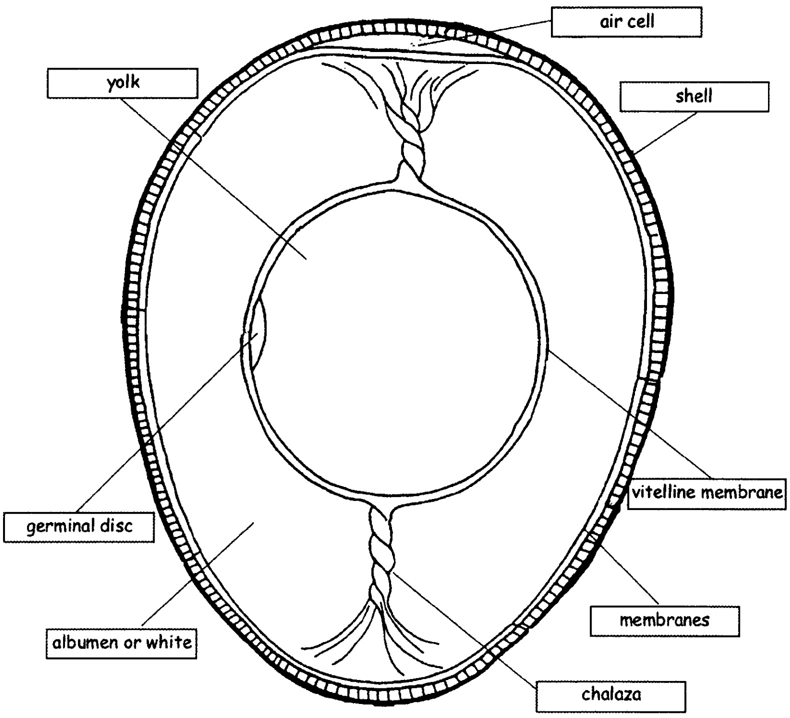

Figure 2.1 Diagram of an egg (Neospark, 2011)

2.13. The components of egg

The albumen or the white form 60% of the total egg weight. It has 12% dry matter content, 10.2% protein, 1.0% carbohydrate and 0.68% ash (Froning, 1998; Watkins, 1995). It consists of thick and thin material, which in the fresh egg alternately surrounds the yolk sphere in three concentric layers; the thin layer, the thick fibrous layer and the outer thin layer (Matthew, 1986).

Thick albumen is a gel and thin albumen is a fluid (Brooks and Hale, 1959). The thick albumen forms a capsule around the yolk that is impenetrable in fresh eggs (Robinson and Monsey, 1972). The albumen as an egg component has little carbohydrate content with negligible amounts of lipids when compared with the yolk (Powrie and Nakai, 1985). Most proteins and enzymes of the egg white possess important physiochemical and biological properties that have attracted high research interest. These include ovalbumin which constitutes 54% of the egg white's total protein (Zabik, 1992), ovomucin (α- and β-) which represent 1.5 to 3.5% of egg white solids and the antibacterial lysozyme (Davis and Reeves, 2002). Ovalbumin contributes to foam formation properties in food systems (Alleoni and Antunes, 2004) while ovomucin is responsible for the viscosity and gel-like structure of the albumen. Other albumen proteins are ovotransferrin, ovomucoid and ovoglobulins (Alleoni, 2006). The level of concentration of these proteins particularly ovomucin makes the difference between the thick and thin albumen (Okubo *et al.*, 1997). The characteristics of egg white and proteins are shown Table 2.6.

The yolk forms 30-33% of the total egg weight. It is composed of vitelline membrane. The total dry matter content of yolk is about 50-52%. The shell forms 9-12% of the total egg weight and largely consists of calcium carbonate, 94%, 1% magnesium carbonate, 1% calcium phosphate and 4% organic matters (Ahn, 2011). The composition of egg is outlined in the Table 2.5.

Table 2.5. Composition of chicken egg (Stadelman, 1995)

Main part	Layer	% of weight of egg
Yolk	Germinal disk (Blastoderm) Latebra Light yolk layer Dark yolk layer Vitelline membrane	30-33
Albumen	Outer thin membrane Outer thick membrane Inner thin membrane Inner thick membrane Chalaza	60
Membrane	Outer shell membrane Inner shell membrane Air cell	0-1
Shell	Cuticle Spongy (calcareous) layer Mammillary layer	9-12

Table 2.6. Egg white proteins and characteristics (Li-Chan *et al*., 1995)

Protein	% of albumen proteins	Characteristics
Ovalbumin	54	Phosphoglycoprotein
Ovatranferrin (Conalbumin)	12	Binds metallic ions
Ovomucoid	11	Inhibits trypsin
Ovomucin	3.5	Sialoproteins, viscous
Lysozyme	3.4	Lyzes proteins
Globulins	8.0	_
Ovoinhibitor	1.5	Inhibits serine proteases
Ovoglycoprotein	1.0	Sialoprotein
Ovoflavoprotein	0.8	Binds riboflavin
Ovomacroglobulin	0.5	Strongly antigenic
Cystatin	0.05	Inhibits thiol ptoteases
Avidin	0.05	Binds biotin

2.14 Egg quality

Egg quality has been defined by Stadelman (1977) as the characteristics of an egg that affect its acceptability by the consumers. Similarly, Kramer (1951), cited by Koelkebeck (1999), defined quality as "the sum of characteristics of a given food item which influence the acceptability or preference for that food by the consumer". Based on the above definitions, it is clear that the egg quality will mean different things to different people and the consumer's perception of quality is likely to vary depending on their intended use of the egg and their own preferences. Egg proteins contain all essential amino acids and therefore egg protein is used as standard for measuring the nutritional quality of other food products (FAO, 2003).

For the egg industry worldwide, the production of eggs with good shell quality and good internal quality is critical to the economic viability of the industry (Roberts, 2004). Zita *et al.* (2009) also emphasized that monitoring of egg quality is important mainly in terms of the production economy. In general, much attention is devoted to eggshell quality, because cracked eggshells present higher losses for egg producers. Approximately 7-8% of the total amount of eggs are generally damaged during the transfer of eggs from producers to consumers (Alkan *et al.* 2008).

As a result, the amount of cracked and broken eggs results in a serious economic problem for both the producers and the dealers (Hamilton, 1982). Moreover, some of the egg quality traits have significant and direct effects on the prices, especially in commercial flocks (Alkan *et al.*, 2008).

It is generally agreed that egg quality is the main contributing factor in terms of price on hatching and table eggs (Khurshid *et al.*, 2004). The following traits are normally considered when describing the quality of table/hatching eggs: egg weight, egg length, egg width, shell weight, shell thickness, shell ratio, shape index, egg surface area, unit surface shell weight, yolk weight, yolk diameter, yolk height, yolk index, yolk ratio, Haugh unit, albumen weight, albumen height and other management conditions and health status of the birds.

Tumova *et al.* (2009) classified quality characteristics of eggs as follows:

External quality characteristics

- egg weight;
- egg length;
- egg width;
- egg shell;
- cleanliness;
- egg shape;
- shell texture.

Internal quality characteristics of an egg:

- air cell size;
- albumen;
- yolk quality;
- presence of blood;
- presence of meat spots.

According to Tumova *et al.* (2009) it is not only genetics that play a major role in egg quality but also housing systems and time of oviposition. There is a natural variability in each main component of the egg (shell, albumen and yolk), which is not in line with the modern consumer's requirements (De Katelaere *et al.*, 2004). Nowadays the concern about egg quality is growing steadily (Kemps *et al.*, 2006). The appearance of an egg is important for the consumer's appeal. For table eggs, the shell must be strong enough to prevent breakage during packing and transportation (Narushin *et al.*, 2004). For hatching eggs, shells must be initially thick and strong to preserve the embryo and must become thin and weak later during incubation for allowing gaseous exchange and easy hatching (Narushin and Romanov, 2002). Eggs are fragile commodities and the quality begins to decline as soon as the egg is laid. Therefore, it is very important to evaluate the egg quality characteristics and factors affecting them. Deterioration in egg quality represents a major challenge that the egg industry must conquer considering the time gap between laying and final consumption, hence the necessity for proper storage management. This is however challenging and not practical in some areas of the world due to economic or energy constraints (Miles and Henry, 2004) resulting in faster deterioration.

2.15 External egg quality and defining parameters

The eggshell is the natural packing material for egg contents and it is important to obtain high shell strength, to resist all the impacts an egg is subjected to during the production chain (Bain, 1990). Mertens *et al.* (2006) emphasized that cracked eggs cause economic loss in three ways: they cannot be sold as first-quality eggs; the occurrence of hair cracks raises the risk for bacterial contamination of the broken egg; leaking eggs cause problems with internal and external quality as well as food safety. The majority of eggs are sold in their shell and a consumer's first impression of an egg is influenced by their perception of shell quality.

In addition, the external quality is evaluated on the basis of cleanliness, shape, texture and egg shell quality. Cleanliness of an egg depends on the laying habit of the chicken (Appleby, 1991). Even with the provision of nest boxes, some hens prefer laying their eggs on the floor and these floor eggs contribute substantially to the existing problem of soiled and dirty eggs, which is one of the major disadvantages of non-caged systems.

2.15.1 Egg shell strength

Shell breaking strength is the actual force required to fracture the shell (Hunton, 2005). Carter (1970) stated that the eggshell will crack if the strength of the shell is less than the strength of the environmental impact to which it is exposed. Shell breaking strength is most commonly measured by quastic-static compression where the egg is compressed under controlled conditions until the shell cracks or breaks and the minimum force required to cause failure or crack of the shell is then recorded (Tyler, 1961). Gerber (2006) emphasized that egg shell strength ultimately affects the soundness of the shell with weaker shelled eggs more prone to cracks and breakage and subsequent microbial contamination. Numerous studies have estimated that the losses due to poor shell quality lead to great economic loss. For example, between 5% and 7% of eggs produced are not able to reach the end user of which between 2% and 3% of the damage is due to the inherent problem while laying and the remaining during the process after laying (Neospark, 2011). A wide range of factors have been reported by researchers to affect the shell strength including age, strain, egg size, stress, temperature, nutrition and water quality.

2.15.1.1 The bird's age and strain

Several studies have shown that egg shell quality decreases as birds grow older (Roland *et al.*, 1976; Nys, 1986). Very young birds with immature shell glands may produce shell-less eggs or eggs with very thin shells. Delaying the onset of sexual maturity by one to two weeks will prevent the laying of shell-less eggs (Coutts and Wilson, 1990). Butcher and Miles (2003) indicated that older birds tend to lay bigger eggs and have a higher egg output, which impacts on the shell strength.

The different strains of laying hens vary significantly in egg shell quality, egg size and production as a result of genetic selection (De Ketelaere *et al.*, 2002). Selection for one characteristic such as production or egg weight can affect other characteristics of the hen such as egg shell quality (Curtis *et al.*, 1995). However, Ahmadi and Rahimi (2011) indicated that genetic selection programs need to monitor a range of characteristics to ensure that improvement of one characteristic is not at the expense of other equally important traits.

2.15.1.2 Egg size

Butcher and Miles (2003) reported that small size eggs have stronger shells than large size ones because hens have a predetermined capacity to deposit calcium in the shell, which results in the same amount of calcium being spread over a large area, in the case of large eggs. Although egg size increases with increasing hen age, that is not accompanied by a proportional increase in shell weight. The ratio of shell weight to egg weight (called percentage shell), decreases as egg size increases (Ahmadi and Rahimi, 2011). However, a decrease in egg size as a result of dietary manipulations may improve egg shell quality in older hens (Elaroussi *et al.*, 1994).

2.15.1.3 Stress

The stress caused by relocation or lack of access to the nest boxes, can cause an increase in the incident of calcium "dusted", white-banded, slab sided and misshapen eggs (Dorminey *et al.*, 1965; Suksupath *et al.*, 1989). Handling birds which are not used to handling can increase the incidence of cracked eggs. A single stress event or disturbance to a flock of laying hens can be enough to de-synchronise the process of egg formation for several days resulting in the following egg quality faults:

- Occurence of oviposition prior to completion of shell deposition results in soft or thin-shelled egg. Therefore, activities which create disturbances in and around the layer shed should be minimized (Coutts and Wilson, 1990).
- Egg retainment in the shell gland, which may cause any subsequent egg laid to spend less time than normal in the shell gland results in insufficient shell deposition and a soft-shell-less egg (Gerber, 2006).
- Stresses that induce delays in the timing of oviposition when hens retain their eggs can result in a high incidence of white-banded and slab-sided eggs (Reynard and Savory, 1999).

2.15.1.4 Temperature

Environmental or shed temperatures of above 25°C may affect the feed and calcium intake of the bird, thus resulting in a decreased availability of calcium for shell deposition (Gerber, 2006). Furthermore, Koelkebeck (1999) emphasized that laying hens will try to overcome heat stress by panting. However, this causes a decrease in the amount of carbon dioxide (CO_2) in the hen's blood, a condition known as alkalosis. Egg shells are made up of 95% of calcium carbonate ($CaCO_3$) (Gerber, 2006). A decrease in blood CO_2 levels increases blood pH and decreases Ca^2+ ions for shell formation leading to an increase in the number of thin or soft shelled eggs produced. A major problem affecting the thickness of the egg shell is related to the internal blood acid status of the bird.

2.15.1.5 Diseases

A number of trematode and *Prosthogonimus* spp can cause an inflammation of the oviduct resulting in the formation of eggs with soft shells or those that lack a shell. Any disease that compromises the health of the bird may indirectly affect egg shell and quality. For example, any pathogenic agent that grows in the tissues of the reproductive tract of the hen can cause problems with the egg shell formation (Ahmadi and Rahimi, 2011). Most of the common avian diseases such as egg drop syndrome (EDS), avian influenza (AI), Newcastle disease (ND) and infectious bronchitis (IB) may produce severe effects on eggshell and internal quality (Butcher and Miles, 2003). The stress caused by a disease challenge can reduce water and feed intake of the affected birds, thus resulting in calcium deficiency which will cause shell problems (Beckman, 1999).

2.15.1.6 Nutrition and water quality

The provision of adequate dietary minerals and vitamins is essential for good eggshell quality (Gerber, 2006). Calcium and phosphorous are essential macro-minerals with calcium forming a significant component of the shell. Phosphorous plays an important role in skeletal calcium deposition and subsequent availability of calcium for egg shell formation (Boorman *et al*., 1989). Feeding of calcium levels above the requirements of the hens for production has not been shown to improve shell quality (Kershavarz and Nakajima, 1993) but has been reported to interfere with the availability of other minerals (NRC, 1994). Gerber (2006) stated that too high levels of calcium can have a negative impact on the ability of a hen to utilize calcium.

Coetzee (2002) investigated the effect of calcium supplementation in drinking water on shell integrity in South African laying hens. Her results demonstrated mean shell strength of 42.6N ± 9.0SD in hens supplemented with an additional 200 mg of calcium per liter of drinking water while the control unsupplemented hens produced eggs with mean shell strength of 38.9N ± 7.0SD.

Water quality may influence egg shell quality. Water containing high levels of electrolytes such as saline drinking water may have long term negative effects on egg shell quality (Bollengierlee *et al*., 1998). The temperature of the water allocated to laying hens is very important especially during hot weather conditions. Hens reduce water intake or may even cease to drink if the water given to them gets too hot (Ahmadi and Rahimi, 2011).

2.15.2 Internal egg quality and defining parameters

Gerber (2006) indicated that unlike external or shell quality, internal quality of the egg decreases as soon as the egg is laid. Although factors associated with the management and nutrition of the hen do play a role in the egg quality, egg handling and storage practices have a significant impact on the quality of the egg reaching the consumer. The internal quality of an egg is determined by the albumen, blood and meat spots.

2.15.2.1 Albumen quality

According to Gerber (2006), albumen quality is related to its consistency, appearance and the functional properties. Albumen quality has a major influence on the overall interior egg quality and thinning or decrease in albumen height which can point to a quality loss. The albumen of an egg is made up of jelly-like thick albumen and watery thin albumen which differ in their consistency (Egg Producers Federation of New Zealand, 2010). Albumen quality is measured in terms of Haugh units (HU) calculated from the height of the albumen and the weight of the egg (Coutts and Wilson, 2006). A minimum measurement in HU for eggs reaching the consumer is 60 HU. Most eggs leaving the farm should be between 75-85 HU (Zaman *et al*, 2005). An egg with a good albumen quality should be free from internal blemishes such as meat and blood spots.

The decrease in internal egg quality after the egg is laid, results from the loss of water and CO_2 which will change the egg pH. The change in egg pH will result in the loss of the thick albumen protein structure, and then the watery albumen will be observed (MAFF, undated). The fresh egg has a cloudy appearance of the albumen due to the presence of CO_2, which diminishes as the egg ages causing the albumen to become transparent. Albumen quality is a quantitative genetic trait (Monira *et al.,* 2003).

As the age of the hen increases; egg, albumen and yolk weights increase while its albumen heights decrease, and there is little or no effect on shell weight (Hill and Hall, 1980; Silversides and Scott, 2001; Silversides *et al*., 2007). Furthermore, Samli *et al.* (2005) and Jones and Musgrove (2005) reported a decrease in egg weight, albumen height, Haugh unit and viteline membrane elasticity during storage. The decrease in elasticity or weakness of the viteline membrane is caused by absorption of water from the albumen by the yolk (Coutts and Wilson, 1990) which in turn facilitates movement of micro-organisms into the yolk (Hughes and Conner, 1998). The quick cooling of shelled eggs at 0°C immediately after collection has been identified as an effective way of maintaining albumen quality (Williams, 1992). According to Cunningham (2004), eggs can be held for a month or more without significant loss in quality when they are properly refrigerated. Longer storage of eggs result in egg weight loss, albumen pH (resulting in watery and thin albumen), increased air cell volume, integrity loss and increased yolk size (Table 2.7).

Table 2.7 Summary of changes occurring as hen egg ages (Coutts and Wilson, 2006)

Egg Component	Changes
Whole egg	Weight loss; stale odour; decreased specific gravity
Whole albumen	Water loss; weight loss; increased pH; decrease in coagulating protein
Air cell	Increase in volume

Thick albumen	Thinning; loss of water to yolk
Vitelline membrane	Loss of integrity/breaking strength
Yolk	Increase then decrease in water; increase then decrease in volume; increase in pH; increase in ammonia level; decrease in coagulating protein; increase in free fatty acids; increase in thiobarbituric acid reacting substances (TBARS) due to lipid oxidation
Egg shell	Occasional mottling

2.15.2.2 Effect of storage time and temperature

Egg storage time and conditions are the critical factors affecting albumen quality. Immediately after an egg is laid, the carbon dioxide evaporates through the shell causing an increase of albumen pH. High temperatures cause a rapid decrease in egg quality. An increase in albumen pH can be a reason for the change in viscosity of the albumen. The albumen height decreases with storage time while its pH increases (Li-Chan and Nakai, 1989). This scenario results in a decrease in the HU. Scott and Silversides (2000) reported that storage time decreased the albumen and egg weights, but had no effect on the eggshell weight. Schäfer *et al.* (1999) reported that with time, the isoelectric point of ovalbumin becomes slightly acidic and this change is in accordance with the formation of S-ovalbumin. They concluded that these changes are related to temperature rather than storage time.

2.15.2.3 The effect of hen strain and age

The study by Gerber (2006) indicated that the strain of hens also plays a role in albumen consistency. Some strains produce eggs with a thin albumen consistency. High producing birds tend to lay eggs with relatively thinner albumen. Although egg numbers are usually considered more important, this albumen problem can be improved by selective breeding. Silversides and Scott (2001) reported that the strain of bird affects the quality of egg. In their study, they found that the eggs from ISA-Brown hens were large, with thicker shell and high albumen but less yolk than those from the ISA-White hens. In addition, the shell and albumen decreases with increasing age of a hen. Coutts and Wilson (1990) also reported a decrease in HU by around 1.5 to 2 units each month of lay. Kröckel *et al.* (2005) found that the age of the hen has an effect on bacterial stability of the eggs.

2.15.2.4. The effect of nutrition

Layer diets affecting albumen quality showed that the quality of the albumen increases with the increasing dietary protein and amino acids (Balnave *et al.*, 2000). Meanwhile, Williams (1992) also found that albumen quality increases with increased dietary lysine concentration while

Franchini *et al*. (2002) found that supplementation of ascorbic acid to the diet can increase albumen quality.

2.15.2.5 The effect of diseases

Newcastle disease and infectious bronchitis causes watery albumen, and this condition may persist for a long period after the disease outbreak has been controlled (Butcher and Miles, 2003). Infectious bronchitis is the main disease that affects albumen quality (Spackman, 1987) because it impairs the synthesis of albumen proteins in the magnum of the oviduct (Butler *et al*., 1972).

2.16. Characteristics of layer breeds common to South Africa

Egg production in South Africa can be divided into three distinct systems: commercial egg production, semi-intensive egg production and household egg production (South African Poultry Association, 2006). Commercial layers are genetically prepared to have high egg productivity but because of their small bodies, they are poor meat producers. The semi-intensive breeds are the dual purpose breeds producing eggs as well as meat. In this category, there are some breeds that are better egg producers and those that are better meat producers. The indigenous breeds produce fewer eggs and survive hardy conditions but their production performance can be improved when there is proper management and feeding.

2.16.1 Description of South African breeds used in the trial

2.16.1.1 Commercial breeds

Amberlink, Hyline and Lohmann are the most commonly used commercial strains in South Africa. Hyline and Lohman were used in this study. Commercial layers offer two business opportunities, namely the pullet rearing that sells point-of-lay pullets at the age of 18 weeks, and production of table eggs (Johnson, 2007). Commercial layers produce up to 300 eggs (about six eggs per week) during a laying period from 18 to 70 weeks of age. At the end of the production cycle, a commercial layer can also be force-molted to renew the production cycle by temporarily removing feed, water and light for a certain period (Johnson, 2007). Genetics and other favourable conditions such as light (ten to sixteen hours of light a day), temperature, humidity, and feed and water routines can be manipulated to stimulate laying (Mosisi, 2009).

Figure 2.2 Hyline Brown

Hyline Brown is a prolific egg producer and hardy layer, rated as the world's most balanced brown producer. She produces over 320 rich brown eggs up to 74 weeks of age and begins laying eggs at an early age with optimum egg size of 59.3-60g/egg. This variety has long been recognized as the most efficient bird available. It produces eggs of high quality, has a better egg weight profile and retains its feathers. Hyline Brown has a better temperament and most significantly consumes less feed (Hyline Brown Variety, 2009).

