

## 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 (14-17<sup>th</sup> 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<sup>-1</sup> of which 87% came from fish yields of 3.5 t ha<sup>-1</sup> (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
<b>Poultry</b>					
Feedlot	***	***	***	*	***
Scavenging	*	**	**	**	**
<b>Pigs</b>					
Feedlot	***	*	**	**	***
Scavenging	*	*	*	**	**
<b>Ruminants</b>					
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 impart 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 Satapornvanit, 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/m <sup>2</sup> /day)						Systems	Output	
	Poultry waste			Other				Fish	g/fish/m <sup>2</sup> /day
	Dry Matter	N	P	Dry Matter	N	P			
<b>Feedlot</b>									
Egg laying ducks	6.71	0.3	0.07	-	-	-	200m <sup>2</sup> pond, 6mths (Edwards <i>et al</i> , 1986)	Tilapia	2.82
Broiler chickens	10.0	0.4	0.46	-	-	-	400m <sup>2</sup> pond, 3mths (Hopkinz & Cruz, 1982)	Tilapia, common carp	2.87
Layer chickens	14.3	0.4	0.3	-	-	-	1,000m <sup>2</sup> ponds, 5mths (Green <i>et al</i> , 1994)	Tilapia	1.33
Layer chickens	1.07	0.03	0.08	-	0.47	0.23	220m <sup>2</sup> ponds, 5 mths (Knud-Hansen <i>et al</i> ,1991)	Tilapia	2.75
<b>Scavenging</b>									
Muscovy ducks	9.7	0.15	0.10	-	-	-	5m <sup>2</sup> tanks, 3mths ; ducks fed 75% <i>ad lib</i> (AFE,1992)	Tilapia	1.38
Egg laying ducks	3.0	0.23	0.03	-	0.17	-	200m <sup>2</sup> ponds, 4mths (AASP, 1996) rice bran	Tilapia	1.21
Egg laying ducks	1.24	0.20	0.01	-	0.17	-	200m <sup>2</sup> 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, landscape; 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<sub>2</sub>) 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<sub>3</sub>), this decrease in blood calcium levels, combined with the increase in blood pH and a subsequent decrease in Ca<sub>2+</sub> 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<sub>12</sub> 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)

<b>Nutrient</b>	<b>Amount</b>
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 <sub>12</sub> (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.

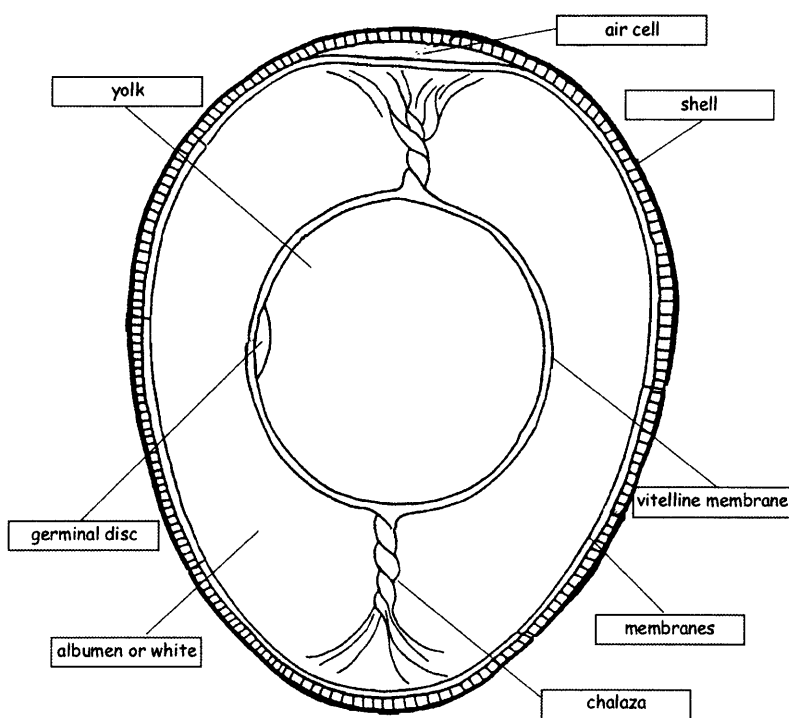


Figure 2.1 Diagram of an egg (Neospark, 2011)

## 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 ( $\alpha$ - and  $\beta$ -) 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)	30-33
	Latebra	
	Light yolk layer	
	Dark yolk layer	
	Vitelline membrane	
Albumen	Outer thin membrane	60
	Outer thick membrane	
	Inner thin membrane	
	Inner thick membrane	
	Chalaza	
Membrane	Outer shell membrane	0-1
	Inner shell membrane	
	Air cell	
Shell	Cuticle	9-12
	Spongy (calcareous) layer	
	Mammillary layer	

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:

- Occurrence 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<sub>2</sub>) in the hen’s blood, a condition known as alkalosis. Egg shells are made up of 95% of calcium carbonate (CaCO<sub>3</sub