Figure 2.3 Hyline Silver

Hyline Silver is a prolific egg producer that lays medium size eggs with an average egg weight of 58.5g. It produces over 330 brown eggs up to 74 weeks of age and begins laying eggs at early age. Hyline-Silver suitable for both alternative production systems and intensive production systems (Hyline-Silver Management Guide, 2009).

Figure 2.4 Lohman Brown

The Lohman Brown displays a productive laying performance of attractive brown eggs. It produces over 320 eggs per year, with average egg weight of 63.5-64.4g. It is also suitable for alternative management systems (Lohman, 2009).

Figure 2.5 Lohman Silver

Lohmann-Silver hens are predominately white feathering layers for the production of uniform brown eggs with lower egg weight compared to Lohman Brown. Lohman-Silver layers lay between 295 and 305 uniform brown eggs per year with average egg weight of 61.6 - 62.5 g. They are predominantly covered with excellent feathering (Lohman, 2009).

2.16.1.2 Dual purpose breeds

The most common layer breeds in this group are New Hampshire, Black Australorp and Red Island Rhode. New Hampshire and Black Australorp hens were used in this study. In this group, there are breeds that are better egg producers and those that are better meat producers.

Figure 2.6 New Hampshire

The New Hampshire is a dual purpose chicken breed that originated in the United States of America and is classified as a heavy breeder, with the cockerel weighing up to 3.9kg, and the hen 3kg. This breed represents a specialized selection out of the Rhode Island Red breed and was selected for its good carcass qualities, rapid growth, fast feathering and early maturing traits. The hen possesses a fair egg laying ability. The New Hampshire has a single and medium to large comb size and those of the females often lop over (ARC, 2006). The ability of the breed to produce a large number of eggs that hatch well has made it a valuable asset to many breeding combinations (North, 1984).

Figure 2.7 Black Australorp

Black Australorp chickens were developed during the 1900's in Australia as a result of improving UK's Orpingtons. They were known as Black Utility Orpingtons. The original colour of the Australorp chickens was glossy black. However, other colour types of chickens have been developed such as blue and splash. Australorps are hardy and are exceptional egg layers with an average of 250 pale brown eggs per year. They also are a good meat bird with reasonably early maturity and white skin. However, their actual egg laying performance will vary from strain to strain. Australorps are divided into two types; large and bantam Australorp. The body weight of large Australorp roosters is between 3.9 and 4.7 kg while hens weigh between 3.7-4.5 kg. The rooster of a bantam has a body weight between 1.8 and 2.3 kg, while hens weigh between 1.7 and 2.2 kg (Small-farm-permiculture-and-sustainability-living.com., 2012).

2.16.1.3 Indigenous breeds

Indigenous chickens are more resistant to disease and are also called local, *ranging*, *traditional* and *family* chickens in literature and other names such as *Zulu* and *Venda* chickens in colloquial language (Wethli, 2003). They scavenge feed that may include grains or cereals, insects, small reptiles, seeds, berries and green herbs (Nhleko *et al.*, 2003). However, local knowledge regarding indigenous chickens is neglected because researchers devote their work to exotic breeds, considering indigenous stock to be unproductive (Naido, 2003). The most known South African indigenous breeds are Potchefstroom Koekoek, Ovambo, Venda and Nacked-Neck. The Potchefstroom Koekoek and Ovambo were used in this study.

Figure 2.8 Ovambo

The Ovambo chickens are the typical local breed found in the northern part of Namibia and Ovamboland. The Ovambo is dark in colour and small in size. They have a variety of colour patterns which helps them to camouflaging for protection from their predators. Their light weight allows them to fly and roost in the top of trees to avoid predators. The Ovambo is very aggressive and agile and can catch and eat mice and young rats. These chickens are characterized as layers and survive under harsh conditions and their broodiness ensures their propagation and survival. According to Ramsey *et al.* (2001) the average body weight of Ovambo hens at 16 weeks is 1.32 kg whereas at 20 weeks the average body weight is 1.54kg. These hens reach their sexual maturity at 143 days of age and their average egg weight is 52.5g.

Figure 2.10 Potchefstroom Koekoek

The Potchefstroom Koekoek was bred at the former Potchefstroom Agricultural Research Institute during the late forties from crosses between the Black Australorp males and the White Leghorn females and is recognized as a locally developed breed (Van Marle-Koster and Nel, 2000). The name "Koekoek" describes a barred colour pattern rather than a breed. The Koekoek colouring is recognised as a variety and is present in as many as nine different breeds. The Koekoek is a hardy dual-purpose breed. It lays brown eggs and, at slaughter, has very attractive deep yellow meat. The Koekoek colouring is sex-linked which makes it very useful in breeding programmes. If a black or red cock is crossed with a Koekoek hen, the offspring can be sexed at a day old as the females are completely black whilst the males have a white spot on the head. Ramsey *et al.* (2001) indicated that the average body weight of Potchefstroom Koekoek hens at 16 weeks of age is 1.4 kg, whereas at 20 weeks of age the average body weight is 1.7 kg. These hens reach sexual maturity within 130 days of age and their average egg weight is 55.7g.

2.17. Conclusion of literature review

In integrated fish-layer farming systems, direct deposit of fresh chicken manure to fish ponds can produce enough natural fish feed organisms, thus maximising profit and reduces production and feed cost. Higher production of animal protein can be achieved from the same area of minimum land with this system. Integrated layer-fish farming systems also provide employment opportunities. Poultry manure is a complete fertiliser. The most valuable poultry production systems for fish production are those systems which produce nutrient-rich and collectable waste. Layers produce more calcium and phosphorus-rich excreta than broilers. The direct use of egg-laying where the birds are of constant weight and produce fairly constant levels of waste, are easier to manage than broilers in which waste availability is cyclical.

For the purpose of this study, it is important to analyse different aspects of layer hens. An in-depth literature review was conducted to determine both genetic as well as environmental basis for production performance and egg quality. Although commercial layer hens are genetically superior in terms of production, indigenous chickens are hardy and thus demand less management interventions. Literature about the production performance of indigenous chickens is still limited and could be complemented by findings of this study. The study envisages that superior performance in an integrated system with aquaculture could be used as a criterion to choose a suitable breed for this purpose.

CHAPTER 3

Materials and methods

3.1 Experimental Site and Housing

The study was conducted at the Animal Production Institute of the Agricultural Research Council (ARC) Irene, in Gauteng Province of South Africa. Chickens were housed in two facilities equipped with cages. The control house (Fig 3.1) had open sides at the top and the bottom for ventilation. The experimental house (Fig 3.2 a-d) was built on top of a concrete dam filled with water and had open sides on top and an open thick mash floor underneath allowing chicken manure to fall directly into the dam.

Figure 3.1 Control house

a.

b.

c. d.

Figure 3.2 a. Chicken house constructed over fish dam
b. Front view
c. Dam underneath the chicken house
d. Inside view

3.2 Experimental Animals

A total of 320 pullets of 8 different layer breeds were used. The two lines of indigenous breeds (i.e. Potchefstroom Koekoek and Ovambo) were purchased from ARC-Irene (Poultry Breeding Section; Fowls for Africa). The commercial breeds used were two lines of Hyline (i.e Hyline-Silver and Hyline-Brown) purchased from Almur Smith and Magalies Eggs, respectively. The dual purpose breeds were New Hampshire and Black Australorp purchased from ARC-Irene, Poultry Breeding Section. Unfortunately, it was not possible to get all the hens from the different breeds at point of lay. Therefore, data were only collected from after peak starting at 48 weeks of age for a total period of five months. Upon arrival at the research site, the chickens were examined and any obviously sick or dehydrated birds were culled. Chickens were then individually placed in wire cages, measuring about 25 cm (breadth) x 38 cm (length) x 40 cm (height) which was part of a two-tiered unit consisting of 32 cages. A lighting program of 16 hours was used. Chickens were provided with 150g/day of a standard layer mash (Table 3.1) (Alzu® Feeds) and water was given *ad libitum* throughout the entire trial. The chickens were adapted to the experimental conditions for at least a month before commencement of the experiment.

Table 3.1 Chemical composition of the experimental diet as stated on the label (Alzu, 2009)

Nutrient	**g/kg**
Protein (min)	160.0
Lysine (min)	7.5
Fibre (max)	70.0
Moisture (max)	120.0
Phosphorous (min)	5.2
Calcium (max)	42.0
Calcium (min)	35.0
Chemical composition of analysed feed	
Crude Protein g/kg	161.7
Calcium g/kg	43.3
Total Phosphorus g/kg	6.0
Potassium g/kg	7.7

3.3 Experimental Design, Treatments and Care of the Birds

Three hundred and twenty laying hens were randomly assigned to either the conventional (control) layer house or the treatment house constructed over a dam. The design used for the study was a randomized block design in each treatment. The houses were blocked in five blocks with one replicate per treatment (breed) in each of the blocks. Each replicate comprised of four hens, individually caged in adjacent cages (Table 3.2).

Table 3.2 Experimental design

Replicates	**Dam house**								**Control house**								
	Commercial breeds				**Dual purpose breeds**		**Indigenous breeds**		**Commercial breeds**				**Dual purpose breeds**		**Indigenous breeds**		
	HB	**HS**	**LB**	**LS**	**BA**	**NH**	**OV**	**PK**	**HB**	**HS**	**LB**	**LS**	**BA**	**NH**	**OV**	**PK**	
1	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	
2	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	
3	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	
4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	
5	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	
Hens/breed	**20**	**20**	**20**	**20**	**20**	**20**	**20**	**20**	**20**	**20**	**20**	**20**	**20**	**20**	**20**	**20**	**Total**
Total/ house								**160**	**Total/ house**							**160**	**320**

HB: Hyline-Brown, HS: Hyline-Silver, LB: Lohman-Brown, LS: Lohman-Silver, BA: Black Australop, NH: New Hampshire, OV: Ovambo, PK: Potchefstroom Koekoek

3.4 Measurements

3.4.1 Egg production parameters and mortalities

Eggs were collected twice daily at 8am and 12pm and labeled clearly according to replicate, breed and housing system.

Figure 3.3 Collection of eggs from different laying hens

3.4.1.1 Egg weight

All eggs were daily weighed individually on an electronic Richter scale (Hocking *et al*., 2003; Singh *et al*., 2009).

Figure 3.4 Weighing of eggs

3.4.1.2 Body weight

Each bird was weighed at least three times during the trial period i.e at the beginning of the trial (at 48wks of age), in the middle of the trial (3 months after the start of the trial) and on the last day of the trial (5 months after the start of the trial). All birds were individually weighed on an electronic scale in kilograms, calibrated to three decimal places.

3.4.1.3 Feed intake

Daily intake of feed was recorded for each replicate by calculating the difference of feed offered and feed remaining in the feeder. Monthly feed intake and feed conversion ratio were calculated and also that of the entire experimental period.

3.4.1.4 Feed conversion ratio

Feed conversion ratio (FCR) of laying hens was observed daily and recorded as a gram of eggs produced per gram of feed consumed for each month. The following formula was used:

$$\text{FCR} = \frac{\text{Total feed intake for a month}}{\text{Total mean egg weight for a month}}$$

3.4.1.5 Hen day production %

Hen-day production percentage was calculated as described by Mussawar *et al*. (2004), using the following formula:

$$\text{Hen-day production \%} = \frac{\text{Number of eggs produced per day}}{\text{Number of live hens on that day}} \times 100$$

3.4.2 Mortalities

Mortalities were recorded and sent to the Poultry Reference laboratory, Faculty of Veterinary Sciences, University of Pretoria, Onderstepoort to determine the cause of death.

3.4.3 Physical characteristics of eggs

3.4.3.1 Albumen height

Albumen height was recorded for six months period, starting during adaptation and for every second month of the trial period. All eggs produced on that day were each broken on a flat mirrored table and the albumen height was measured using the Mutotuyo gauge (Figure 3.5 & 3.6).

Figure 3.5 Measuring albumen height

3.4.3.2 Haugh unit

Haugh unit was recorded for six months starting during the adaptation and for every second month of the trail period. Records of eggs used for measuring albumen height and its shelled egg weights were used to calculate Haugh unit as described by Doyon *et al.* (1986) using the following formula:

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

Where

HU = Haugh unit

H = Height of the albumen (mm)

W = Weight of the shelled egg (g)

Figure 3.6 Mututoyo gauge for measuring albumen height

3.4.3.3 Specific gravity

Specific gravity was measured for six months starting during the adaptation and for every second month of the trail period. All eggs produced for that day used for this measurement. Specific egg gravity was determined by immersing the eggs in saline solution with densities ranging between 1.075 and 1.080 and between 1.085 and 1.090. Specific gravity was always determined within 24 hours of collection as recommended by Butcher and Miles (2003). Prior to placing the eggs in salt solutions, the solutions were re-stirred and re-checked to verify their densities of saline concentration. The temperature of solutions was also measured before starting, to ensure constant temperature of the solution. Sampled eggs were placed in a medium sized wire basket with a minimum capacity of 5-10 eggs (depending on egg sizes) and immersed into solutions with increasing concentration of salt, from the weakest to the strongest solution (Figure 3.7). Every egg that floated in the weakest to the strongest solutions was removed from the solution and placed in the plastic fillers and all the floaters for every solution were recorded according to the different breeds, houses and specific gravity.

Procedure for measuring specific gravity

In preparing the salt solutions the appropriate amount of salt needs to be dissolved in the appropriate amount of water.

- The salt was dissolved in water first. The solutions were stirred thoroughly using a magnetic stirrer.
- A 4000ml cylinder was filled with the solution and the hydrometer was placed in the cylinder.
- Specific gravity was determined. If the reading was too high, the hydrometer was removed from the cylinder. A small amount of water was added to the solution in a cylinder and bestirred to dilute the saline concentration and the specific gravity was determined.
- This was repeated until the desired density of specific gravity was obtained. If the reading was too low, a small amount of saline was added to the solution and bestirred, and then

specific gravity was determined again. The small amount of saline was repeatedly added to the solution until the desired density was obtained. Once the desired densities were obtained the solutions were stored in a cool room overnight in buckets with lids to minimize contamination and evaporation of the solutions.

- The next morning after the collection of eggs, specific gravity was rechecked and eggs were immersed in different solutions, starting with the weakest to the strongest.

Figure 3.7 Measuring specific gravity of eggs: An egg floating on top of the salt solution

Figure 3.8 Immersing eggs in different concentrations of salt solutions

3.4.3.4 Egg shell strength

Egg shell strength was measured for six months starting during the adaptation and for every second month of the trail period. All eggs produced on that day from both housing systems were used to measure egg shell strength. Breaking eggshell strength of uncracked eggs was measured with an Instron apparatus (model 1011, Instron Ltd, Bucks, UK) (Rodriguez-Navarro *et al.*, 2002; Phosa, 2009). A constantly increasing force was applied on an egg facing up until it broke, depending on its shell strength. The applied force that was necessary to crush the eggshell of each egg was recorded in newtons (N) (Figure 3.9).

Figure 3.9 Measuring egg shell strength using Instron 10111

Procedures for breaking egg shell strength and Instron apparatus calibration were used as described by Phosa (2009). The Instron was calibrated each time before use according to standard procedures as described by the manufacturer.

3.4.3.5 Meat and Blood spots

Haugh unit eggs were used to identify meat and blood spots. All eggs produced on that day were from all the treatments were broken on a flat mirrored table (Figure 3.10). The eggs were visually examined for meat and blood spots and the total number of meat and blood spots was recorded for each treatment. Both types of spots were treated as single traits as described by Honkatukia (2010), solely as an indication of visual faultiness that might occur.

Figure 3.10 Meat and Blood spots (MBS)

3.5 Statistical analysis

Repeated data were analysed statistically as a randomized block design with the GLM model (Statistical Analysis System, 2011) for the average effect over time. Repeated Measures Analysis of Variance with the GLM model was used for repeated period measures. Means and standard deviations were calculated and significance of difference ($P<0.05$) between means was determined by Fischers test (Samuels, 1989).

CHAPTER 4

Results

The following results were obtained during the 5 month trial period.

4.1.1. Egg production

The effect of housing system and breed on total egg production over 5 the month trial period is presented in Table 4.1. Unfortunately, it was not possible to get all the hens from the different breeds at point of lay. Therefore, data were only collected from after peak starting at 48 weeks of age for a total period of five months. The following measurements: egg production, egg weight, feed intake, feed conversion ratio and hen day production % of hens from all the breeds were taken from 48 weeks of age for a of 5 month trial period.

Table 4.1 The effect of breed and housing system on total egg production (± standard deviation) over the 5 month trial period

Types	Breeds	Housing system: Dam house	Housing system: Control house	Mean egg production for breed
Commercial breeds	HB	118.7^{a} (± 6.97)	109.7^{b} (± 9.76)	114.17^{b} (± 9.30)
	HS	125.1^{a} (± 8.94)	123.4^{a} (± 10.32)	124.25^{a} (± 9.14)
	LB	121.4^{a} (± 8.30)	120.0^{ab} (± 4.07)	120.71^{ab} (±6.42)
	LS	127.6^{a} (± 4.23)	126.2^{a} (± 5.52)	126.91^{a} (± 4.70)
Dual purpose breeds	BA	86.8^{c} (± 4.41)	88.3^{cd} (± 10.58)	87.56^{d} (±7.68)
	NH	93.7^{bc} (± 6.95)	93.8^{c} (± 3.79)	93.74^{cd} (±5.03)
Indigenous breeds	OV	88.3^{c} (± 10.04)	82.4^{d} (± 8.20)	85.38^{d} (±9.18)
	PK	102.4^{b} (± 7.41)	95.4^{c} (± 7.58)	98.90^{c} (±7.99)
	Mean	**108.0 (± 17.55)**	**104.99 (±17.74)**	

$^{1-2}$ Row means with the same superscript do not differ significantly (P>0.05)
$^{a-d}$ Column means with the same subscript do not differ significantly (P>0.05)
HS=Hyline Silver; HB= Hyline Brown; LS= Lohman Silver; LB= Lohman Brown;
PK= Potchefstroom Koekoek; NH= New Hampshire; BA= Black Australorp; OV= Ovambo.

As shown in Table 4.1, there was no significant (P>0.05) difference in the total egg production over the 5 month period between commercial breeds kept in the dam house system. Egg production of commercial breeds was significantly higher (P<0.05) than the dual purpose and indigenous breeds. The Potchefstroom Koekoek had a significantly (P<0.05) higher egg production than the Black Australorp and Ovambo. There was no significant difference (P>0.05) in egg production between Black Australorp and Ovambo hens.

In the control house, there was a significant difference (P<0.05) in total egg production over the 5 months period between the commercial breeds. The Hyline-Brown hens had a significantly (P<0.05) lower egg production than the Hyline-Silver and Lohman-Silver. Egg production of the Hyline-Brown hens did not differ significantly (P>0.05) from the Lohman-Brown hens. The commercial breeds produced significantly (P<0.05) more eggs than the dual purpose and indigenous breeds. The Ovambo and Black Australorp hens produced the least eggs from all the different breeds kept in the control house.

There was no effect of housing system on the total egg production of laying hens over the trial period.

4.1.2. Monthly egg production

The effect of breed and housing system on the monthly egg production of laying hens is depicted in Table 4.2.

Table 4.2 The effect of breed and housing systems on monthly egg production (± standard deviation)

Months	Types	Breeds	Housing system		Mean egg production for breed
			Dam house	Control house	
1	Commercial breeds	HB	25.35^{a} (± 1.24)	23.15^{a} (± 1.65)	24.25^{a} (± 1.80)
		HS	26.50^{a} (± 1.29)	23.13^{a} (± 4.09)	24.82^{a} (± 3.63)
		LB	26.95^{a} (± 1.97)	23.69^{a} (± 2.97)	25.32^{a} (± 2.86)
		LS	25.90^{a} (± 2.69)	26.20^{a} (± 1.09)	26.05^{a} (± 1.94)
	Dual purpose breeds	BA	13.70^{c} (± 2.86)	10.88^{d} (± 2.12)	12.92^{d} (± 2.79)
		NH	17.31^{b} (± 4.15)	19.30^{c} (± 3.09)	18.31^{b} (± 3.74)
	Indigenous breeds	OV	18.00^{b1} (± 3.01)	12.90^{d2} (± 3.29)	15.45^{c} (± 4.01)
		PK	19.30^{b} (± 2.61)	17.05^{c} (± 2.45)	18.18^{b} (± 2.66)
		Mean	**21.63 (± 5.49)**	**19.54 (± 5.80)**	
2	Commercial breeds	HB	24.65^{a} (± 1.10)	23.35^{a} (± 2.05)	24.00^{a} (± 1.69)
		HS	25.20^{a} (± 2.35)	23.15^{a} (± 4.06)	24.18^{a} (± 3.31)
		LB	24.70^{a} (± 0.96)	24.25^{a} (± 2.07)	24.48^{a} (±1.46)
		LS	24.90^{a} (± 1.88)	25.35^{a} (± 1.62)	25.13^{a} (± 1.68)
	Dual purpose breeds	BA	16.30^{c} (± 4.41)	13.53^{c} (± 5.25)	14.92^{c} (± 4.79)
		NH	18.31^{bc} (± 4.07)	17.70^{b} (± 2.56)	18.01^{bc} (± 3.21)
	Indigenous breeds	OV	19.15^{bc1} (± 2.62)	14.02^{bc2} (± 2.52)	16.58^{c} (± 3.63)
		PK	21.6^{ab1} (± 2.53)	17.70^{b2} (± 3.89)	19.65^{b} (± 3.72)
		Mean	**21.85 (± 4.28)**	**19.88 (± 5.35)**	
3	Commercial breeds	HB	24.20^{ab} (± 1.89)	20.60^{abc}(± 3.79)	22.40^{ab} (± 3.41)
		HS	26.05^{a} (± 2.56)	24.15^{a} (± 4.65)	25.10^{a} (± 3.68)
		LB	23.40^{abc} (± 3.14)	23.25^{ab} (± 3.42)	23.33^{ab} (± 3.06)
		LS	25.05^{ab} (± 2.76)	24.15^{a} (± 2.88)	24.60^{a} (± 2.70)
	Dual purpose breeds	BA	20.05^{cd} (± 1.35)	18.55^{c} (± 4.91)	19.30^{b} (± 3.49)
		NH	19.12^{d} (± 2.76)	19.05^{bc} (± 2.74)	19.09^{b} (± 2.57)
	Indigenous breeds	OV	19.75^{cd} (± 2.52)	19.55^{bc} (± 2.86)	19.65^{b} (± 2.55)
		PK	21.60^{bcd} (± 2.52)	21.10^{abc} (± 2.75)	21.35^{b} (± 2.50)
		Mean	**22.40 (± 3.34)**	**21.30 (± 3.91)**	

4	Commercial breeds	HB	23.00^{a} (±1.41)	19.80^{bc} (± 4.17)	21.40^{b} (± 3.38)
		HS	24.35^{a} (±2.40)	23.55^{a} (± 4.04)	23.95^{a} (± 3.16)
		LB	22.10^{ab} (± 2.93)	21.25^{ab} (± 3.09)	21.68^{ab} (± 3.84)
		LS	23.95^{a} (± 2.93)	23.65^{a} (± 2.98)	23.80^{ab} (± 2.79)
	Dual purpose breeds	BA	18.45^{c} (± 1.96)	17.35^{c} (± 3.66)	17.90^{c} (± 2.83)
		NH	16.50^{c} (± 1.90)	18.00^{bc} (± 2.82)	17.25^{c} (± 2.45)
	Indigenous breeds	OV	18.03^{c} (± 1.47)	18.94^{bc} (± 1.62)	18.51^{c} (± 1.54)
		PK	18.85^{bc} (± 3.26)	19.65^{bc} (± 2.39)	19.25^{bc} (± 2.73)
		Mean	**20.65 (± 3.56)**	**20.28 (± 3.67)**	
5	Commercial breeds	HB	21.45^{abc} (± 2.29)	17.80^{bc} (± 3.89)	19.62^{b} (± 3.57)
		HS	22.95^{ab} (± 1.87)	21.55^{ab} (± 4.14)	22.25^{ab} (± 3.12)
		LB	21.05^{abc} (± 3.23)	21.19^{ab} (± 2.99)	21.12^{ab} (± 2.98)
		LS	24.00^{a} (± 3.64)	21.90^{a} (± 4.22)	22.95^{a} (±3.87)
	Dual purpose breeds	BA	18.90^{c} (± 1.05)	17.55^{c} (± 3.52)	18.25^{bc} (± 2.55)
		NH	16.25^{d} (± 1.76)	17.30^{c} (± 2.62)	16.78^{bc} (± 2.21)
	Indigenous breeds	OV	16.25^{d} (± 2.76)	16.95^{c} (± 2.66)	16.60^{c} (± 2.58)
		PK	20.10^{bc} (± 1.65)	20.00^{ab} (± 2.77)	20.05^{b} (± 2.15)
		Mean	**20.12 (± 3.47)**	**19.28 (± 3.67)**	

[1-2] Row means with the same superscript do not differ significantly (P>0.05)
[a-d] Column means with the same subscript do not differ significantly (P >0.05)
HS=Hyline Silver; HB= Hyline Brown; LS= Lohman Silver; LB= Lohman Brown; PK= Potchefstroom Koekoek; NH= New Hampshire; BA= Black Australorp; OV= Ovambo.

During the 1st month of the trial, there was no significant difference (P>0.05) in egg production between the commercial breeds kept in both houses but commercial breeds produced significantly (P<0.05) more eggs than other breeds. In the dam house, Black Australorp hens produced significantly (P<0.05) less eggs than New Hampshire, Ovambo and Potchefstroom Koekoek hens. However, in the control house, both Black Australorp and Ovambo produced significantly (P<0.05) less eggs than New Hampshire and Potchefstroom Koekoek breeds. The housing system only affected egg production for the Ovambo breed where hens in the dam house produced significantly (P<0.05) more eggs than those in the control house.

During the second month of the trial period, commercial breeds produced significantly more (P<0.05) eggs than all the other breeds except Potchefstroom Koekoek (P>0.05) kept in the dam house. Egg production for Potchefstroom Koekoek did not differ significantly from that of New Hampshire and Ovambo breeds (P>0.05). However, in the control house, commercial breeds produced significantly higher eggs (<P0.05) than all the other breeds. Although no significant difference was noticed between New Hampshire, Ovambo and Potchefstroom Koekoek (P>0.05), both New Hampshire and Potchefstroom Koekoek produced significantly (P<0.05) more eggs than Black Australorp, in the control house. However, the housing system only affected the indigenous breeds (Ovambo and Potchefstroom Koekoek) where egg production was significantly lower (P<0.05) in the control house.

Although there was no significant (P>0.05) difference in egg production within the commercial breeds in the dam house during the third month, it was only the Hyline-Silver which produced significantly (P<0.05) more eggs than the other breeds. No significant (P>0.05) difference was noticed between Potchefstroom Koekoek and commercial hens, in the control house. With the exception of Hyline-Silver, in the dam house, egg production for Potchefstroom Koekoek did not differ significantly from other commercial breeds as well as the dual and indigenous breeds ($P>0.05$), in both houses. However, no significant effects ($P>0.05$) of the housing systems were noticed.

In the dam house, no significant ($P>0.05$) differences in egg production occurred during the fourth month between commercial breeds. Although egg production for the Potchefstroom Koekoek did not differ significantly with the dual and indigenous breeds in the dam house, it also did not differ ($P>0.05$) with that of Lohman-Brown hens, a commercial breed. In the control house, only Hyline-Silver and Lohman-Silver produced significantly ($P<0.05$) more eggs than other breeds. Lohman-Brown hens only produced significantly ($P<0.05$) more eggs than Black Australorp whose production was the same ($P>0.05$) as that of Hyline-Brown. Again, no significant effects of the housing systems were observed in egg production of laying hens during the fourth month.

During the fifth month of the trial period, there was no significant difference ($P>0.05$) in egg production between the commercial breeds kept in the dam house but only Lohman-Silver produced significantly ($P<0.05$) more eggs than all other breeds. Egg production for Hyline-Silver was significantly ($P<0.05$) higher than for the other breeds except for the Potchefstroom Koekoek. Both Hyline Brown and Lohman-Brown had the same ($P>0.05$) egg production than the Potchefstroom Koekoek and Black Australorp while Ovambo and New Hampshire produced less ($P<0.05$) eggs than all other breeds. In the control house, Lohman-Silver produced significantly ($P<0.05$) more eggs than Hyline-Brown although its production did not differ ($P>0.05$) from the rest of the commercial breeds. Potchefstroom Koekoek hens had the same ($P>0.05$) egg production than the commercial breeds but its production was significantly ($P<0.05$) higher than other dual and indigenous breeds, whose production was the same ($P>0.05$) as that of Hyline-Brown. No significant effect of housing systems was noticed for egg production of laying hens during the fifth month.

4.1.3. Egg weight

The mean egg weight produced by laying hens of different breeds in two different housing systems within a five month trial period is shown in Table 4.3.

Table 4.3 The effect of breed and housing system on mean egg weight (g) (± standard deviation) over the 5 month trial period

Types	Breeds	Housing system		Mean egg weight for breed
		Dam house	Control house	
Commercial breeds	HB	48.43^{ab} (± 6.11)	44.74^{ab} (± 15.80)	46.59^{a} (± 11.46)
	HS	50.47^{a} (± 2.88)	48.72^{a} (± 6.63)	49.60^{a} (± 4.91)
	LB	53.32^{a} (± 2.96)	47.63^{ab} (± 3.48)	50.47^{a} (± 4.22)
	LS	46.28^{ab} (± 8.59)	43.78^{ab} (± 12.92)	45.03^{ab} (± 10.43)
Dual purpose breeds	BA	30.85^{c} (± 4.58)	35.93^{bc} (± 10.62)	33.39^{bc} (± 8.16)
	NH	29.52^{c} (± 13.12)	38.38^{abc} (± 5.55)	33.95^{bc} (± 10.08)
Indigenous breeds	OV	28.29^{c} (± 10.74)	28.27^{c} (±15.40)	28.28^{c} (± 12.52)
	PK	38.11^{bc} (± 5.70)	37.30^{abc} (±3.51)	37.70^{b} (± 4.48)
	Mean	**40.94 (± 11.71)**	**40.59 (± 11.54)**	

$^{1-2}$ Row means with the same superscript do not differ significantly (P >0.05)
$^{a-c}$ Column means with the same subscript do not differ significantly (P >0.05)
HS=Hyline Silver; HB= Hyline Brown; LS= Lohman Silver; LB= Lohman Brown;
PK= Potchefstroom Koekoek; NH= New Hampshire; BA= Black Australorp; OV= Ovambo.

In the dam house, the mean egg weight of the commercial breeds during the trial period did not differ significantly (P>0.05) from each other, but only Hyline-Silver and Lohman-Brown produced significantly (P<0.05) heavier eggs than all the other breeds. No significant (P>0.05) differences were detected between egg weights of both dual and indigenous breeds. With the exception of Potchefstroom Koekoek, the dual purpose and indigenous breeds produced significantly lighter (P<0.05) eggs than the commercial breeds.

There was no significant difference (P>0.05) in egg weight between dual and indigenous breeds, and within commercial breeds in the control house. However, egg weight for both New Hampshire and Potchefstroom Koekoek did not differ significantly (P>0.05) from that of the commercial breeds. On the other hand, eggs of the Ovambo was significantly (P<0.05) lighter than that of all commercial breeds, while the Black Australorp hens produced significantly lighter eggs than the commercial breeds. The housing systems had no significant (P>0.05) effect on egg weight of laying hens over the trial period.

4.1.4. Monthly egg weight

The effect of breed and housing system on the monthly egg weight of laying hens is shown in Table 4.4.

Table 4.4 The effect of breed and housing system on monthly mean egg weight (g) (± standard deviation) of laying hens

Months	Types	Breeds	Housing system		Mean egg weight for breed
			Dam house	Control house	
1	Commercial breeds	HB	63.12^{a} (± 1.22)	63.28^{a} (± 0.73)	63.20^{a} (± 0.95)
		HS	58.72^{b1} (± 1.76)	60.97^{b2} (± 0.85)	59.84^{c} (± 1.76)
		LB	62.77^{a1} (± 2.17)	60.77^{b2} (± 1.39)	61.78^{b} (± 2.05)
		LS	58.75^{b} (± 3.04)	57.77^{c} (± 0.81)	58.26^{d} (± 2.16)
	Dual purpose breeds	BA	55.80^{c} (± 1.06)	57.30^{c} (± 0.55)	56.55^{e} (± 1.12)
		NH	55.34^{c} (± 0.97)	57.08^{c} (± 0.98)	56.21^{e} (± 1.26)
	Indigenous breeds	OV	56.95^{bc} (± 1.69)	54.67^{d} (± 0.67)	55.81^{ef} (± 1.71)
		PK	54.68^{c} (± 1.10)	55.05^{d} (± 1.32)	54.87^{f} (± 1.16)
		Mean	**58.27 (± 3.44)**	**58.36 (± 3.00)**	
2	Commercial breeds	HB	63.24^{a} (± 1.24)	63.04^{a} (± 1.24)	63.14^{a} (± 1.17)
		HS	58.47^{bc} (± 0.52)	53.04^{d} (± 1.09)	58.39^{b} (± 0.81)
		LB	63.93^{a} (± 3.02)	61.29^{a} (± 1.35)	62.61^{a} (± 2.68)
		LS	60.05^{b1} (± 1.01)	58.25^{b2} (± 1.11)	59.15^{b} (± 1.37)
	Dual purpose breeds	BA	55.62^{c1} (± 1.14)	57.53^{b2} (± 1.46)	56.57^{c} (± 1.59)
		NH	56.91^{c} (± 1.29)	55.68^{c} (± 1.20)	56.30^{c} (± 1.29)
	Indigenous breeds	OV	55.83^{c} (± 1.41)	54.16^{c} (± 1.48)	54.99^{d} (± 1.62)
		PK	55.24^{c} (± 0.75)	54.64^{c} (± 0.61)	54.94^{d} (± 0.72)
		Mean	**58.66 (± 3.53)**	**57.86 (± 3.13)**	
3	Commercial breeds	HB	65.10^{a} (± 3.92)	66.88^{a} (± 2.16)	65.99^{a} (± 3.12)
		HS	58.99^{b} (± 1.07)	58.19^{c} (± 0.84)	58.59^{cd} (± 1.00)
		LB	64.17^{a1} (± 2.01)	61.24^{b2} (± 2.77)	62.71^{b} (± 2.69)
		LS	60.89^{b1} (± 0.79)	58.08^{c2} (± 1.09)	59.48^{c} (± 1.74)
	Dual purpose breeds	BA	56.86^{c} (± 0.91)	57.28^{c} (± 0.77)	57.07^{d} (± 0.83)
		NH	55.82^{cd} (± 1.49)	57. 39^{c} (± 0.75)	56.61^{de} (± 1.34)
	Indigenous breeds	OV	56.60^{cd} (± 1.38)	54.64^{d} (± 0.36)	55.62^{e} (± 1.41)
		PK	54.59^{d} (± 0.91)	55.12^{d} (± 0.64)	54.85^{e} (± 0.79)
		Mean	**59.13 (± 4.07)**	**58.60 (± 3.91)**	
4	Commercial breeds	HB	62.88^{ab} (± 1.55)	64.49^{a} (± 1.26)	63.68^{a} (± 1.58)
		HS	59.17^{c} (± 1.33)	59.63^{c} (± 1.94)	59.04^{b} (± 1.58)
		LB	63.95^{a} (± 3.05)	62.26^{b} (± 2.18)	63.11^{a} (± 2.69)
		LS	61.19^{b1} (± 0.61)	58.25^{cd2} (± 1.46)	59.72^{b} (± 1.87)
	Dual purpose breeds	BA	55.83^{d} (± 1.27)	57.59^{d} (± 1.41)	56.71^{c} (± 1.57)
		NH	55.76^{d} (± 0.62	56.29^{d} (± 0.72)	56.02^{c} (± 0.69)
	Indigenous breeds	OV	55.27^{d} (± 1.44)	55.68^{d} (± 0.96)	55.48^{c} (± 1.17)
		PK	56.72^{d} (± 1.81)	55.96^{d} (± 0.64)	56.34^{c} (± 1.35)
		Mean	**58.84 (± 3.61)**	**58.77 (± 3.25)**	

5	Commercial breeds	HB	63.16^{ab1} (± 1.22)	65.82^{a2} (± 1.69)	64.49a (± 1.98)
		HS	59.26^{c} (± 1.27)	60.70^{c} (± 0.54)	59.98c (± 1.19)
		LB	64.13^{a} (± 1.07)	62.52^{b} (± 1.88)	63.32b (± 1.62)
		LS	61.78^{b1} (± 0.94)	58.82^{de2} (± 0.83)	60.30c (± 1.77)
	Dual purpose breeds	BA	55.60^{d1} (± 1.33)	59.03^{d2} (± 1.01	57.30d (± 2.14)
		NH	57.93^{c} (± 0.57)	57.28^{e} (± 1.19	57.61d (± 0.98)
	Indigenous breeds	OV	55.81^{d1} (± 2.24)	54.01^{f2} (± 0.93)	54.91e (± 1.87)
		PK	55.96^{d} (± 1.22)	55.78^{f} (± 1.09)	55.77e (± 1.11)
		Mean	**59.20 (± 3.52)**	**59.22 (± 3.76)**	

[12] Row means with the same superscript do not differ significantly (P >0.05)
[a-f] Column means with the same subscript do not differ significantly (P >0.05)
HS=Hyline Silver; HB= Hyline Brown; LS= Lohman Silver; LB= Lohman Brown;
PK= Potchefstroom Koekoek; NH= New Hampshire; BA= Black Australorp; OV= Ovambo

During the first month, Hyline-Brown and Lohman-Brown produced significantly heavier eggs (P<0.05) than all the other breeds in the dam house. Hyline-Silver and Lohman-Silver also produced significantly (P<0.05) heavier eggs than the dual purpose and indigenous breeds except Ovambo. In the control house, Hyline-Brown produced significantly (P<0.05) heavier eggs than all the other breeds. Lohman-Silver produced the same egg weights as the dual purpose whilst the indigenous breeds produced significantly (P<0.05) lighter eggs than all the other breeds. A house effect was only observed for Hyline-Silver, producing lighter eggs in the dam house than the control house while the inverse occurred with Lohman-Brown (P<0.05).

In both housing systems, Hyline-Brown and Lohman-Brown produced significantly (P<0.05) heavier eggs than the other breeds during the second month. In the control house, Hyline-Silver produced lighter eggs than all the other breeds (P<0.05) while Black Australorp and Lohman-Silver produced heavier (P<0.05) eggs than the rest of dual and indigenous breeds. Egg weight for Hyline-Silver declined while that of Black Australorp increased in the control house (P<0.05).

During the third month, all commercial breeds produced significantly (P<0.05) heavier eggs than other breeds in the dam house. Hyline-Brown and Lohman-Brown hens produced significantly heavier eggs than Hyline-Silver and Lohman-Silver hens. Black Australorps produced significantly (P<0.05) heavier eggs than Potchefstroom Koekoeks. No significant (P>0.05) differences were detected between egg weight for Potchefstroom Koekoek and that of New Hampshire and Ovambo. Although Hyline-Brown produced significantly (P<0.05) heavier eggs than Lohman-Brown, both breeds produced heavier (P<0.05) eggs than the rest of the breeds in the control house. Indigenous breeds produced significantly (P<0.05) lighter eggs than the dual breeds as well as Hyline-Silver and Lohman-Silver breeds. Hyline-Brown and Lohman-Brown hens produced significantly (P<0.05) heavier eggs in the dam house than the control house.

Hyline-Silver produced the lightest eggs and Hyline-Brown the heaviest of all commercial breeds in the dam house and control house, respectively (P<0.05), during the 4^{th} month. In the dam house, Lohman-Brown had significantly (P<0.05) heavier eggs than Lohman-Silver but not Hyline-Brown. All commercial breeds produced significantly heavier eggs than the dual purpose and indigenous breeds in the dam house. In the control house, both Hyline-Silver and Lohman-Silver produced significantly (P<0.05) lighter eggs than the other commercial breeds. Egg weights for Lohman-Silver did not differ significantly with that of dual purpose and indigenous breeds. Breed and house interaction were only detected for Lohman-Silver where eggs significantly lighter ($P<0.05$) in the control house than in the dam house.

During the fifth month, Hyline-Silver produced significantly ($P<0.05$) lighter eggs than other commercial breeds in the dam house. Within the commercial breeds significant ($P<0.05$) differences were only noticed between egg weights of Lohman-Brown and Lohman-Silver. With the exception of Hyline-Silver, which had the same egg weight with New Hampshire, all commercial breeds produced significantly ($P<0.05$) heavier eggs than dual and indigenous breeds. New Hampshire hens also produced heavier ($P<0.05$) eggs than the rest of the dual and also the indigenous breeds. In the control house, Lohman-Silver produced significantly ($P<0.05$) lighter eggs than other commercial breeds. Egg weight differed significantly ($P<0.05$) within commercial breeds with the heaviest eggs produced by Hyline-Brown followed by Hyline-Silver and Lohman-Brown. Black Australorp produced heavier ($P<0.05$) eggs than New Hampshire but the eggs of both breeds were significantly heavier than indigenous breeds. Eggs of the Ovambo and Lohman-Silver hens were significantly heavier, in the dam house while the inverse occurred for Black Australorp and Hyline-Brown.

4.1.5. Feed intake

The effect of breed and housing system on average daily feed intake of laying hens is outlined in Table 4.5.

Table 4.5 The effect of breed and housing system on average daily feed intake (g) (± standard deviation) over the 5 month trial period

Types	Breeds	Housing system		Mean feed intake for breed
		Dam house	Control house	
Commercial breeds	HB	149.96^{a} (± 0.011)	149.87^{ab} (± 0.113)	149.91 (± 0.089)
	HS	149.97^{a} (± 0.005)	149.95^{a} (± 0.025)	149.96 (± 0.019)
	LB	149.96^{a} (± 0.008)	149.94^{ab} (± 0.029)	149.95 (± 0.021)
	LS	149.96^{a1} (± 0.011)	149.85^{b2} (± 0.104)	149.90 (± 0.090)
Dual purpose breeds	BA	149.92^{a} (± 0.082)	149.90^{ab} (± 0.116)	149.91 (± 0.095)
	NH	149.96^{a} (± 0.008)	149.88^{ab} (± 0.095)	149.92 (± 0.079)
Indigenous breeds	OV	149.95^{a1} (± 0.009)	149.86^{b2} (± 0.137)	149.91 (± 0.105)
	PK	149.95^{a} (± 0.005)	149.89^{ab} (± 0.084)	149.92 (± 0.065)
	Mean	**149.95 (± 0.032)**	**149.89 (± 0.094)**	

^{12} Row means with the same superscript do not differ significantly ($P>0.05$)
^{ab} Column means with the same subscript do not differ significantly ($P>0.05$)
HS=Hyline Silver; HB= Hyline Brown; LS= Lohman Silver; LB= Lohman Brown; PK= Potchefstroom Koekoek; NH= New Hampshire; BA= Black Australorp; OV= Ovambo.

No significant differences ($P>0.05$) were noticed for feed intake between breeds and housing system over the total five month trial period and within months. All the hens finished the daily feed ration of 150g/hen/day allocated to them. Differences were too small to even worth mentioning.

4.1.6. Feed conversion ratio (FCR)

The effect of breed and housing systems on the feed conversion ratio over the 5 month trial period is shown in Table 4.6.

Table 4.6 The effect of breed and housing system on the feed conversion ratio (total feed intake/eggs weight) (± standard deviation) over the 5 month trial period

Types	**Breeds**	**Housing system**		**Mean FCR for breed**
		Dam house	**Control house**	
Commercial breeds	HB	3.04^{d} (± 0.146)	2.83^{c} (± 0.145)	2.94^{c} (± 0.177)
	HS	3.07^{d} (± 0.249)	3.10^{c} (± 0.189)	3.09^{c} (± 0.209)
	LB	2.83^{d} (± 0.133)	3.08^{c} (± 0.080)	2.96^{c} (± 0.167)
	LS	2.88^{d} (± 0.106)	3.08^{c} (± 0.132)	2.98^{c} (± 0.152)
Dual purpose breeds	BA	4.72^{a1} (± 0.182)	3.93^{b2} (± 0.384)	4.33^{a} (± 0.503)
	NH	4.27^{bc} (± 0.210)	4.27^{a} (± 0.306)	4.27^{ab} (± 0.252)
Indigenous breeds	OV	4.06^{c1} (± 0.237)	4.48^{a2} (± 0.201)	4.27^{ab} (± 0.304)
	PK	3.88^{c} (± 0.318)	4.24^{a} (± 0.392)	4.07^{b} (± 0.385)
	Mean	**3.58 (± 0.71)**	**3.64 (± 0.68)**	

^{12} Row means with the same superscript do not differ significantly (P >0.05)
$^{a-d}$ Column means with the same subscript do not differ significantly (P>0.05)
HS=Hyline Silver; HB= Hyline Brown; LS= Lohman Silver; LB= Lohman Brown;
PK= Potchefstroom Koekoek; NH= New Hampshire; BA= Black Australorp; OV= Ovambo.

As expected, commercial breeds had a significantly (P<0.05) better feed conversion ratio than dual purpose and indigenous breeds, in both housing systems. Feed conversion ratio varied significantly among dual and indigenous breeds. Among these breeds, Potchefstroom Koekoeks had the best (P<0.05) FCR in the dam house but not in the control house. The inverse was true for Black Australorp, which had the poorest FCR in the dam house but a significantly (P<0.05) better FCR in the control house. The FCR for Ovambo also improved significantly (P<0.05) in the dam house, as compared to its FCR in the control house.

4.1.7. The monthly feed conversion ratio

The effect of breed and housing system on feed conversion ratios of laying hens during different monthly periods is outlined in Table 4.7.

Table 4.7 The effect of breed and housing systems on feed conversion ratio (total feed intake/eggs weight) (± standard deviation) of laying hens during different monthly periods

Months	Types	Breeds	Housing system		Mean monthly FCR for breed
			Dam house	Control house	
1	Commercial breeds	HB	2.86^{d} (± 0.101)	2.81^{c} (± 0.175)	2.86^{c} (± 0.137)
		HS	2.89^{d} (± 0.094)	2.96^{c} (± 0.186)	2.89^{c} (± 0.144)
		LB	2.69^{d} (± 0.209)	2.96^{c} (± 0.126)	2.69^{c} (± 0.219)
		LS	2.82^{d} (± 0.142)	2.93^{c} (± 0.065)	2.81^{c} (± 0.120)
	Dual purpose breeds	BA	4.03^{b1} (± 0.448)	3.33^{b2} (± 0.346)	4.03^{b} (± 0.502)
		NH	4.26^{ab1} (± 0.083)	3.85^{a2} (± 0.222)	4.26^{a} (± 0.268)
	Indigenous breeds	OV	4.44^{a1} (± 0.591)	3.77^{a2} (± 0.144)	4.44^{a} (± 0.537)
		PK	3.67^{c} (± 0.257)	3.88^{a} (± 0.050)	3.67^{b} (±0.208)
		Mean	**3.46 (± 0.74)**	**3.31 (± 0.47)**	
2	Commercial breeds	HB	2.88^{c} (± 0.111)	2.81^{c} (± 0.159)	2.88^{c} (± 0.134)
		HS	2.91^{c} (± 0.075)	3.00^{c} (± 0.261)	2.91^{c} (± 0.187)
		LB	2.93^{c} (± 0.035	2.88^{c} (± 0.062	2.93^{c} (± 0.051)
		LS	2.92^{c} (± 0.051)	3.02^{c} (± 0.128)	2.92^{c} (±0.106)
	Dual purpose breeds	BA	5.22^{a1} (± 1.121)	3.78^{b2} (± 0.474)	5.22^{a} (± 1.132)
		NH	3.92^{b} (± 0.381)	3.78^{b} (± 0.135)	4.01^{b} (± 0.297)
	Indigenous breeds	OV	3.70^{b} (± 0.235)	4.12^{ab} (± 0.170)	3.07^{b} (± 0.296)
		PK	3.65^{b1} (± 0.266)	4.30^{a2} (± 0.605)	3.65^{b} (± 0.558)
		Mean	**3.52 (± 0.87)**	**3.46 (± 0.63)**	
3	Commercial breeds	HB	2.74^{cd}(± 0.137)	2.74^{c}(± 0.229)	2.74^{e} (± 0.178)
		HS	2.85^{c}(± 0.172)	2.80^{c}(± 0.088)	2.85^{de}(± 0.131)
		LB	2.62^{d1}(± 0.201)	2.93^{c2} (± 0.040)	2.62^{de}(± 0.222)
		LS	2.86^{c}(± 0.071)	2.94^{c} (± 0.045)	2.86^{de}(± 0.071)
	Dual purpose breeds	BA	3.63^{b1} (± 0.162)	3.40^{b2} (± 0.093)	3.63^{c} (± 0.251)
		NH	3.92^{a} (± 0.060)	3.79^{a} (± 0.232)	3.92^{a} (± 0.182)
	Indigenous breeds	OV	3.61^{b} (± 0.246)	3.81^{a} (± 0.143)	3.61^{ab}(± 0.216)
		PK	3.63^{b}(± 0.274)	3.72^{a} (± 0.202)	3.63^{b} (± 0.232)
		Mean	**3.23 (± 0.51)**	**3.27 (± 0.46)**	
4	Commercial breeds	HB	3.01^{b}(± 0.109)	2.71^{c} (± 0.141)	3.01^{c}(± 0.198)
		HS	3.07^{b} (± 0.226)	2.91^{c} (± 0.060)	3.07^{bc}(± 0.177)
		LB	2.94^{b}(± 0.163)	3.27^{b} (± 0.108)	2.94^{b}(± 0.218)
		LS	2.93^{b}(± 0.131)	2.94^{bc} (± 0.042)	2.93^{bc}(± 0.092)
	Dual purpose breeds	BA	3.97^{a} (± 0.099)	3.70^{a} (± 0.125)	3.97^{a} (±0.203)
		NH	4.18^{a}(± 0.478)	3.96^{a} (± 0.086)	4. 17^{a}(± 0.320)
	Indigenous breeds	OV	3.87^{a} (±0.479)	3.89^{a} (± 0.129)	3.87^{a}(± 0.342)
		PK	4.13^{a}(± 0.626)	3.86^{a} (± 0.151)	4.13^{a}(± 0.452)
		Mean	**3.51 (± 0.62)**	**3.40 (± 0.50)**	

5	Commercial breeds	HB	2.83^{cd} (± 0.076)	2.77^{d}(± 0.132)	2.83^{d}(± 0.107)
		HS	2.97^{c} (± 0.111)	2.83^{d}(± 0.111)	2.97^{d}(± 0.126)
		LB	2.70^{d} (± 0.132)	2.87^{d}(± 0.110)	2.70^{d}(± 0.145)
		LS	2.81^{cd} (± 0.116)	2.78^{d} (± 0.113)	2.81^{d}(± 0.109)
	Dual purpose breeds	BA	3.42^{b} (± 0.232)	3.34^{b} (± 0.190)	3.42^{c}(± 0.199)
		NH	4.05^{a1} (± 0.373)	3.71^{a2} (± 0.229)	4.05^{a}(± 0.332)
	Indigenous breeds	OV	3.87^{a} (± 0.078)	3.81^{a} (± 0.300)	3.87^{a}(± 0.205)
		PK	3.59^{b} (± 0.225)	3.60^{ab} (± 0.322)	3.59^{b}(± 0.261)
		Mean	**3.28 (± 0.51)**	**3.21 (± 0.46)**	

^{12} Row means with the same superscript do not differ significantly (P >0.05)
$^{a\text{-}d}$ Column means with the same subscript do not differ significantly (P >0.05)
HS=Hyline Silver; HB= Hyline Brown; LS= Lohman Silver; LB= Lohman Brown;
PK= Potchefstroom Koekoek; NH= New Hampshire; BA= Black Australorp; OV= Ovambo

Commercial breeds in both housing systems showed less variation in FCR during the first two months of the trial, in both housing systems, and had better (P<0.05) FCR throughout the trial. During the first month, Potchefstroom Koekoek in the dam house had significantly (P<0.05) better FCR than other dual purpose and indigenous breeds in the dam house. In the control house, Black Australorp hens had significantly (P<0.05) better FCR than other breeds in these categories. With the exception of Potchefstroom Koekoek, all other dual and indigenous breeds had significantly (P<0.05) better FCR in the control house than in the dam house.

During the second month, Black Australorp hens had significantly (P<0.05) worse FCR than other dual and indigenous breeds in the dam house, while Potchefstroom Koekoek had significantly better FCR than dual breeds only. The FCR for Black Australorp hens in the control house was significantly (P<0.05) better the FCR of the breeds in the dam house. The Potchefstroom Koekoek hens kept in the dam house had a better FCR than the Potchefstroom Koekoek hens in the control house.

During the third month of the trial, there were no significant (P>0.05) differences in FCR between the commercial breeds in the control house. In the dam house, Lohman-Brown and the Hyline-Brown had significantly (P<0.05) lower FCRs than the other two commercial breeds. New Hampshire hens had significantly (P<0.05) a higher FCR than other dual and indigenous breeds in the dam house. The FCR for Lohman-Brown was significantly (P<0.05) higher in the control house than in the dam house, while that of Black Australorp hens was lower in the control house than in the dam house. Compared to all the breeds in the control house, the Black Australorp performed best in terms of its FCR.

During the fourth month, there were no significant (P>0.05) differences in FCR between commercial breeds in the dam house as well as that of dual and indigenous breeds in both the housing systems. However, in the control house Lohman Brown had a significantly lower FCR than Hyline-Brown and Hyline-Silver. There was no breed and house interaction during this month in the trial period.

During the fifth month, no significant (P>0.05) differences in FCR occurred within commercial breeds in the control house, but Hyline-Silver had a significantly (P<0.05) lower FCR than

Lohman-Brown, in the dam house. Black Australorp and Potchefstroom Koekoek had significantly (P<0.05 lower FCR than New Hampshire and Ovambo breeds in the dam house. In the control house, while only Black Australorp hens had a significantly (P<0.05) lower FCR than the rest of the dual and indigenous breeds. New Hampshire hens had significantly (P<0.05) higher FCR, in the control than dam house. The FCR of the New Hampshire hens that were kept in the control house was significantly lower (P<0.05) compared to the FCR of the New Hampshire hens in the dam house.

4.1.8 Hen day production percentage

The effect of breed and housing system on hen day production percentage of laying hens over 5 months period is outlined in Table 4.8.

Table 4.8 The effect of breed and housing system on the hen day production % (± standard deviation) over the 5 month trial period

Types	Breeds	Housing system		Mean hen-day production %
		Dam house	Control house	
Commercial Breeds	HB	80.75^{b} (± 4.147)	80.35^{a} (± 2.416)	80.55^{b} (± 3.21)
	HS	85.29^{ab} (± 2.384)	82.81^{a} (± 5.349)	84.05^{ab} (± 4.12)
	LB	84.30^{ab} (± 4.239)	79.67^{a} (± 1.326)	81.98^{ab} (± 3.95)
	LS	87.03^{a} (± 2.560)	84.11^{a} (± 3.679)	85.57^{a} (± 3.36)
Dual purpose Breeds	BA	59.57^{cd1} (± 1.177)	64.93^{b2} (± 3.008)	62.25^{d} (± 3.55)
	NH	64.15^{cd} (± 3.461)	63.45^{b} (± 2.206)	63.81^{cd} (± 2.66)
Indigenous Breeds	OV	59.43^{d} (± 6.117)	54.94^{c} (± 5.470)	57.18^{e} (± 5.96)
	PK	68.27^{c} (± 5.572)	63.59^{b} (± 5.074)	65.93^{c} (± 5.59)
	Mean	**73.84 (± 11.92)**	**71.53 (± 11.23)**	

[12] Row means with the same superscript do not differ significantly (P>0.05)
[a-e] Column means with the same subscript do not differ significantly (P >0.05)
HS=Hyline Silver; HB= Hyline Brown; LS= Lohman Silver; LB= Lohman Brown;
PK= Potchefstroom Koekoek; NH= New Hampshire; BA= Black Australorp; OV= Ovambo.

There were no significant differences in hen day production percentage (HDP %) between commercial breeds kept in the control house. For the birds in the control house, Lohman Silver had a significantly higher HDP % than Hyline-Brown. The HDP % for commercial breeds was significantly higher than that of dual and indigenous breeds in the two housing systems. In addition, the Ovambo breed had significantly lower HDP% than Potchefstroom Koekoek in both housing systems. The type of housing had an effect only on Black Australorp hens where HDP% was significantly higher in the control house.

4.1.9. Monthly hen-day production percentage

The results of the effect of breed and housing systems on monthly hen day production % of laying hens at different monthly periods are outlined in Table 4.9. Commercial breeds generally had significantly higher HDP % than dual and indigenous breeds for the first three months of the trial.

Table 4.9. The effect of breed and housing systems on monthly hen day production % (± standard deviation)

Month	Type	Breeds	Housing system		Mean monthly hen-day production %
			Dam house	Control house	
1	Commercial Breeds	HB	84.51^{a} (± 4.15)	84.22^{ab} (± 3.06)	84.37^{a}(± 3.44)
		HS	88.33^{a1} (± 4.29)	81.45^{b2} (± 4.69)	84.89^{a}(± 5.58)
		LB	89.84^{a} (± 6.58)	85.07^{ab} (± 3.11)	87.45^{a} (± 5.62)
		LS	86.33^{a} (± 8.99)	89.05^{a} (± 2.71)	87.69^{a} (± 6.42)
	Dual purpose Breeds	BA	64.22^{b} (± 8.73)	63.33^{cd} (± 6.87)	63.78^{b}(± 7.42)
		NH	64.44^{b} (± 5.13)	69.33^{c} (± 3.46)	66.89^{b}(± 5.35)
	Indigenous Breeds	OV	65.00^{b} (± 3.17)	59.89^{d} (± 8.02)	62.44^{c} (± 6.35)
		PK	68.67^{b} (± 3.77)	67.00^{c} (± 2.21)	67.83^{b} (± 3.04)
		Mean	**76.42 (± 12.59)**	**74.92 (± 11.50)**	
2	Commercial Breeds	HB	82.67^{a} (± 2.97)	83.94^{a} (± 2.74)	83.30^{a} (±2.78)
		HS	86.95^{a} (± 2.83)	82.67^{a} (± 7.64)	84.81^{a} (± 5.88)
		LB	82.67^{a} (± 2.73)	83.12^{a} (± 2.75)	82.90^{a} (± 2.57)
		LS	84.50^{a} (± 3.37)	84.67^{a} (± 3.56)	84.58^{a}(± 3.27)
	Dual purpose Breeds	BA	51.72^{d} (± 9.27)	50.11^{c} (± 10.76)	50.92^{c} (± 9.51)
		NH	64.31^{c} (± 3.61)	61.22^{b} (± 4.49)	62.76^{b} (± 4.01)
	Indigenous Breeds	OV	62.00^{c1} (± 5.69)	48.50^{c2} (± 5.63)	55.25^{c} (± 8.89)
		PK	75.06^{b1} (± 3.93)	54.83^{bc2} (± 7.21)	64.95^{b} (±11.98)
		Mean	**73.73 (± 13.04)**	**68.63 (± 16.59)**	
3	Commercial Breeds	HB	82.33^{b} (± 6.87)	79.39^{b} (± 5.16)	80.86^{b} (± 5.93)
		HS	88.67^{a} (± 4.92)	88.05^{a} (± 5.24)	88.36^{a} (± 4.08)
		LB	84.22^{ab} (± 7.95)	83.20^{ab} (± 3.16)	83.71^{b} (± 5.97)
		LS	87.11^{ab} (± 2.29)	85.00^{ab} (± 3.12)	86.06^{ab} (±2.80)
	Dual purpose Breeds	BA	65.72^{d} (± 5.19)	68.72^{c} (± 7.29)	67.22^{c} (± 6.17)
		NH	71.46^{cd} (± 1.42)	68.72^{c} (± 3.61)	70.09^{c} (±3.06)
	Indigenous Breeds	OV	71.50^{cd} (± 2.07)	69.50^{c} (± 1.80)	70.50^{c} (± 2.11)
		PK	74.28^{c} (± 5.67)	70.67^{c} (± 3.29)	72.47^{c} (± 4.77)
		Mean	**78.16 (± 9.31)**	**76.66 (± 8.70)**	
4	Commercial Breeds	HB	78.45^{b} (± 3.28)	82.70^{b} (± 2.54)	80.57^{b} (± 3.56)
		HS	84.88^{a} (± 5.51)	89.94^{a} (± 4.19)	87.41^{a} (± 5.33)
		LB	81.49^{ab} (± 8.49)	77.16^{bc} (± 0.98)	79.32^{b} (± 6.54)
		LS	86.44^{a} (± 1.87)	86.15^{a} (± 4.11)	86.29^{a} (± 3.02)
	Dual purpose Breeds	BA	59.31^{cd} (± 2.62)	69.08^{c} (± 2.82)	64.19^{c} (± 5.75)
		NH	53.23^{d} (± 2.27)	68.10^{c} (± 0.61)	60.67^{d} (± 7.97)
	Indigenous Breeds	OV	62.36^{c} (± 4.06)	73.39^{c} (± 1.74)	67.87^{c} (± 6.52)
		PK	64.25^{c} (± 3.14)	68.56^{c} (± 2.50)	66.41^{c} (±8.67)
		Mean	**71.30 (± 13.27)**	**76.89 (± 8.56)**	

	Commercial Breeds	HB	77.92^{c} (± 6.42)	77.80^{c} (± 4.90)	77.86^{c} (± 5.38)
		HS	83.93^{b} (± 2.82)	84.40^{b} (± 3.21)	84.17^{b} (± 2.86)
		LB	86.07^{ab} (± 2.57)	82.74^{b} (± 1.63)	84.40^{b} (± 2.72)
		LS	90.18^{a} (± 3.34)	90.00^{a} (± 2.78)	90.09^{a} (± 2.90)
5	Dual purpose Breeds	BA	65.89^{e} (± 0.74)	74.58^{cd} (± 3.80)	70.24^{d} (± 5.26)
		NH	64.74^{e} (± 1.78)	66.61^{e} (± 2.79	65.67^{e} (± 2.46)
	Indigenous Breeds	OV	68.69^{de} (± 4.35)	64.40^{e} (± 3.07)	66.54^{e} (± 4.21)
		PK	72.74^{d} (± 3.14)	72.62^{d} (± 4.88)	72.68^{d} (± 3.87)
		Mean	**76.27 (± 9.69)**	**76.64 (± 9.03)**	

[12] Row means with the same superscript do not differ significantly (P>0.05)
[a-e] Column means with the same subscript do not differ significantly (P >0.05)
HS=Hyline Silver; HB= Hyline Brown; LS= Lohman Silver; LB= Lohman Brown; PK= Potchefstroom Koekoek; NH=New Hampshire; BA= Black Australorp; OV= Ovambo.

Although commercial breeds had significantly (P<0.05) higher HDP % than dual and indigenous breeds, HDP % did not differ significantly within breed categories, in the dam house, during the first month. In the control house, Lohman-Silver had a significantly (P<0.05) higher HDP % than Hyline-Silver. Dual and indigenous breeds also had significantly lower HDP % than all commercial breeds. However, New Hampshire hens had significantly (P<0.05) higher HDP % than Ovambo hens. In terms of the effect of housing system, the Hyline-Silver breed had a significantly (P<0.05) higher HDP % in the dam house than the control house.

There were no significant differences in HDP % between commercial breeds in the two housing systems, during the second month of the trial. The HDP % for Black Australorp was significantly lower than that of other dual and indigenous breeds in the dam house, but differed only with that of the New Hampshire breeds in the control house. The housing system had an effect only on indigenous breeds where the HDP % was significantly higher in the dam house than the control house.

In both housing systems, the Hyline-Silver had a significantly (P<0.05) higher HDP % than the Hyline-Brown during the third month of the trial. No significant differences occurred between the HDP% of dual and indigenous breeds in the control house, but Potchefstroom Koekoek had a significantly (P<0.05) higher HDP% than Black Australorp in the dam house.
With the exception of Lohman-Brown in the control house, all commercial breeds had a significantly (P<0.05) higher HDP% than dual and indigenous breeds during the fourth month. Hyline-Brown had significantly (P<0.05) lower HDP% than Hyline-Silver and Lohman-Silver in the dam house while Hyline-Silver and Lohman-Silver had significantly (P<0.05) higher HDP% than other commercial breeds in the control house. The New Hampshire breed in the dam house had significantly lower HDP% than indigenous breeds but no differences were detected in HDP% of dual and indigenous breeds in the control house. There was no significant housing effect observed for all laying hens during the fourth month of the trial.

During the fifth month, with the exception of Hyline-Brown in the control house, all commercial breeds had significantly higher HDP% than dual and indigenous breeds. In both housing systems, the Lohman-Silver breed had significantly (P<0.05) higher HDP% than other commercial breeds except Lohman-Brown in the dam house. In both housing systems, Hyline-Brown had significantly (P<0.05) lower HDP% than other commercial breed and did not differ significantly (P>0.05) with Black Australorp. The HDP% for Potchefstroom Koekoek was significantly (P<0.05) higher than that of dual breeds in the dam house, while both Potchefstroom Koekoek and Black Australorp had significantly higher HDP% than New Hampshire and Ovambo breeds in the control house. No significant housing system effect occurred for hen day egg production % of laying hens during the fifth month.

4.1.10. Body weight

The effect of breed and housing system on body weight of laying hens over different trial periods is depicted in Table 4.10.

Table 4.10 The effect of housing system and breed on the body weight (g) of laying hens (± standard deviation)

Period/3mths	Type	Breeds	Housing system		Mean body weight for breed
			Dam house	Control house	
Trial commencement	Commercial Breeds	HB	1.94 (± 0.10)	1.78 (± 0.10)	1.86 (± 0.12)
		HS	1.94 (± 0.08)	1.80 (± 0.08)	1.87 (± 0.11)
		LB	2.00^{1} (± 0.14)	1.76^{2} (± 0.08)	1.88 (± 0.17)
		LS	2.03 (± 0.10)	1.91 (± 0.04)	1.97 (± 0.10)
	Dual purpose Breeds	BA	2.82^{1} (± 0.13)	2.43^{2} (± 0.14)	2.62 (± 0.24)
		NH	2.45 (± 0.13)	2.36 (± 0.06)	2.41 (± 0.11)
	Indigenous Breeds	OV	2.09 (± 0.27)	2.06 (± 0.05)	2.08 (± 0.18)
		PK	2.08 (± 0.15)	1.97 (± 0.13)	2.03 (±0.16)
		Mean	**2.17 (± 0.32)**	**2.02 (± 0.26)**	
Mid-trial	Commercial Breeds	HB	1.91 (± 0.10)	1.80 (± 0.09)	1.86 (± 0.11)
		HS	1.85 (± 0.09)	1.81 (± 0.06)	1.83 (± 0.07)
		LB	1.98^{1} (± 0.11)	1.76^{2} (±0.12)	1.87 (± 0.14)
		LS	1.97 (± 0.09)	1.95 (± 0.06)	1.96 (± 0.07)
	Dual purpose Breeds	BA	2.58 (± 0.24)	2.50 (± 0.16)	2.54 (± 0.20)
		NH	2.48 (± 0.12)	2.39 (± 0.14)	2.43 (± 0.13)
	Indigenous Breeds	OV	2.04 (± 0.20)	2.08 (± 0.10)	2.06 (± 0.15)
		PK	2.04 (± 0.11)	1.95 (± 0.08)	1.99 (± 0.10)
		Mean	**2.11 (± 0.29)**	**2.04 (± 0.28)**	
Ending-period	Commercial Breeds	HB	1.94 (± 0.11)	1.82 (± 0.11)	1.88 (± 0.12)
		HS	1.91 (± 0.09)	1.79 (± 0.06)	1.85 (± 0.10)
		LB	1.97^{1} (± 0.12)	1.72^{2} (± 0.04)	1.84 (± 0.16)
		LS	1.98 (± 0.11)	1.85 (± 0.08)	1.91 (± 0.11)
	Dual purpose Breeds	BA	2.70^{1} (± 0.17)	2.44^{2}(± 0.12)	2.57 (± 0.19)
		NH	2.54 (± 0.09)	2.45 (± 0.07)	2.50 (± 0.09)
	Indigenous Breeds	OV	1.98 (± 0.26)	2.02 (± 0.11)	2.00 (± 0.19)
		PK	2.15^{1}(± 0.18)	1.90^{2} (± 0.10)	2.02 (± 0.19)
		Mean	**2.14 (± 0.32)**	**2.01 (± 0.28)**	

$^{1-2}$ Row means with the same superscript do not differ significantly (P>0.05)

HS=Hyline Silver; HB= Hyline Brown; LS= Lohman Silver; LB= Lohman Brown; PK= Potchefstroom Koekoek; NH=New Hampshire; BA= Black Australorp; OV= Ovambo.

The housing system influenced the body weight of Black Australorp and Lohman Brown hens which was significantly higher ($P<0.05$) in the dam house than in the control house at the commencement of the trial. All other breeds were not affected by the housing system on the body weight. During the mid-trial period only Lohman-Brown had a significantly higher ($P<0.05$) body weight in the dam house than in the control house. At the end of the trial-period the body weight of Black Australorp, Lohman-Brown and Potchefstroom Koekoek was significantly higher ($P<0.05$) in the dam house than at the control house.

4.1.11 Mortality

The effect of housing systems on mortality of laying hens from different breeds over the over 5 months trial period is described in Table 4.11.

Table 4.11 Effect of housing system and breed on mortality (%) of laying hens over 5 months period

Type	Breeds	Housing system		Mortality %
		Dam house	Control house	
Commercial breeds	HB	0	10	10
	HS	0	10	10
	LB	5	25	30
	LS	0	10	10
Dual purpose Breeds	BA	5	10	15
	NH	10	5	15
Indigenous Breeds	OV	5	0	5
	PK	0	5	5
	Mean%	**6.25%**	**10.71%**	**12.5%**

HS=Hyline Silver; HB= Hyline Brown; LS= Lohman Silver; LB= Lohman Brown;
PK= Potchefstroom Koekoek; NH=New Hampshire; BA= Black Australorp; OV= Ovambo.

The hens kept in the control house had a higher mortality rate than hens in the dam house. No mortalities occurred in the dam house for Hyline-Brown, Hyline-Silver, Lohman-Silver and Potchefstroom Koekoek. Only the Ovambo hens had no mortalities in the control house while Black Australorp, Hyline-Brown, Hyline-Silver and Lohman-Brown had higher mortality rates. It must be noted that 20% of the loss of Lohman-Brown hens in the control house was due to the theft.

4.2 Egg quality parameters

The results of egg quality parameters of the eggs of laying hens in different housing systems are presented in Tables 4.2.1- 4.2.5. The egg quality parameters were analyzed in laying hens with different ages, therefore it was important to look at the effect of breed in different housing system.

4.2.1 Albumen height

The effect of housing system on albumen height of eggs from laying hens of different breeds is depicted in Table 4.12.

Table 4.12 The effect of housing system and breed on albumen height (mm) of eggs (± standard deviation) from different laying hens

Interval	Types	Breeds	Housing system: Dam house	Housing system: Control house
1	Commercial Breeds	HB	7.26 (± 0.72)	7.23 (± 0.61)
		HS	6.50 (± 0.34)	6.52 (±1.03)
		LB	6.73 (± 0.37)	6.25 (±0.97)
		LS	5.57 (± 0.64)	5.78 (±0.61)
	Dual purpose Breeds	BA	4.06 (±2.39)	3.49 (±2.06)
		NH	4.82 (± 0.96)	5.61 (± 1.38)
	Indigenous Breeds	OV	4.51 (± 1.59)	4.03 (± 2.84)
		PK	5.70 (± 0.71)	5.97 (± 0.94)
2	Commercial Breeds	HB	6.47 (± 0.48)	5.83 (±0.72)
		HS	5.02 (± 0.77)	5.32 (± 1.81)
		LB	5.11 (± 0.68)	5.44 (± 0.91)
		LS	4.47 (± 0.86)	4.68 (± 0.66)
	Dual purpose Breeds	BA	4.38 (± 0.91)	4.31 (± 1.02)
		NH	4.46 (± 0.77)	5.09 (± 0.54)
	Indigenous Breeds	OV	4.65 (± 1.54)	3.91 (± 1.09)
		PK	4.90 (± 0.65)	4.28 (± 4.28)
3	Commercial Breeds	HB	8.18 (± 0.66)	8.18 (± 0.42)
		HS	7.47 (± 1.05)	7.02 (± 0.73)
		LB	7.35 (± 0.40)	7.74 (± 0.99)
		LS	7.34 (± 0.89)	6.92 (± 0.87)
	Dual purpose Breeds	BA	6.84 (± 1.07)	6.28 (± 0.80)
		NH	6.28 (± 1.15)	5.41 (± 3.23)
	Indigenous Breeds	OV	6.36 (± 1.78)	5.91 (± 0.90)
		PK	6.37 (± 0.34)	6.77 (± 0.65)
4	Commercial Breeds	HB	4.92 (± 0.20)	5.18 (± 0.50)
		HS	4.41 (± 0.33)	4.25 (± 0.59)
		LB	4.07 (± 0.44)	4.85 (± 1.10)
		LS	3.69 (± 0.56)	3.88 (± 0.62)
	Dual purpose Breeds	BA	2.82 (± 0.75)	2.53 (± 0.91)
		NH	2.73 (± 0.72)	2.99 (± 0.83)
	Indigenous Breeds	OV	1.81 (± 0.77)	2.63 (±0.96)
		PK	2.50^1 (± 0.97)	3.44^2 (± 0.48)

$^{1-2}$ Row means with the same superscript do not differ significantly (P>0.05)
HS=Hyline Silver; HB= Hyline Brown; LS= Lohman Silver; LB= Lohman Brown;
PK= Potchefstroom Koekoek; NH=New Hampshire; BA= Black Australorp; OV= Ovambo.

There was no significant difference in albumen height of eggs between the breeds except on Potchefstroom Koekoek in the fourth interval, which had significantly lower albumen height in the dam house than in the control house.

4.2.2. Haugh unit

The effect of housing system and breed on Haugh units of eggs produced by laying hens is depicted in Table 4.13

Table 4.13 The effect of housing system and breed on Haugh units of eggs from laying hens (± standard deviation)

Interval	Types	Breeds	Housing system	
			Dam house	Control house
1	Commercial Breeds	HB	83.19 (± 5.18)	82.32 (± 4.08)
		HS	80.23 (± 2.46)	79.95 (± 6.06)
		LB	80.09 (± 3.92)	77.92 (± 7.98)
		LS	73.07 (± 5.31)	73.80 (± 5.17)
	Dual purpose Breeds	BA	70.24 (±3.74)	66.25 (±3.18)
		NH	74.32 (±12.24)	72.88 (±11.92)
	Indigenous Breeds	OV	62.75 (±16.70)	67.70 (±12.47)
		PK	75.15 (± 7.05)	75.77 (± 7.02)
2	Commercial Breeds	HB	77.57 (± 1.92)	71.20 (± 9.12)
		HS	67.89 (± 7.66)	68.05 (±18.76)
		LB	68.18 (± 5.44)	71.41 (± 6.79)
		LS	63.75 (± 5.89)	64.74 (± 6.34)
	Dual purpose Breeds	BA	58.85 (± 9.39)	59.72 (± 9.99)
		NH	68.91 (± 8.37)	67.18 (± 4.19)
	Indigenous Breeds	OV	68.03 (±14.19)	71.69 (±9.96)
		PK	66.14 (± 7.14)	59.66 (±7.00)
3	Commercial Breeds	HB	87.56 (± 1.22)	90.08 (± 2.54)
		HS	83.97 (± 7.49)	82.99 (± 4.49)
		LB	85.73 (± 3.38)	86.87 (± 2.75)
		LS	85.13 (± 5.52)	82.72 (± 5.65)
	Dual purpose Breeds	BA	64.41 (±2.77)	71.52 (± 4.57)
		NH	84.68 (±5.92)	86.55 (±4.25)
	Indigenous Breeds	OV	62.52 (± 4.63)	68.73 (±7.43)
		PK	55.18 (± 6.83)	60.60 (± 6.61)
4	Commercial Breeds	HB	80.75 (± 4.53)	75.24 (± 4.97)
		HS	62.57 (± 4.56)	55.25 (±11.15)
		LB	54.71 (± 4.96)	57.95 (± 8.68)
		LS	63.79 (± 6.81)	59.02 (± 12.60)
	Dual purpose Breeds	BA	44.69 (± 4.83)	49.79 (±4.73)
		NH	44.37 (±16.65)	47.79 (±14.48)

	Indigenous Breeds	OV PK	63.33 (±10.67) 47.68 (± 6.91)	65.98 (± 7.73) 48.66 (± 5.47)

$^{1-2}$ Row means with the same superscript do not differ significantly (P>0.05)
HS=Hyline Silver; HB= Hyline Brown; LS= Lohman Silver; LB= Lohman Brown; PK= Potchefstroom Koekoek; NH=New Hampshire; BA= Black Australorp; OV= Ovambo.

The breed and housing system did not affect Haugh unit of laying hens significantly.

4.2.3. Egg shell strength

The effect of housing system on egg shell strength of eggs produced by laying hens of different breeds is shown in Table 4.14

Table 4.14 The effect of housing systems and breed on egg shell strength (N) of laying hens (± standard deviation)

Interval	Types	Breeds	Housing system	
			Dam house	Control house
1	Commercial Breeds	HB	40.35 (±10.57)	34.60 (±8.47)
		HS	31.98 (± 1.64)	35.86 (±2.96)
		LB	41.58 (±7.72)	41.49 (±9.37)
		LS	41.96 (± 4.21)	39.97 (±7.58)
	Dual purpose Breeds	BA	43.57 (±18.74)	29.63 (± 20.35)
		NH	34.18 (±2.77)	37.05 (± 1.56)
	Indigenous Breeds	OV	36.06 (±10.80)	42.26 (± 7.87)
		PK	28.05 (± 9.73)	25.99 (±9.06)
2	Commercial Breeds	HB	30.28 (± 6.30)	28.07 (± 9.49)
		HS	30.53 (±10.62)	30.07 (±5.83)
		LB	37.80 (± 5.88)	36.21 (± 7.87)
		LS	42.71 (± 3.08)	39.72 (± 3.44)
	Dual purpose Breeds	BA	27.42 (±18.76)	27.99 (±18.41)
		NH	29.24 (±14.89)	29.07 (±4.20)
	Indigenous Breeds	OV	44.04 (± 10.73)	32.83 (±7.24)
		PK	42.23 (± 10.99)	37.70 (±12.44)
3	Commercial Breeds	HB	27.19 (± 5.21)	29.90 (± 3.52)
		HS	34.50 (± 5.81)	35.76 (± 4.22)
		LB	42.65 (± 2.93)	41.39 (± 6.92)
		LS	41.61 (± 2.19)	36.74 (± 6.32)
	Dual purpose Breeds	BA	34.29 (± 6.99)	36.30 (±3.13)
		NH	35.36^{1} (±4.89)	18.91^{2} (±14.27)
	Indigenous Breeds	OV	50.05 (±9.67)	40.25 (± 5.60)
		PK	37.61 (±8.76)	45.17 (± 4.55)

4	Commercial Breeds	HB HS LB LS	26.11 (±3.08) 26.37 (± 3.61) 34.78 (± 5.84) 40.51 (± 2.04)	28.14 (± 6.83) 26.86 (± 0.78) 30.19 (± 7.08) 40.89 (± 7.46)
	Dual purpose Breeds	BA NH	31.87 (±14.68) 26.85 (±8.32)	33.71 (±15.94) 29.57 (±14.56)
	Indigenous Breeds	OV PK	34.71 (±11.37) 41.07 (±7.12)	31.06 (±10.03) 28.25 (± 5.14)

[1-2] Row means with the same superscript do not differ significantly (P>0.05)
HS=Hyline Silver; HB= Hyline Brown; LS= Lohman Silver; LB= Lohman Brown; PK= Potchefstroom Koekoek; NH=New Hampshire; BA= Black Australorp; OV= Ovambo.

The egg shell strength of eggs from New Hampshire hens was significantly (P<0.05) lower in the dam house than the control house during the third interval.

4.2.4. Specific gravity

The effect of housing system on specific gravity of eggs produced by different breeds in different housing systems is Table 4.15

Table 4.15 The effect of housing system and breed on specific gravity (g/cm^3) of eggs from laying hens (± standard deviation)

Interval	Types	Breeds	Housing system	
			Dam house	Control house
1	Commercial Breeds	HB HS LB LS	1.087 (±0.003) 1.085 (± 0.485) 1.089 (± 0.002) 1.089 (± 0.000)	1.087 (± 0.003) 1.0830 (±0.484) 1.087 (± 0.002) 1.090 (± 0.000)
	Dual purpose Breeds	BA NH	1.081 (± 0.002) 1.082 (± 0.003)	1.083 (± 0.002) 1.084 (± 0.003)
	Indigenous Breeds	OV PK	1.085 (± 0.003) 1.083 (± 0.003)	1.083 (± 0.003) 1.084 (± 0.004)
2	Commercial Breeds	HB HS LB LS	1.084 (± 0.001) 1.086 (± 0.002) 1.086 (± 0.002) 1.087 (± 0.002)	1.082 (± 0.006) 1.087 (± 0.002) 1.085 (± 0.002) 1.088 (± 0.002)
	Dual purpose Breeds	BA NH	1.079 (± 0.002) 1.079 (± 0.483)	1.083 (± 0.484) 1.081 (± 0.004)
	Indigenous Breeds	OV PK	1.077[1] (± 0.596) 1.080 (± 0.003)	1.086[2] (± 0.004) 1.080 (± 0.006)
	Commercial Breeds	HB HS LB LS	1.085 (± 0.003) 1.087 (± 0.003) 1.087 (± 0.004) 1.087 (± 0.002)	1.086 (± 0.004) 1.088 (± 0.002) 1.088 (± 0.002) 1.089 (± 0.487)

3	Dual purpose Breeds	BA NH	1.084 (± 0.005) 1.083 (± 0.593)	1.084 (± 0.484) 1.084 (± 0.003)
	Indigenous Breeds	OV PK	1.088 (± 0.485) 1.085 (± 0.003)	1.086 (± 0.486) 1.087 (± 0.003)
4	Commercial Breeds	HB HS LB LS	1.090 (± 0.000) 1.088 (± 0.002) 1.090 (± 0.000) 1.090 (± 0.000)	1.089 (± 0.003) 1.090 (± 0.000) 1.087 (± 0.003) 1.089 (± 0.002)
	Dual purpose Breeds	BA NH	1.088 (± 0.004) 1.087 (± 0.486)	1.087 (± 0.004) 1.089 (± 0.002)
	Indigenous Breeds	OV PK	1.080 (± 0.593) 1.085 (± 0.004)	1.090 (± 0.486) 1.087 (± 0.486)

$^{1-2}$ Row means with the same superscript do not differ significantly (P>0.05)
HS=Hyline Silver; HB= Hyline Brown; LS= Lohman Silver; LB= Lohman Brown; PK= Potchefstroom Koekoek; NH=New Hampshire; BA= Black Australorp; OV= Ovambo.

The specific gravity of Ovambo breed was significantly (P<0.05) lower in the dam house than the control house during the second interval. There was no effect of housing system in specific gravity for all other breeds throughout all the intervals.

4.2.5. Meat and blood spots

The effect of housing system and breed on meat and blood spots in eggs of laying hens is depicted in Table 4.16

Table 4.16 The effect of housing system and breed on meat and blood spots in eggs produced by laying hens (± standard deviation)

Interval	Types	Breeds	Housing system	
			Dam house	**Control house**
1	Commercial Breeds	HB HS LB LS	0.10 (± 0.14) 0.30 (±0.21) 0.45 (± 0.21) 0.25 (± 0.31)	0.20 (± 0.21) 0.40 (± 0.29) 0.25 (± 0.31) 0.35 (± 0.29)
	Dual purpose Breeds	BA NH	0.15 (± 0.14) 0.15 (± 0.14)	0.10 (± 0.14) 0.15 (± 0.22)
	Indigenous Breeds	OV PK	0.15 (± 0.22) 0.25 (± 0.18)	0.10 (± 0.22) 0.30 (± 0.27)
2	Commercial Breeds	HB HS LB LS	0.25 (± 0.11) 0.25 (± 0.14 0.55 (± 0.29) 0.50 (± 0.21	0.02 (± 0.11) 0.15 (± 0.14) 0.35 (± 0.29) 0.45 (± 0.21)
	Dual purpose Breeds	BA NH	0.20 (± 0.29 0.25 (± 0.25)	0.35 (± 0.29) 0.25 (± 0.25)

	Indigenous Breeds	OV PK	0.20 (± 0.29) 0.45 (± 0.21)	0.35 (± 0.29) 0.20 (± 0.21)
3	Commercial Breeds	HB HS LB LS	0.15 (± 0.14) 0.30 (± 0.21) 0.50 (± 0.25) 0.25 (± 0.18)	0.25 (± 0.25) 0.45 (± 0.21) 0.25 (± 0.25) 0.25 (± 0.18)
	Dual purpose Breeds	BA NH	0.40 (± 0.34) 0.15 (± 0.14)	0.15 (± 0.22) 0.20 (± 0.21)
	Indigenous Breeds	OV PK	0.15 (± 0.14) 0.35 (± 0.42)	0.35 (± 0.14) 0.25 (± 0.25)
4	Commercial Breeds	HB HS LB LS	0.25 (± 0.18) 0.50 (± 0.31) 0.45 (± 0.27) 0.55 (± 0.21)	0.45 (± 0.41) 0.50 (± 0.35) 0.40 (± 0.29) 0.50 (± 0.18)
	Dual purpose Breeds	BA NH	0.25 (± 0.25) 0.20 (± 0.21)	0.35 (± 0.29) 0.30 (± 0.21)
	Indigenous Breeds	OV PK	0.30 (± 0.21) 0.40 (± 0.14)	0.45 (±0.21) 0.50 (± 0.18)

[1-2] Row means with the same superscript do not differ significantly (P>0.05)
HS=Hyline Silver; HB= Hyline Brown; LS= Lohman Silver; LB= Lohman Brown; PK= Potchefstroom Koekoek; NH=New Hampshire; BA= Black Australorp; OV= Ovambo.

The housing system did not influence the occurrence of meat and blood spots in eggs of laying hens of different breeds.

4.3 Economic efficiency of laying hens from different breeds in two different housing systems

Economic performance of laying hens was measured by subtracting the total cost of layers and feed from the total income of egg and spent layer sales, as described by Das *et al.* (2003).

Table 4.17 Economic efficiency of poultry layer production using commercial breeds compared with indigenous and dual purpose breeds

4.3.1 Expenditure

1.Breed	Number of birds/breed	Unit price/layer	Total cost
Hyline-Brown	40	@R41.38/hen	1655.28
Hyline-Silver	40	@R48.10/hen	1924.00
Lohman-Brown	40	@R45.60/hen	1824.00
Lohman-Silver	40	@R45.60/hen	1824.00
Black Australorp	40	@R30/hen	1200.00
New Hampshire	40	@R30/hen	1200.00

Potchefstroom Koekoek Ovambo	40 40	@R30/hen @R30/hen	1200.00 1200.00
Total chicks cost			**R12027.28**
2. Breed	**Number of feed bags/breed**	**Unit price/ bag**	**Cost/breed**
Hyline-Brown Hyline-Silver Lohman-Brown Lohman-Silver	17.90bags 17.90bags 15.92 bags 17.90 bags	@ R181.00/50kg bag @ R181.00/50kg bag @ R181.00/50kg bag @ R181.00/50kg bag	3239.90 3239.90 2881.52 3239.9
Black Australorp New Hampshire	17.99 bags 17.81 bags	@ R181.00/50kg bag @ R181.00/50kg bag	3256.19 3223.61
Potchefstroom Koekoek Ovambo	17.36 bags 17.71 bags	@ R181.00/50kg bag @ R181.00/50kg bag	3142.16 3205.51
Total feed cost			**R25428.24**
Total expenditure (feed + chickens)			**R37455.97**

4.3.2 Income

1. Spent layers	**Number of birds sold/breed**	**Unit price/ hen**	**Income/breed**
Hyline-Brown Hyline-Silver Lohman-Brown Lohman-Silver	38 38 34 38	@R30 @R30 @R30 @R30	R1140 R1140 R1020 R1140
Black Australorp New Hampshire	37 37	@R30 @R30	R1110 R1110
Potchefstroom Koekoek Ovambo	39 39	@R30 @R30	R1170 R1170
Total income of layers			**R 9 000**
2.Eggs sold /breed	**Number of eggs/size/breed**	**Price/30eggs/size**	**Income/breed/ egg size**
Hyline-Brown Medium Large X-Large Jumbo	 156 2579 1392 110	 @ R32.00/30eggs @R28/30eggs @ R38.99/30eggs @R40/30eggs	 R166.40 R2407.07 R1809.13 R146.67 **R4529.27**
Hyline-Silver Medium Large X-Large	 968 3283 437	 @ R32.00/30eggs @R28/30eggs @ R38.99/30eggs	 R1032.53 R3064.13 R567.95 **R4664.61**
Lohman-Silver Medium	 935	 @ R32.00/30eggs	 R997.30

Large	3269	@R28/30eggs	R3051.06
X-Large	431	@ R38.99/30eggs	R560.16
			R4608.52
Lohman-Brown			
Medium	156	@ R32.00/30eggs	R166.40
Large	2699	@R28/30eggs	R2519.06
X-Large	905	@ R38.99/30eggs	R1176.2
Jumbo	76	@R40/30eggs	R101.33
			R3962.99
Black Australorp			
Medium	173	@ R32.00/30eggs	R184.53
Large	1938	@R28/30eggs	R1808.80
X-Large	173	@ R38.99/30eggs	R224.84
			R2218.17
New Hampshire			R69.33
Medium	65	@ R32.00/30eggs	R1766.80
Large	1893	@R28/30eggs	R83.18
X-Large	64	@ R38.99/30eggs	**R1919.31**
Potchefstroom Koekoek			
Medium	548	@ R32.00/30eggs	R584.53
Large	1989	@R28/30eggs	R1856.40
X-Large	157	@ R38.99/30eggs	R204.05
			R2644.98
Ovambo			
Medium	214	@ R32.00/30eggs	R228.27
Large	1882	@R28/30eggs	R1756.53
X-Large	514	@ R38.99/30eggs	R668.03
			R2652.83
Total income of eggs			**R27200.68**
Total income (eggs + spent layers)			**R32872.52**

4.3.3 Profit

Breed	**Income/breed(egg + spent layer)**	**Expenditure/breed (feed + layer cost)**	**Profit/Breed (income – expenditure)**
Hyline-Brown	R5669.27	R4895.18	R774.09
Hyline-Silver	R5804.61	R5163.61	R640.71
Lohman-Brown	R4982.99	R4705.52	R277.47
Lohman-Silver	R5748.52	R5063.9	R684.62
Black Australorp	R3328.17	R4456.19	-R1128.02
New Hampshire	R3029.31	R4423.61	-R1394.3
Potchefstroom Koekoek	R3783.25	R4342.16	-R558.91
Ovambo	R3854.57	R4405.51	-R550.94
Total	**R32872.52**	**R37455.97**	**R2376.89**

In terms of economic efficiency of the different breeds, commercial breeds were more profitable than all the other breeds. The dual purpose and indigenous breeds showed a negative profit. All the breeds were bought at different prices from different suppliers and were sold as spent layers after production at the same price. More eggs were sold from commercial breeds than dual purpose and indigenous breeds.

CHAPTER 5

Discussion

The type of housing system can affect production of laying hens (Reiter and Kurtz, 2001). In a study of integrated duck-cum-fish farming in Bangladesh egg production was adversely affected by storms and heavy rains (Latif *et al.,* 1993). Edwards *et al.* (1983) also reported poor laying rates during the rainy season and in very hot weather in Thailand. In the current study, the overall egg production did not differ between housing systems. However, breed and house interactions were observed only in the Ovambo breed during the first month where hens in the dam house produced more eggs than those in the control house. This confirms the results reported by Little and Satapornavit (1995) showing that confining poultry next to or over water can also improve their productivity under tropical conditions. During the second month both Potchefstroom Koekoek and Ovambo hens produced more eggs in the dam house than in the control house. This could be attributed to the adaptation of these two breeds in the second month and the more favourable environmental conditions in the dam house during very hot days, thus improving their production (Falayi, 1998).

As expected, the commercial breeds produced more eggs than the dual-purpose and indigenous breeds, of which the Potchefstroom Koekoek performed the best. This is in agreement with studies by Prinsloo *et al.* (1999) who reported high total egg production for Hyline Silver kept in in an integrated chicken-fish farming systems in Limpopo Province, South Africa. Singh *et al.* (2009) reported that Lohman White and Lohman Brown hens produced more eggs than non-commercial crosses between Rhode Island Red and Barred Plymouth Rock. Roushdy *et al.* (2008) also reported higher egg production by Hyline commercial chickens than Fayoumi and Dandarawi breeds (Egyptian native breeds). The genetic superiority of commercial breeds is also illustrated in ducks (Edwards, 1983; Sharma, 1989; Latif *et al.*, 1993; Das *et al.*, 2003). The results of this study are in agreement with the study by Van Marle-Koster and Casey (2001) showing the higher egg production over a production cycle of 51 weeks by Potchefstroom Koekoeks compared to Naked Neck, Venda and Ovambo hens, all kept in a battery cage system. Similar results were also reported by Grobbelaar *et al.* (2010) for a 52 weeks production cycle in a floor system. This confirms the high egg production potential of Potchefstroom Koekoek hens amongst the South African indigenous breeds, which are known for its lower egg production.

Breed and month interactions were observed in the dam house on Potchefstroom Koekoek hens during the second, third, fourth and fifth months of the trial, where their egg production did not differ significantly with that of the commercial breeds. Egg production for Potchefstroom Koekoek differed to that of the Ovambo hens during the fourth and fifth months. Theimsiri (1992) suggested that evaporative cooling water from the pond can reduce heat stress in broilers, which can increase egg production in laying hens. Hyline-Brown produced fewer eggs than other breeds during the fourth month while Black Australorp hens produced the least among all the breeds. The lower egg production of these breeds might be due to the heat stress in the control house that caused lower feed intakes and subsequently lower egg production.

The results of the current study indicated that the egg weights of laying hens were not affected by the housing systems over the five month trial period. Egg weight is influenced by the breed of laying hens (Halaj *et al.*, 1998). Moula *et al.* (2009) also reported lower egg weights for the Ardennaise and Famennoise (indigenous) breeds compared to the Lohman strain (commercial). Commercial breeds produced heavier eggs than the indigenous breeds, although within breed differences occurred between brown and white lines. The brown lines in this study produced heavier eggs than the white lines which are in line with Preisinger (2000) reporting Lohman-Brown strains with heavier eggs of 65.4g than Lohman-White strains with lighter eggs of 63.1g. The heavier egg weight of the brown lines is due to the selection for this trait by the breeders.

The lower egg weight of indigenous hens in this study is in line with the results by Adetayo and Babafunso (2001) reporting that the mean egg mass of the Nigerian indigenous chickens was 36.8g. Gueye (1998) also reported that the mean egg mass of the indigenous chickens in Ethiopia was 40g using an intensive system during trials conducted at the Jimma College of Agriculture. Furthermore, Nhleko *et al.* (2003) also reported that the mean mass of eggs collected from indigenous chickens from subsistence households in the rural district of Paulpietersburg, north-eastern Kwazulu-Natal, South Africa, was 48.9g while Iqbal *et al.* (2009) reported egg weights of indigenous chickens of Kashmir in India of 46.06g. However, contrasting results were reported for ducks by Das *et al.* (2003) where similar egg weights were observed between commercial and indigenous duck breeds kept in an integrated fish farming system. Our results also indicated that Potchefstroom Koekoek hens produced heavier eggs than Ovambo and dual purpose hens.

The monthly variations in egg weights of laying hens in different housing systems observed in this study could be due to the late sexual maturity of the indigenous breeds (Melesse *et al.*, 2010), or selection for high egg weight in the commercial breeds. However, egg weight is said to be largely affected by environmental factors, food restriction and parental average body weight (Shaler and Pasternak, 1993). Differences in the current study could therefore be attributed to these factors but evidence of genetic involvement including breed effect could also be observed.

The results showed that housing systems and breed did not affect feed intake of laying hens in the current study throughout the whole trial period. Das *et al.* (2003) reported that the Indian runner (IR), Khaki Campbell (KC) and Zending (Z) ducks in integrated fish-duck farming systems were fed the same diet at 115g/duck/day and no significant differences in feed intake were observed between breeds. In the current study, laying hens were given the same feed at 150g/hen/day and all breeds finished all the feed in both housing systems. However, most studies reported a significant effect of housing systems on feed intake of laying hens (Yakubu *et al.*, 2007). Farooq *et al.* (2002) also stated that feed intake is a variable phenomenon and is influenced by several factors such as strain of the bird, energy content of the diet, ambient temperature, density of birds in the shed, hygienic conditions and rearing environment.

The results of the current study indicated a strong relationship between egg weight and feed efficiency in commercial breeds, as they ate more feed and produced heavier eggs which mean they converted feed efficiently. Although all the breeds had the same high feed intakes, the indigenous and dual purpose breeds had poor conversion efficiencies possibly because of genetic differences in physical activity, physical condition, basal metabolic rate, body temperature and body composition (Singh *et al.*, 2009).

Feed conversion can be influenced by the housing system. Feed conversion is poorer in aviary and free range systems than in cages (Hughes *et al*., 1985; Van Horne and Van Niekerk, 1998). In alternative housing systems, hens have to use some of their energy for heat production (Preisinger, 2000) and movement, because of lower stocking densities and sometimes lower temperatures in these systems. This leads to higher feed consumption and unfavorable feed conversion. The differences in feed conversion ratio is related to the strain, possibly because of the genetic differences in the physical activity, physical condition, basal metabolic rate, body temperature and body composition (Singh *et al*., 2008). In the current study, the FCR of Black Australorp hens were poorer in the dam house than in the control house during the five month trial period. This could be attributed to the unfavourable climatic conditions in the dam house. In contrast, Ovambo hens had a better FCR in the dam house than at the control house during the five month trial period which is in agreement with previous studies by Barash *et al*. (1982) and Falayi (1998) who reported a better feed conversion ratio on ducks integrated with fish than those on land. The authors further explained that the environmental condition of the house on top of the dam improved performance of ducks due to the evaporative cooling and cleanness of water from the integrated fish farming system. The results of the current study are supported by the findings of Falayi (1998). A better FCR was also reported in the study by Das *et al*. (2003) on three different duck genotypes integrated with fish.

During the first month, FCR of the dual purpose breeds and Ovambo breed on the dam was poor compared to the control house. In this case, it could be that the dual purpose and Ovambo breeds did not utilise the feed consumed efficiently for egg production. However, according to Little and Satapornavit (1995), these hens might have pecked more on their feed than other breeds so that more of the feed got spilled over the dam water. The commercial breeds had a better FCR than all the other breeds, both in the dam house and also in the control house. This could be due to their genetic potential of efficiently converting their feed consumed into eggs.

During the second month, FCR was poor for Black Australorp at the dam house than at the control house. It shows that the breed was performing not as good under the integrated farming system (dam house) than at the control house during this month. Literature is not available to support this finding. The inverse occurred in the Potchefstroom Koekoek with a better FCR at the dam than control house due to environmental conditions that was more favourable for the breed to be productive. During the third month, the commercial breeds also had a better FCR than all the other breeds in both housing systems.

During the fourth and fifth months the FCR of the commercial breeds was better than all the other breeds. However, better conversion ratios in indigenous chicken have been reported in cases where they were provided with commercial feeds (Kingori *et al*., 2003).

The commercial breeds had higher HDP % than all the other breeds throughout the trial. This is due to their higher genetic potential for egg production. The current result is supported by Farooq *et al*. (2002) reporting that strain of the chicken and rearing system had a significant effect on hen-day egg production percentage. The above authors reported that Hisex was more persistent in percentage hen-day production percentage than Nick-chick. Differences in hen-day egg production percentage among various strains of chicken were also reported by North (1984) and Lai and Kan (2000).

During the first month HDP% of Hyline-Silver and the indigenous breeds during the second month was higher at the dam house than at the control house, probably because the environment was favourable for the breeds to be more efficient in production. The result of the current study is in line with the findings of Rashed Hasnath (2002). However, studies by Badudi and Ravindran (2004) demonstrated a strong and positive correlation between daily feed intake and hen day production.

The results of the current study showed that Lohman-Brown hens in the dam house had higher body weights during all three periods of the study than those in the control house. The Potchefstroom Koekoeks showed similar trends at the end of the trial. This shows that these breeds were adjusting well in the dam house and that the environment at the dam house was conducive for the laying hens, which improved body weight (Little and Satapornavit, 1995). These results are in agreement with the study by Barash *et al*. (1982) who reported that ducks integrated with fish over the pond had higher body weights than the ducks in a normal system on land. Koeypudsa *et al*. (2005) also reported an increased body weight for broilers in a dam house (from 1.32kg ± 0.19 to 4.22kg ± 0.48 x10^3) compared to broilers in a control house which increased their weights from 1.33kg ± 0.20 to 3.64kg ± 0.57 x 10^3. In contrast Das *et al*. (2003) reported a similar body weight gain in three different duck genotypes in integrated duck-fish farming system.

The results of the current study shows a lower percentage of mortality in laying hens kept in an integrated chicken-fish farming system than in a battery cage system on land. This could be due to the conducive and favourable environmental conditions for laying hens at the dam house than the control house. The current result is supported by Barash *et al*. (1982) who reported a lower 3.5% increase in mortality rate of ducks in integrated duck-fish farming system than ducks kept in pens. Prinsloo and Schoombie (1999) also reported zero mortality of Hyline-Silver hens in a 200 days period in the production of poultry in integrated aquaculture agriculture systems trial with no control. However, the results by Das *et al*. (2003) indicated a similar mortality rate for different duck genotypes in integrated duck-fish farming system without a control.

There is limited information on egg quality of laying hens in integrated fish farming systems. The Haugh unit is an expression relating egg weight and height of thick albumen. The higher the Haugh unit, the better the egg quality. Egg quality has a genetic basis and its parameters vary between strains of hens (Silversides *et al*., 2007) and is also influenced by the housing system under which the hens are kept (Vits *et al*., 2005; Sekeroglu *et al*., 2010). The results of the present study showed no significant effect of housing systems on egg quality parameters of laying hens i.e. albumen height, Haugh unit, specific gravity, shell strength, as well as blood and meat spots. The results of this study are in line with the report by Englmaierová and Tumanová (2009).

Finally, the commercial breeds provided a higher profit from egg sales and spent layers income compared to indigenous and dual purpose breeds. In general, Potchefstroom Koekoek showed the potential to produce more eggs than the other dual purpose and indigenous breeds, which is in agreement with reports by Van Marle-Koster and Casey (2001) and Grobbelaar *et al*. (2009).

Conclusion

The main objective of the study was to identify the best performing chicken layer breed for an integrated fish farming system. The hypothesis of this study was that the production performance of different laying hens kept under integrated layer-fish farming system and conventional battery cage will not differ.

The first objective was to compare the egg production, body weight, mortality rate, feed conversion ratio, feed intake and hen-day production % of different layer breeds kept under an integrated fish farming system with those kept in a normal battery system situated on land. Results of this study showed that the type of housing affected the performance of some breeds of layers over time. It is concluded that commercial breeds had superior performance compared to dual and indigenous breeds for most variables, such as egg production, egg weight, FCR and HDP%.

In terms of body weight, Black Australorp and Potchefstroom Koekoek had higher body weights in the dam house than control house, indicating that higher carcass weight per kilogram will be attained thus increasing profit when selling spent hens. It is concluded that this parameter will enhance viability of the integrated fish and chicken production systems.

The second objective was to compare the egg quality of eggs from layer breeds kept under an integrated fish farming system with those kept in a normal battery system. In contrast to other results, Potchefstroom Koekoek hens had significantly lower albumen height than all the other breeds, in the dam house. It is concluded that eggs from this breed will have shorter shelf life than those of other breeds, under the integrated systems.

Only New Hampshire hens showed lower egg shell strength in the dam house than control house. It is therefore concluded that the eggs of this breed may be more susceptible to cracking when used in an integrated fish and chicken production system which might result in an economic loss.

The third objective was to determine the economic efficiency of the different chicken layer breeds. The commercial breeds gave the highest economic returns and were followed by the Potchefstroom Koekoek. This indigenous breed can therefore be regarded as the most economically viable among the different dual and indigenous breeds for use in integrated fish farming system.

The null hypothesis that the performance of different breeds in two housing systems do not differ is therefore rejected, and the alternate hypothesis that one or more laying hens are more suitable for use in an integrated fish farming system is accepted.

Recommendations

It is recommended that the commercial breeds be used in integrated fish farming system because of its economic viability and returns. It is also recommended that the layer chicken breed that can be used under integrated chicken-fish farming system should be a breed that can realise the highest profit to add on the economic viability of the whole integrated chicken-fish farming system. It is recommended that the system needs proper skills and management for both farming enterprise for the profitability of the system. It is recommended that much more research is done on the Potchefstroom Koekoek's potential kept in intensive management systems. The dual and indigenous breeds should not be used in the integrated chicken fish farming system, because it proofed to be less profitable.

CHAPTER 6

References

AFE, Agricultural and Food Engineering, 1992. Final report-Muscovy duck project : The development of economic feeding systems for Muscovy ducks (*Cairhina moschata*) in duck/fish integration in Thailand (15 May 1988 - 31 December 1991). Agricultural and Food Engineering, Asian Institute of Technology.

AASP, Agricultural and Aquatic Systems Program, 1996. Final technical report-IDRC: The development of feeding systems for fish and an integrated duck-fish system (30 December 1991 - 31 April 1996). Agricultural and Aquatic Systems Program, School of Environment, Resources and Development, Asian Institute of Technology.

Abdelqader, A., Wollny, C.B.A. & Gauly, M., 2007. Characterization of local chicken production system and potential under different level of management practice in Jordan. T*ropic. Anim. Health Prod.* 39, 55-164.

Adetayo, A.S. & Babafunso, S.E., 2001. Comparison of the performance of Nigerian indigenous chickens from three agro-ecological zones. *Livest. Res. Dev*. 13, 2.

Ahmadi, F. & Rahimi, F., 2011. Factors affecting quality and quantity of egg production in laying hens: A review. Department of Animal Science, Faculty of Nursing and Obstetric, Islamic Azad University, Sanandaj Branch, Kurdistan, Iran. *World Appl. Sci. J.* 12, 372-384.

Ahmed, M. & Lorica, M.H., 1999. Improving developing country food security through aquaculture development: socioeconomic and policy issues. Paper Presented at World Aquaculture 99, the Annual International Conference and Exposition of the World Aquaculture Society, Sydney, Australia, 26 April-2 May.

Ahn, D., 2011. Egg components. Animal Science Department. Iowa State University http://docs.google.com/viewer?a=v&q=cache:aDq0T4hVn8EJ/Egg%2520Components.

Akinokun, O. & Dettmers A., 1977. Performance of the indigenous chickens of Nigeria and the Apollo. Egg weight, rate of production and factors affecting them. *Niger. J. Anim. Prod.* 4, 67-79.

Alkan, S., Karabag, K., Galic, A. & Soner Balcioglu. A., 2008. Predicting yolk height, yolk width, albumen length, eggshell weight, egg shape index, eggshell thickness, egg surface area of Japanese Quails using various eggs traits as regressors. *Int. J. Poult. Sci.*7, 85-88.

Alleoni, A.C.C., 2006. Review on albumen protein and functional properties of gelation and foaming. Scientific Agriculture (Piracicaba. Braz.), 63, Piracicaba May/June 2006.

Alleoni, A.C.C. & Antunes, A.J., 2004. Albumen foam stability and s-ovalbumin contents in the eggs coated with whey protein concentrate. Revista Brasileira de Ciência Avícola. 6, 77-82.
Alzu, 2009. Chemical composition of layer diet.

Anang, A., Mielenz, N. & Schüler, L., 2000. Genetic and phenotypic parameters for monthly egg production in White Leghorn hens. *J. Anim. Breed. Genet.* 11,407-415.

Anon., 1989. United States Department of Agriculture Nutrition Information Service. Handbook 8, Supplement. National Academies Press, Washington, DC.

Anonymous., 1987. Manual of poultry production in the Tropics, CAB International.

Ansa, E.J. & Jiya, J., 2002. Effect of pig manure on the growth of *Oreochromis niloticus* under integrated Fish cum-pig faming system. *Aquacult. Sci.* 17, 85-87.

Appleby, M.C. & Hughess, B.O., 1991. Welfare of laying hens in cages and in alternative systems-environmental, physical and behavioural- aspects. *World's Poult. Sci, J.* 47,109-128.

Applegate, E., 2000. Introduction: Nutritional and functional roles of eggs in diet. *J. Am. Coll. Nutr.* 19, 495-498.

Arad, Z., Marder, J. & Soller, M., 1981. Effect of gradual acclimatization to temperature up to 44°C on productive performance of the desert Bedouin fowl, the commercial white Leghorn and the two crossbreds. *Brit. Poult. Sci.* 22, 511-520.

Asala, G.N., 1994. Principles of integrated aquaculture. In: Olatunde A.A; Ayeni J.S.O and Ogunsuyi I.M (eds), Proceedings of the Nat. Fisheries workshop on aquaculture development, fish seed production and post-harvest tech. NIFFR-FACU 1994, pp. 206-220.

Atay, D. & Demir, N., 1998. The effects of chicken manure on the phytoplankton primary production in carp ponds. *Acta Hydrobiol.* 40, 215-225.

Ayinla, O.A., 2003. Integrated fish farming: A veritable tool for poverty alleviation/ Hunger eradication in the Niger Delta Region. In Eye A.A and Atanda J.O (eds). Conference Proceedings of Fisheries Society of Nigeria, Owerri, Nigeria, pp.40-41.

Ayyagari, V., Mohapatra, S.C., Venkatramaiah, A., Thiagasundaram, T., Choudhuri, D., Johri, D. C. & Renganathan, P., 1980. Selection for egg production on part records. Part 1: Evaluation of short term response to selection. *Theor. Appl. Gen.* 57, 277-283.

ARC, 2006. The indigenous poultry breeds of SA.

Badubi, S.S., Ravindran, V. & Reid, J., 2004. A survey of small scale broiler production systems in Botswana. *Trop. Anim. Health. Prod.* 36, 823-834.

Bain, M., 1990. Eggshell strength: A mechanical ultra-structural evaluation. PhD. Thesis. University of Glasgow, Scotland, UK.

Balnave, D., Gill, R.J., Li, X. & Bryden, W.L., 2000. Responses of Isa Brown laying hens to a pre-layer diet containing additional calcium and to dietary protein and lysine concentrations during lay. *Austr. J. Agric. Res.* 51, 779-784.

Banerjee, R.K., Ray, P., Singit, G.S. & Dutta, B.R., 1979. Poultry droppings-Its manorial potentiality in aquaculture. *Inland Fish. Soc.* 2, 94-108.

Barash, H., Plavnik, I. & Moav, R., 1982. Integration of duck and fish farming: Experimental results. *Aquacult.* 27, 129-140.

Beckman, B. & Grieve D., 1999. Influence of disease on egg quality. Egg industry.

Bedford, M. & Mowbray, D., 1998. Net Worth: Research with the rural women of Bangladesh. CGIAR Gender Program, Washington, DC, USA.

Bollengierlee, S., Mitchell, M.A., Utomo, D.B., Williams, P.E.V. & Whitehead, C.C., 1998. Genetic variation of egg production, egg quality and bone strength in selected and traditional breeds of laying fowl. *Brit. Poult. Sci.* 39, 106-112.

Boorman, K.N., Volynchook, J.G. & Belyavin, C.G., 1989. Egg shell formation and quality. In: Recent developments in poultry nutrition. Eds: Cole, D.J.A & Haresign, W. Butterworths, Kent, England.

Brooks, J. & Hale, H.P., 1959. The mechanical properties of the thick white of the hen's egg. *Bioch. Biophys. Acta.* 32, 237-250.

Brown, E. E., 1983. World fish farming: Cultivation and economics. *Avi Publishing Co* (USA), 263- 426.

Butcher, G. D. & Miles, R. D., 2003. Concepts of eggshell quality. University of Florida. http://edis.ifas.ufl.edu/pdffiles/VM/VM01300.pdf

Butler, E.J., Curtis, M.J., Pearson, A.W. & McDougall, J.S., 1972. Effect of infectious bronchitis on the structure and composition of egg albumen. J. *Sci. Food Agric.* 23, 359-369.

Carter, T.C., 1970. Why do egg shells crack? *World Poult.Sci. J.* 26, 549-561.

Chen, F.Y., 1989. Chicken farming in integrated fish farming. Regional Aquaculture, Centre Wuxi China. *NACA Technical Manual.* 11, 4-30.

Coche, A.G., 1967. Fish culture in rice fields. A worldwide synthesis. *Hydrobiol.* 30, 1-44.

Coetzee, C., 2002. The effect of elevated calcium levels in drinking water on shell integrity. *Spesfeed News*, Summer 2002.

Coutts, J.A. & Wilson, G.C., 1990. Egg quality. Handbook. Queensland Department of Primary Industries, Australia.

Coutts, J.A., Wilson, G.C., Fernandez, S., Rasales, E., Weber, G. & Hernandez, J.M., 2006. Optimum egg quality-A practical approach. 5M Publishing: Shefield UK, 63.

Csavas, I., 1992. Regional review on livestock-fish production systems in Asia. In Mukherjee, T.K., Moi, P.S., Panandam, J.M., and Yang, Y.S. (Eds.), Proceedings of the FAO/IPT Workshop on integrated livestock-fish production systems, 16-20 December 1991, Institute of Advance Studies, University of Malaya, Kuala Lumpur, Malaysia.

Curtis, P.A., Gardner, F.A. & Mellor, D.B., 1995. A comparison of selected quality and compositional characteristics of brown and white shell eggs. I. Shell quality. *Poult. Sci.* 64, 297-301.

Cunningham, L.D., 2004. Maintaining egg quality. University of Georgia's Poultry Science. Poultry tips, January, 2004, 8-10.

Dalsgaard, J.P.T. & Prein, M., 1999. Integrated smallholder agriculture–aquaculture in Asia: optimising trophic flows. In: Smaling, E.M.A., Oenema, O., Fresco, L.O. (Eds.), Nutrient Disequilibria in Agro-ecosystems: Concepts and Case Studies. CABI, Wallingford, UK, pp. 141–155.

Dandapat, A., 2009. Factors affecting egg production. Poultry line. Genetics & Animal Breeding. Chandmaridanga, Bankura, West Bengal-722101, India.

Das, G.B., Haque, M.E., Ali, M.L., Chanda, G.C. & Das, C., 2003. The performance of Indian Runner, Zending and Khaki Campbell in integrated duck-cum-fish farming system. *Pakist. J. Biol. Sci.* 6, 198-201.

Davis, C. & Reeves, R., 2002. High value opportunities from chicken egg. Rural Ind. Res. Dev. Corp. Pub. 02, 094.

De Ketelaere, B., Govaerts, T., Coucke, P., Dewil, E., Visscher, J., Decuypere, E. & De Baerdemaeker, J., 2002. Measuring the eggshell strength of 6 different genetic strains of laying hens: techniques and comparisons. *Brit. Poult. Sci.* 43, 238-244.

De Ketelaere, B., Bamelis, F., Decuypere, E. & De Baerdemaeker, J.G., 2004. Non-destructive measurements of the egg quality. *World Poult. Sci. J.* 60, 289-302.

Devendra, C., 1997. Mixed farming and intensification of animal production system. *Outlook on Agricul.* 26, 255-265.

Doyon, G., Bernier-Cardou, M., Hamilton, R.M.G., Castaigne, F. & Randall, C.J., 1986. Egg quality. Albumen quality of eggs from five commercial strains of white leghorn hens during one year of lay. *Poult. Sci.* 65, 63-66.

Dorminey, R.W., Jones, J.J. & Wilson, H.R., 1965. Influence of cages size and frightening on incidence of body checked eggs. *Poult. Sci.* 44, 307-308.

Du Plessis, P.H.C., 1945. High egg-laying records at the central competition at Glen. Farming in South Africa. Reprint No. 50.

Edwards, P., 1983. The future potential of integrated farming systems in Asia. In Takashi, 1, (ed), Proceedings of the fifth World Conference on Animal Production, Tokyo, Japan. *Japanese Soc. Zootech. Sci.* 1, 273-281.

Edwards, P., Kaewpaitoon, K. & Meewan, A., 1983. A feasibility study of fish/duck integrated farming at the family level in Central and Northeast Thailand. Asian Institute of Technology, Research Report No. 163.

Edwards, P., Kaewpaitoon, K., McCoy, E.W. & Chantachaeng, C., 1986. Pilot small-scale crop/livestock/fish integrated farm. AIT Research Report, 184, AIT, Bangkok, Thailand, pp.131.

Edwards, P., Pullin, R.S.V. & Gartner, J.A., 1988. Research and education for the development of integrated crop-livestock-fish farming systems in the tropics. International Center for Living Aquatic Resources Management. Manila, Philippines. *ICLARM Studies and Reviews*. 16, 53.

Edwards, P., 1998. A systems approach for the promotion of integrated aquaculture. *Aquac. Eco. Managm.* 2, 1-12.

Edwards, P., 2000. Aquaculture, Poverty impacts and livelihoods. ODI Natural Resource Perspectives 56. ODI, London, UK.

Egg Producers Federation of New Zealand., 2010. Egg quality.

Elaroussi, M.A., Forte, L.R., Eber, S.L. & Biellier, H.V., 1994. Calcium homeostasis in the laying hen's age and dietary calcium effects. *Poult. Sci.* 73, 1581-1589.

Englmaierova, M. & Tumova, E., 2009. The effect of housing system and storage time on egg quality characteristics. Department of Animal Husbandry, Faculty of Food and Natural Resources Prague, Czech University of Life Sciences, Kamycka 129, 165 21, Prague 6-Suchdol, Czech Republic.

Evans, T., 2007. Growth slows in global demand for poultry products. *Poult. Int.* 46, 12-16.

Falayi, B.A., 1998. Inclusion to poultry manure in a complete ratio for *Tilapia O. niloticus* fingerlings. Thesis submitted to the Dept. of Fisheries & Wildlife Fed. Uni. of Tech Akure, for the award of P.G. Diploma in Fisheries and Wildlife Management, pp. 14-17.

Farooq, M., Mian, M.A., Durrani, F.R. & Syed, M., 2002. Feed consumption and efficiency of feed utilization by egg type layers for egg production. *Livest. Res. Rur. Dev.* 14, 2002.

Fashakin, E.A., Falayi, B.A. & Eyo A.A., 2000. Inclusion of poultry manure in complete feed for tilapia *0. niloticus* (I). *Fish. Tech.* 2, 51-56.

FAO, 2004. Poultry for profit and pleasure. FAO diversification booklet. 3, 10.

FAO, 2003. Egg marketing: A guide for the production and sale of eggs. *FAO Agricultural Services Bulletin.* 150, 20-34.

FAO, 2002. Food and Agriculture publication, Year Report 2002. FAO Rome, 1-6.

FAO, 2001. Integrated agriculture-aquaculture. A primer. FAO Fisheries technical paper No. 407. FAO, Rome.

FAO, 2000. Small ponds make a big difference: Integrating fish with crop and livestock farming. Farm management and production economics service and inland water resources and aquaculture service, FAO, Rome, Italy.

FAO, 1979. Freshwater fish farming. How to begin. FAO Better farming ser. 27, 43.

Fitzsimmons, D.S., 1971. Are-evaluation of the ovulatory cycle of the domestic hen (Gallus domesticus). *Poult. Sci.* 51, 646-651.

Franchini, A., Sirri, F., Tallarico, N., Minelli, G., Iaffaldano, N. & Meluzzi, A., 2002. Oxidative stability and sensory and functional properties of eggs from laying hens fed supra-nutritional doses of vitamins E and C. *Poult. Sci.* 81, 1744-1750.

Froning, G.W., 1998. Recent advances in egg products research and development. In "Egg processing workshop". (Riverside and Modesto ed.). University of Carlifornia, USA.

Gabriel, U.U., Akinrotimi, O.A., Bekibele, D.O., Anyanwu, P.E. & Onunkwo, D.N., 2007. Economic benefit and ecological efficiency of integrated fish farming in Nigeria. *Sci. Res. Ess.* 2, 302-308.

Gerber, N., 2006. Factors affecting egg quality in the commercial laying hen: A review.

Gondwe, T.N.P., 2004. Characterization of local chicken in low input-low output production system: is there scope for appropriate production and breeding strategies in Malawi? PhD thesis, Georg-August-Universitat Gottingen, Germany.

Gowe, R.S. & Fairfull, R.W., 1985. The direct response to long-term selection for multiple traits in egg stocks and changes in genetic parameters with selection. In: Hill, W. G.; Manson, J. M.;. Hewitt, D. (eds), Genetic and phenotypic parameters for egg production in hens, Poultry Genetics and Breeding. British Poultry Sci. Ltd, Longman Group. Harlow, UK.

Gooley, G., 2000. R & D plan for integrated agri-aquaculture systems 1999-2004. A report for the Rural Industries Research and Development Corporation. RIRDC Project No. MFR 1A. *RIRDC Publication* 99, 153.

Gregorowski, J.J., 1984. Random sample test. Biennial report of the Animal and Dairy Science Research Institute. Internal document.

Green, B.W., Teichert-Coddington, D.R. & Hanson, T.R., 1994. Development of semi-intensive aquaculture technologies in Honduras. International Center for Aquaculture and Aquatic Environments Research and development Series Number 39, 48, Auburn University, Alabama, USA.

Grobbelaar, J.A.N., 2009. Egg production potentials of four indigenous chicken breeds in South Africa. M.Tech. thesis. Tshwane University of Technology, Animal production. Pretoria, South Africa.

Grobbelaar, J.A.N., Sutherland, B. & Molalakgotla, N.M., 2010. Egg production potentials of certain indigenous chicken breeds from South Africa. *Anim. Gen. Res.* 46, 25-32.

Guèye, H.F. & Bessei, W., 1997. The importance of poultry farming in Senegal. *Anim. Res. Dev.* 45, 82-88.

Guèye, H.F., 1998. Village egg and fowl meat production in Africa. *World Poult. Sci. J.* 54, 73-86.

Halaj, M., Benkova, J. & Baumgartner, J., 1998. Parameters of hen egg quality in various breeds and strains. *Czech J. Anim. Sci.* 43, 375-378.

Hamilton, R.M.G., 1982. Methods and factors that affect the measurements of egg shell quality. *Poult. Sci.* 61, 2002-2039.

Hasler, C.M., 2000. The changing face of functional foods. *Am. Coll. Nutr. J.* 19, 499-506.

Haugh, R.R., 1937. Egg quality. The US egg and poultry magazine, September 1937, 552-573.

Haylor, G., 2000. Proceedings of the e-mail conference on Aquatic Resources Management for Sustainable Livelihoods of Poor People in SE Asia, June 2000. DFID-SEA Aquatic Resources Management Programme, Bangkok, Thailand.

Hill, A.T. & Hall J.W., 1980. Effects of various combinations of oil spraying, washing, sanitizing, storage time, strain, and age upon albumen quality changes in storage and minimum sample sizes required for their measurement. *Poult. Sci.* 59, 2237-2242.

Hocking, P.M., Bain, M., Channing, C.E., Flemming, R. & Wilson, S., 2003. Genetic variation for egg production, egg quality and bone strength in selected and traditional breeds for laying fowl. *Brit. Poult. Sci.* 44, 365-373.

Honkatukia, M., 2010. Molecular genetics of chicken egg quality. PhD thesis, MTT Agrifood Research Finland. MTT Science, 14.

Hopkins, K.D., 1982. Outstanding yields and profits from livestock-tilapia integrated farming. *ICLARM Newsl.* 5, 13.

Hopkins, K.D. &. Cruz, E. M., 1982. The ICLARM-CLSU, integrated animal-fish farming project: final report. ICLARM Technical Reports 5. Freshwater Aquaculture Centre-central Luzon State University and International Centre for Living Aquatic Resources Management, Nueva Ecija, Philippines.

Huazhu, Y.B. & Baotony., 1989. Integrated fish farming in China, Naca Technical Manual Bangkok, Thailand, 153-209.

Hughes, B.O., Dun, P. & Mccorquodale, C.C., 1985. Shell strength of eggs from medium-bodied hybrid hens housed in cages or on range in outside pens. *Brit. Poult. Sci.* 26, 129–136.

Hughes, L.A. & Corner, D.E., 1998. Salmonella growth in egg components as affected by ratio of Yolk: Albumen. *Poult. Sci.* 77, 309-321.

Hunton, P., 2005. Research on eggshell structure and quality: An historical overview. *Braz. Poult. Sci.*7, 67-71.

HVB-Hyline Variety Brown, 2009. Commercial Management Guide 2009- 2011. A publication of Hyline International, West Des Moines, Iowa, U.S.A.

HVSB-Hyline Variety Silver Brown, 2009. Commercial Management Guide 2009-2011. A publication of Hyline International, West Des Moines, Iowa, U.S.A.

Ibe, S.N., Rutledge, J.J. & McGibbon, W.H., 1982. Curvilinear trends in direct and some correlated response to nineteen generation of selection for part record rate of egg production in a random bred line of chickens. *Poult. Sci. 61, 821-828.*

ICLARM, 2000. Food for the rural poor through integrated aquaculture-agriculture. ICLARM Focus for Research. 3, 1-6.

IIRR, ICLARM, 1992. Farmer-proven integrated agriculture-aquaculture: Technology information Kit. ICLARM, Manila, Philippines and IIRR, Silang, Cavite, Philippines.

Ingram, B.A., Gooley, G.J. & McKinnon, L.J., 2000. Aquaculture-agriculture systems integration: an Australian prospective. *Fisher. Managm. Ecol.* 7, 33-43.

Iqbal, S., Pampori, Z. A. & Hasin, D., 2009. Carcass and egg characteristics of indigenous chicken of Kashmir (Kashmir favorella). *Indian J. Anim. Res*. 43, 194-196.

Jacob, J.P., Wilson, H.R., Miles, R.D., Butcher, G.D. & Mather, F.B., 1998. Factors affecting egg production in backyard chicken flocks. University of Florida, Institute of food and agricultural services. Animal Science Department. Florida co-operative extension services. Gainesville. Fact sheet PS-35.

Johnson, S., 2007. Commercial layers. In: KwaZulu-Natal Poultry Institute: Basic poultry production short course. Pietermaritzburg: KwaZulu-Natal Poultry Institute.

Jones, D.R. & Musgrove, M.T., 2005. Effects of extended storage on egg quality factors. Poult. Sci. 84, 1174-1777.

Kabatange, M.A. & Katule, A.M., 1989. Rural poultry production systems in Tanzania. In: Proceedings of an International Workshop on Rural Poultry Development in Africa (Sonaiya, E.B., Ed.), 13-16 Nov 1989, Ile-Ife, Nigeria, pp. 171-176.

Kekeocha, C.C., 1985. Poultry production handbook. Pfizer, Mcmillan Publishers Limited. pp. 61-62.

Kemps, B., Bamelis, F., De Ketelaere, B., Mertens, K., Tona K., Decuypere, E.M. & De Baerdemaeker, J.G., 2006. Visible transmission spectroscopy for assessment of egg quality. *J. Sci. Food Agric.* 86, 1399-1406.

Kershavarz, K. & Nakajima, S., 1993. Re-evaluation of calcium and phosphorous requirements of laying hens for optimum performance and egg shell quality. *Poult. Sci.* 72, 144-153.

Kingori, A.M., Tuitoek, J.K., Muiruri, H.K. & Wachira, A.M., 2003. Protein requirements of growing indigenous chicken during the 14-21 weeks growing period. *S. Afr. J. Anim. Sci*. 33, 78-82.

Khurshid, A., Farooq, M., Durrani, F.R., Sarbiland, K. & Manzoor, A., 2004. Hatching performance of Japanese quails. *Livest. Res. Rur. Dev. 16, 1.*

Knud-Hansen, C.F., Batterson, T.R., McNabb, C.D. & Kitjar, J., 1991.Yield of Nile Tilapia (*Orechromis niloticus*) in fish ponds in Thailand using chicken manure supplemented with Nitrogen and Phosphorus. *In* Eighth Annual Administrative Report (1 Sept 1989 to 31 Aug 1990). (Eds: Egna H S., Bowman, J. & McNamara, M.) Pond dynamics/Aquaculture CRSP, Oregon, USA, pp. 54-62.

Koelkebeck, K.W., 1999. What is egg quality and conserving it? University of Illinois. Illini Poultry Net Papers.

Koeypudsa, W., Yakupitiyage, A. & Tangtrongpiros, J., 2005. The fate of chlortetracycline residues in a simulated chicken-fish integrated farming systems. *Aqua. Res.* 36, 570-577.

Kramer, A., 1951. What is quality and how can it be measured: From a food technology point of view. In: Market Demand and Product Quality. Mktg. Res. Workshop Rept., Michigan State College.

Kröckel, L., Poser, R. & Schwägele, F., 2005. Low resolution proton nuclear resonance spectroscopy: Application for the determination of the internal quality of intact eggs microbiological aspects. *Fleischwirtschaft.* 85, 108-112.

Lai, M.K. & Kan, C.L., 2000. Effects of cage floor area and population size on the laying performance of the brown Tsaiya laying ducks. *Taiw. Livest. Res. J.* 33, 281-291.

Latif, M.A., Alam, M.J. & Rahman, M.A., 1993. Integrated duck cum fish farming in Bangladesh. *J. World Aquacult. Soc.* 24, 402-409.

Lightfoot, C., Bimbao, M.P., Dalsgaard, J.P.T. & Pullin, R.S.V., 1993. Aquaculture and sustainability through integrated resources management. *Outlook on Agriculture.* 22, 143-150.

Liljedahl, L. E., Gavora, J. S., Fairfull, R. W. & Gowe, R. S., 1984. Age changes in genetic and environmental variation in laying hens. *Theor. Appl. Genet.* 67, 391-401.

Little, D.C. & Muir, J., 1987. A guide to integrated warm water aquaculture. Institute of Aquaculture, University of Stirling, Stirling, UK.

Little, D. & Satapornavit, K., 1995. Poultry and fish production-A framework for their Integration in Asia. Livestock Feed Resources within Integrated Farming Systems, pp. 425-453.

Little, D.C. & Edwards, P., 1999. Alternative strategies for livestock-fish integration with emphasis on Asia. *Ambio* 28: 118-124.

Little, D.C. & Edwards, P., 2003. Integrated livestock-fish farming systems: the Asian experience and its relevance for other regions. Inland Water Resource and Aquaculture Services and Animal Production Services. Food and Agriculture Organization, Rome.

Li-Chan, E. & Nakai, S., 1989. Biochemical basis for the properties of egg white. Critical Reviews. *Poult. Biol.* 2, 21-59.

Lohmann, 2009. Layer management program-Lohmann Brown and Lohmann Silver. Lohmann Tierzucht G.M.B.H., Cuxhaven, Germany.

Lomanika, K. & Minokova, K., 2006. A study of the factors affecting the foaming properties of egg white-A review. *Czech J. Food Sci.* 24, 110-118.

Li-Chan, E.C.Y., Powrie W.D. & Nakai, S., 1995. The chemistry of eggs and egg products. In Egg Science and Technology. (Cotterill, W.J.S.O.J. ed). Food products Press. An Imprint of the

Hawarth Press, Inc. New York. London Lomakina, K. & Míková, K., 2006. A study of the factors affecting the foaming properties of egg white. *Czech. J. Food Sci.* 24, 110-118.

Maree, W., 2008. Report of the egg organization committee for 2008. South African Poultry Association, Congress and Exhibition 2009 brochure, 35-38.

Matthews, W.W., 1986. Atlass of descriptive embryology. Macmillan Publishing Co., New York, 108.

Mathias, J.A., Charles, A.T. & Hu, B.T., 1998. Integrated fish farming. Proceedings of a workshop on integrated fish farming, 11-15 October, Wuxi, Jiangsu Province, China. CRC Press, Boca Raton, Florida, USA.

Melesse, A., Maak, S. & von Lengerken, G., 2010. Effect of long-term heat stress on egg quality traits of Ethiopian naked neck chickens and their F1 crosses with Lohmann White and New Hampshire chicken breeds. Livestock Research for Rural Development, 71.
http://www.lrrd.org/lrrd22/4/mele22071.htm

Mertens, K., Bamelis, F., Kemps, B., Kamers, B., Verhoelst, E., De Ketelaere, E., Bain, M., Decuypere, E. & De Baerdemaeker, J., 2006. Monitoring of eggshell breakage and eggshell strength in different production chains of consumption eggs. *Poult. Sci.* 85, 1670-1677.

Miles, R.D. & Henry, P.R., 2004. The effect of time and storage conditions on albumen quality of eggs from hens fed Vanadium. *J. Appl. Poult. Res.* 13, 619-627.

Monira, K.N., Salahuddin, M. & Miah, G., 2003. Effect of breed and holding period on egg quality characteristics of chicken. *Int. J. Poult. Sci.* 2, 261-263.

Moula, N., Antoine-Moussiaux, N., Farnir, F. & Leroy, P., 2009. Two Belgian local breeds and one commercial strain. *Int. J. Poult. Sci.* 8, 768-774.

Moreki, J.C., 2001. Village poultry and poverty alleviation. Workshop proceedings of community based management of animal genetic resources, Swaziland. 7-11 May.

Mosisi, M.P., 2009. Can small-scale poultry production contribute to household food security in the Maphephetheni lowlands, KwaZulu-Natal? MAgric (Food Security), African Centre for Food Security, School of Agricultural Sciences and Agribusiness, Faculty of Science and Agriculture, University of KwaZulu-Natal, Pietermaritzburg, South Africa.

Muhiye, M.E., 2007. Characterization of smallholder poultry production and marketing system of Dale, Wonsho and Loka Abaya Weredas of Southern Ethiopia. MSc. Thesis. School of graduate studies of Hawassa University. Ethiopia.

Mussawar, S., Durrani, T.M., Munir, K., Zahoor-ul-Haq, Rahman, M.T. & Sarbiland, K., 2004. Status of layer farms in Peshawar division, Pakistan. *Livest. Res. Rur. Dev.* 16, 5.

Naido, M., 2003. Indigenous poultry production systems in Northern KwaZulu-Natal, South

Africa. Proceedings of the 1st National Workshop on Indigenous Poultry Development. Pietermaritzburg, Nature and Development Group of Africa, 66-73.

Narushin, V.G. & Romanov, M.N., 2002. Egg physical characteristics and hatchability. *World Poult. Sci. J.* 58, 297-303.

Narushin, V.G., Van Kempen, T.A., Wineland, M.J. & Christensen, V.L., 2004. Comparing infrared spectroscopy and egg size measurements for predicting eggshell quality. *Biosystems Eng.* 87, 367-373.

National Department of Agriculture, 2002. The integrated food security strategy for South Africa. Pretoria, 17 July 2002.

NACA, 1989. Integrated fish farming in China (NACA Technical Manual 7). Asian-Pacific regional research and training centre in integrated fish farming, Wuxi, China. Network of Aquaculture Centres in Asia and the Pacific, Bangkok, Thailand.

NACA/FAO, 2000. Aquaculture development beyond 2000: the Bangkok declaration and strategy. Conference on Aquaculture in the Third Millenium, 20–25 Feb 2000, Bangkok, Thailand. Network of Aquaculture Centers in Asia, Bangkok, Thailand and FAO, Rome, Italy.

Neospark, 2011. Eggshell defects and dietary essentials. http://www.neospark.com/images/EggshellDefects.pdf

Ngou Ngoupayou, J.D., 1990. Country report on small-holder rural poultry production in Cameroon. In: CTA Seminar Proceedings 2, Smallholder Rural Poultry Production, Thessalonika, Greece, pp. 39-47.

Nhleko, M.J., Slippers, S.C. & Nsahlai, I.V., 2003. A preliminary report of on-farm performance of rural chickens kept under farmers' management. Nature and Development group of Africa NGO Registration no. 026-851-NPO. Proceedings of the 1st National Workshop on indigenous poultry development, pp. 79-83.

Nnaji, C.J., Okoye, F.C. & Ogunseye, J.O., 2003. Integrated fish farming practices with special reference to combination rates production figures and economic evaluation In: Eyo, A.A. & Ayanda, J.O. (eds). Conference proceedings of fisheries society of Nigerian (FISON) Owerri 8th-12th December, 2003, pp. 173-178.

Nnaji, J.C., Uzairu, A., Gimba, C. & Kagbu, J.A., 2011. Heavy metal risks in integrated chicken-fish farming. *J. Appli. Sci.* 11, 2092-2099.

North, M.O. & Bell, D.D., 1990. Commercial chicken production manual. 4th ed. New York: The Macmillan Pres Ltd.

North, M. O., 1984. Breeder management. In commercial chicken production manual. *The Avi. Publishing Company.* Inc. Westport, Connecticut, pp. 240-243; 298-321.

NRC (National Research Council), 1994. Nutrient requirements of poultry: 9th revised ed. *National Academy Press*, Washington D.C.

Nys, Y., 1986. Relationships between age, shell quality and individual rate and duration of shell formation in domestic hens. *Brit. Poult. Sci.* 27, 253-259.

Okubo, T., Akachi, S. & Hatta, H., 1997. Structure of hen eggs and physiology of egg laying. In: Hen eggs: Their Basic and applied Science. Eds Yammamoti, T., Juneja L.R., Hatta, H. & Kim, C. *CRC Press*, 1-12.

Oladosu, G.A., Ayinla, O.A., Onuoha, G.C. & Mecdom J.G., 1990. Performance of *Clarias gariepinus* in a polyculture with *Orechromis niloticus* under the integrated broiler chicken fish farming. *NIOMR Technical/paper*, 65.

Osuji, C.N., Ockiya, A.J. & Chinda A.C., 2003. Dominance shift of phytoplankton in relation to different organic fertilizer treatment in Clarias Gariepinus Culture. In: Eyo, A.A Ayanda, J.O. (eds). Conference proceedings of fisheries society of Nigeria (FISON). Owerri 8th-12th Dec, pp. 62-66.

Otubusin, S.O., 1983. A proposed integrated guinea fowl cum-fish culture in Lake Kainji. In: The Helmet Guinea fowl (Numida meleagris láleata Pallas) in Nigeria. Ed, Ayeni, J.S.O. pp.66-71.

Otubusin, S.O., 1986. A proposed integrated livestock-rice-poultry-cum-fish culture in enclosure system. FISON Conference Proceedings, pp. 319-326.

Pearl, H.W. & Tucker O.S., 1995. Ecology of blue green algae in aquaculture ponds. *J. World Aquacult. Soc.* 26, 109-131.

Phosa, M.A., 2009. The nutritive value of macadamia oil cake meal and wood ash as alternative feed ingredients for chickens in rural areas. M. Inst Agrar (Animal Production), Department of Animal and Wildlife Sciences, Faculty of Natural and Agricultural Sciences, University of Pretoria, Pretoria, South Africa.

Poggenpoel, D.G., Ferreira, G.F., Hayes, J.P. & Du Preez, J.J., 1996. Response to long-term selection for egg production in laying hens. *Brit. Poult. Sci.* 37, 743-756.

PoultryHub, 2009. Eggs and egg products. Chicken layer industry

Powrie, W.D. & Nakai, S., 1985. Characteristics of edible fluid of animal origin: eggs. Food chemistry. Ed. Fennema, O.R. New York, Marcel Dekker, 829-855.

Pratt, P.F., 1975. Utilization of animal manure and sewage sludges in food and fibre production. *Agric. Sci. Technol.* 3, 23-25.

Prein, M., Lightfoot, C. & Pullin, R.S.V., 1995. ICLARM's approach to the integration of aquaculture into sustainable farming systems. In: Devendra, C., Gardiner, P. (Eds.), Global Agenda for Livestock Research. ILRI, Nairobi, Kenya, 117-125.

Prein, M. & Ahmed, M., 2000. Integration of aquaculture into smallholder farming systems for improved food security and household nutrition. *Food and Nutrition Bulletin.* 21, 466-471.

Prein, M., 2002. Integration of aquaculture into crop–animal systems in Asia. *Agricul. Syst.* 71, 127-146.

Preisinger, R., 2000. Genetic changes in layer breeding: historical trends and future prospects. In the challenge of genetic change in animal production (eds. Hill, W.G., Bishop, S.C McGuirk, B., McKay, J.C., Simm, G. & Webb, A.J). British Society of Animal Science, Edinburgh. Occasional publication. 27, 20-28.

Prinsloo, J.F., Schoonbee, H.J. & Theron J., 1999. The production of poultry in integrated aquaculture-agriculture systems. Part II: The integration of laying hens with fish and vegetables in integrated aquaculture-agriculture food production systems. *Water SA.* 25, 233-238.

Pullin, R.S.V. & Shehadeh, Z., 1980. Integrated agriculture-aquaculture farming systems. ICLARM Conference Proceedings 4, Manila, Philippines.

Qureshi, A.W., 1996. Animal production: an African perspective. *WAAP Newsletter*, 35. 25-31 Aug.

Rahman, M.M., Varga, I. & Chowdhry, S.N., 1992. Manual on polyculture and integrated fish farming in Bangladesh. *Project report.* 11, 65.

Ramsey, K., Harris, L. & Kotze, A., 2001. Landrace breeds. South Africa's indigenous and locally developed farm animals. Pretoria, Farm Animal Conservation Trust.

Rana, K., Perotti, M., Montanuro, S. & Inmink, A., 1998. Aquaculture production in China. FAO Aquaculture newsletter, 9-10 Dec.

Rashed Hasnath, M., 2002. Effect of feeding systems on the egg production of Fayoumi hens of model breeding units under PLDP programme in Bangladesh. MSc Thesis, Department of Animal Science and Animal Health and Network for Smallholder Poultry Developmet The Royal Veterinary & Agricultural University, Dyrlaegevej, 1870 Frederiksberg C., Denmark & Chittagong Govt. Veterinary College, Chittagong, Bangladesh.

Reynard, M. & Savory, C.J., 1999. Stress-induced oviposition delays in laying hens: duration and consequences for eggshell quality. *Brit. Poult. Sci.* 40, 585-591.

Roberts, R.J., 2004. Factors affecting egg internal quality and egg shell quality in laying hens. *Poult. Sci.* 41, 161-177.

Robinson, F.E. & Renema, R.A., 2008. Female reproduction: control of ovarian function. Alberta Poultry Research Centre, University of Alberta Edmonton, AB, Canada T6G 2P5.

Robinson, D.S. & Monsey, J.B., 1972. Changes in the composition of ovomucin during liquefaction of thick white. *J. Sci. Food Agric.* 23, 29-38.

Robinson, L., 1948. Modern poultry keeping: Official Organ of the poultry association of Great Britain. London: SPBA Ltd.

Rodriguez-Navarro, A., Kalin, O., Nys, Y. &. Garcia-Ruiz, J.M., 2002. Influence of the microstructure on the shell strength of eggs laid by hens of different ages. *Brit. Poult. Sci.* 43, 395-403

Roland, D.A., Sloan, D.R. & Harms, R.H., 1976. The ability of hens to maintain calcium deposition in the egg shell and egg yolk as the hen ages. *Poult. Sci.* 54, 1720-1723

Rose, S.P., 1997. Principles of poultry science. New York: CABI Publishing.

Roushdy, K.H., El-Dein, A.Z., Fathi, M.M., Ali, U.M. & Assy, H.M., 2008. Microsatellite genetic differentiation analysis of two local chicken breeds compared with foreign Hy-Line strain. *Int. J. Poult. Sci.* 7, 1045-1053.

Ruddle, K. & Prein, M., 1998. Assessing the potential nutritional and household economic benefits of developing integrated farming systems. In: Mathias, J.A., Charles, A.T., Baotong, H. (Eds.), Integrated/Agricultural Fish Farming Systems (2002). 71, 127-146, 145. Proceedings of a Workshop on Integrated Fish Farming, 11-15 October 1994, Wuxi, Jiangsu Province, China. CRC Press, Boca Raton, Florida, USA, 111-121.

Samli, H.E., Agma, A. & Senkoylu, N., 2005. Effects of storage time and temperature on egg quality in old laying hens. *J. Appl. Poult. Res.*14, 548-553.

Samuels, M.L., 1989. Statistics for the life sciences. Collier Macmillian publishers, London.

Savas, T., Von Preisinger, R., Ro¨ He, R., Thomsen, H. & Kalm, E., 1998. The effect of the Box–Cox transformation on the estimation of breeding values for egg production. *WCGALP*. 24, 353.

SAS Institute, 2011. Statistical Analysis System (SAS) User's Guide Statistics. SAS Institute Inc., Cary, NC

Schäfer, A., Drewes, W. & Schwägele, F., 1999. Effect of storage temperature and time in egg white protein. *Nahrung*. 43, 86-89.

Scott, T.A. & Silversides, F.G., 2000. The effect of storage and strain of hen on egg quality. *Poult. Sci.* 79, 1725-1729.

Sekeroglu, A., Sarica, M., Demir, E., Ulutas, Z., Tilki, M., Saatci, M. & Omed, H., 2010. Effects of different housing systems on some performance traits and egg quality of laying hens. *J. Ani. Vet. Adv.* 9, 1739-1744.

Sevilleja, R., Torres, J., Sollows, J. & Little, D., 2001. Using animal wastes in fish ponds. Halwart, M., Gonsalves, J. & Prein, M. (Eds.), Integrated agriculture-aquaculture: A primer, FAO Fisheries Technical Paper 407, pp.49-53, FAO, Rome.

Shalev, B.A., 1995. Comparison of white and brown eggshell laying stock. *World Poultry. Sci. J.* 51, 7-16.

Shaler, B.A. & Pasternak, H., 1993. Increment of egg weight with hen age in various commercial avian species. *British Poult. Sci. 34, 915-924.*

Sharma, B.K., 1989. Recent trends in integrated fish farming system. In ICAR training programme on integrated fish farming for Tripura Fisheries officers. CIFA, Bhubaneswar, Orssa, India. Compound Lect. 2, 1-10.

Silversides, F.G & Scott, T.A., 2001. Effect if storage and layer age on quality of eggs from two lines of hens. *Poult. Sci. J.* 80, 1240-1245.

Silversides, F.G., Shaver, Mc. Q.D. & Song, Y., 2007. Pure line laying chickens at the Agassiz Research Center. *Anim. Gen. Res. Inform. 40, 79-85.*

Singh, R., Cheng, K.M., & Silversides, F.G., 2009. Production performance and egg quality of four strains of laying hens kept in conventional cages and floor pens. *Poult. Sci.* 88, 256-264.

Small-farm-permiculture-and-sustainability-living.com., 2012. Types of chickens. Review of different breeds of chickens. http://www.small-farm-permaculture-and-sustainable-living.com/types_of_chickens.html

Smith, G.A. & Yoshida, I., 2011. Sustainable integrated Kyusei Nature Farming EM technology and food security in Africa. Session X - New Horizons in Kyusei Nature Farming and EM. Fifth International Conference on Kyusei Nature Farming, Bangkok, Thailand.

Song, W.O. & Kerver, J.M., 2000. Nutritional contribution of egg to the American diet. *J. Am. Coll. Nutr.* 29, 556-562.

SAPA, South African Poultry Association, 2011. Short summary-egg industry 2011.

Sparks, N.H.C., 2006. The hens' egg-Is its role in human nutrition changing? Avian Science Research Centre, Animal Health Group, SAC, Edinburgh, Scotland.

Spackman, D., 1987. The effect of disease on egg quality. In : Egg quality current problems and recent advances. Ed Wells, R.G and Belyavin, C.G. Butterworths, London, Boston, Durban, pp. 255-282.

Srilakshmi, B., 2003. Eggs. In: Food Science, 3rd ed., *New Age Inter. Pub,* pp. 123-147.

Stadelman, W.J., 1995. Quality identification of egg science and technology. Ed. Stadelman, W.J and Cotterill, O.J., The Haworth press, Inc., New York, London, pp. 39-66.

Stadelman, W. J., 1977. Quality identification of shell eggs in egg science and technology. Ed. Stadelman, W.J. & Cotterill, D.J, AVI Publishing company Inc. Westport, Connecticut, 2nd Edn, 33.

Steyn, N.P., Nel, J.H., Prinsloo, J.F., Tichelaar, H.Y., Dhansay, M.A., Theron, J., Hoffman, L.C. & Benade, A.J.S., 1995. Nutritional status of underweight rural preschool children consuming a diet rich in *Clarias gariepinus. S. Afri. J. Food. Sci. Nutr.* 7, *158-163.*

Sultana, P., 2000. Household fish consumption and socio-economic impacts in Kapasia. Paper Presented at the Workshop on Aquaculture Extension: Impacts and Sustainability, 11 May 2000, Dhaka, Bangladesh. ICLARM, Penang, Malaysia and the Department of Fisheries, Dhaka, Bangladesh.

Suksupath, S.E., Cole, E.A., Cole, R.J. & Bryden, W.L., 1989. Toxicity of cyclopiazonic acid in the laying hen. Proceedings of the Australian Poultry Science Symposium, Sydney, 94.

Symoens, J.J. & Micha, J.C., 1995. The management of integrated freshwater agro-piscicultural ecosystems in tropical areas. Proceedings of the International Seminar, 16-19 May 1994, Brussels, Belgium. The Technical Centre for Agricultural and Rural Co-operation (CTA), Wageningen, Netherlands and the Belgian Royal Academy of Overseas Sciences (ARSOM), Brussels, Belgium.

Taiganides, E.P., 1978. Principles and techniques of animal waste management and utilisation . In FAO, Soils Bulletin, 36, Food and Agriculture Organization, Rome, Italy, pp. 341-362.

Taiganides, E. P., 1979. Wastes are resources out of place. *Agricult. Wastes*.1, 1-9.

Theimsiri, S., 1992. New concept on poultry breeder management in tropical countries 65-71. In Proceedings of Luang Suwan International Poultry Symposium, the sixth Animal Science Congress of AAAP, 27-28 November, Bangkok. 129.

Thilsted, S.H. & Roos, N., 1999. Policy issues on fisheries in relation to food and nutrition security. In: Ahmed, M., Delgado, C., Sverdrup-Jensen, S., Santos, R.A.V. (Eds.), Fisheries Policy Research in Developing Countries: Issues, Priorities and Needs. ICLARM conference proceedings 60. ICLARM, Penang, Malaysia, pp. 61-69.

Thompson, P., Sultana, P., Nuruzzaman, M. & Firoz Khan, A.K.M., 1999. Fisheries extension evaluation project. Progress report, March 1998 to Mid-1999. ICLARM, Penang, Malaysia.

Tipraqsa, P., Creswell, E.T., Noble, A.D. & Schmidt-Vogt, D., 2007. Resource integration for multiple benefits: Multifunctionality of integrated farming systems in Northeast Thailand. *Agricul. Syst.* 94, 694-703.

Tokrisna, R., 1992. Integration livestock-fish farming systems in Thailand. In Mukherjee, T.K., Moi, P.S., Panadam, J.M, & Yang, Y.S. (Eds) Proceedings of the FAO/IPT Workshop on integrated livestock-fish production systems, 16-20 December, 1991. Institute of Advanced Studies, University of Malaya, Kuala Lumpur, Malaysia.

Tuleum, C.D., 1992. The utilization of heat treated poultry manure in chick's diets. Paper presented at the 17th annual conference of the N.S.A.P Abuja. 23-27 March, 8.

Tůmová, E., Skřivan, M., Englmaierová, M. & Zita. L., 2009. The effect of genotype, housing system and egg collection time on egg quality in egg type hens. *Czech J. Anim. Sci.* 54:17–23.

Tyler, C., 1961. Shell strength. Its measurement and relationship to other factors. *Brit. Poult. Sci.* 2, 3-19.
Van Horne, P.L.M. & Van Niekerk, T.G.C.M., 1998. Volieren- und Ka¨fighaltung im Vergleich. Dtsch. Geflugelwirtsch. Schweineprod. 6, 14-16.

Van Marle-Koster, E. & Casey, N.H., 2001. Phenotypic characterisation of native chicken lines. *S. Afr. Anim. Genet. Resour.* 29, 71-78.

Van Marle-Koster, E. & Nel, L.H., 2000. Genetic characterization of indigenous South African chicken populations: evaluation and selection of polymorphic microsatellite markers. *S. Afr. J. Anim. Sci.* 30, 1-6.

Van Vleck, L.D. & Doolittle, D.P., 1964. Genetic parameters of monthly egg production in the Cornell controls. *Poult. Sci. J.* 43, 560-567.

Velasquez, C.C., 1980. Health constraints to integrated animal fish farming in the Philippines. In: Rogers S.U, Pulins & Zrad H (eds). Integrated aquaculture farming systems ICLARM-58A RCA Manilla. Philippines, pp. 103-111.

Viljoen, W.C.J., 1979. Hoenderrasse. Pluimvee A.2. Boerdery in Suid Afrika.

Vincke, M., 1988. Developing productive systems under village conditions. In: Village level aquaculture development in Africa. King, H.R. Ibrahim, & K.H. (eds), Proceedings of the commonwealth consultative workshop on village level aquaculture development in Africa, Freetown, Sierra Leone, 14–20 February 1985, Commonwealth Secretariat, London, 39-57.

Vincke, M.M.J., 1992. Integrated farming of fish & livestock: Present status and future development. FAO/IPT. Workshop on integrated livestock-fish production systems c/o institute of advanced studies, University of Malaysia, 1992.

Vits, A., Weizenburger, D., Hamann, H. & Distl, O., 2005. Influence of different small group systems on production traits, egg quality and bone breaking strength of laying hens. First communication: Production traits and egg quality. *Zuchtungskunde.* 77, 303-323.

Von Preisinger, R. & Savas, T., 1997. Vergleich zweier Methoden zur Scha¨tzung der Varianzkomponenten für Leistungsmerkmale bei Legehennen. *Zu¨ chtungskunde*. 69, 142-152.

Watkins, B.A., 1995. The nutritive value of the egg. In egg science and technology" (Cotterill, W.S.O.J. ed). Food products press. An imprint of the Haworth Press, Inc. New York, London.

Wethli, E., 2003. Improving the productivity of indigenous chickens in rural villages. Proceedings of 1st National Workshop on indigenous poultry development. Pietermaritzburg, South Africa, 29-30 October.

Wiener, G., 1994. Animal breeding. Tropical agriculturist. Macmillan Education Limited London, 28.

Williams, K.C., 1992. Some factors affecting albumen quality with particular reference to Haugh unit score. *World Poult. Sci. J.* 48, 516.

Willman, R., Halwatt, M. & Barg, U., 1998. Integrating fisheries and agriculture to enhance fish production and food security. *FAO Aquaculture Newsletter.* 22, 3-9.

Wohlfarth, G.W. & G.L. Schroeder., 1979. Use of manure in fish farming –a review. A*gricul. Wastes*. 1, 279-299.

World Fish Centre, 2003. Fish an issue for everyone: A concept paper for fish for all summit, 10.

Yakubu, A., Salako, A.E. & Ige, A.O., 2007. Effects of genotype and housing system on the laying performance of chickens in different seasons in the semi humid tropics. *Int. J. Poult. Sci.* 6, 434-439.

Yami, A., 1995. Poultry production in Ethiopia. *World Poult. Sci. J.* 51, 197-201.

Yingzue, F., Xianzten, G., Jikun, W., Xiuzherg, F. & Zhinyna L., 1986. Effect of different animal manure in fish farming. In: Maclean, JL., Dixon, L.B., & Hosillos, L.V (eds). First Asia Fisheries Forum. The Asian Fisheries society, Manila, Philippines, pp. 117-120.

Zabik, M., 1992. Eggs and products. Food theory and applications. Ed. Bowers, J., Macmillan Publishing Co., New York, pp. 359-411.

Zaman, M.A., Ahmed, S. & Sutradhar, B.C., 2005. Study on the egg quality of a breed and three crossbreds at various ages under semi scavenging system of management. *Pakist. J. Biol. Sci.* 8, 211-214.

Zita, L., Tůmová, E. & Štolc, L., 2009. Effects of genotype, age and their interaction on egg quality in brown-egg laying hens. *Acta Vet. BRNO.* 78, 85–91.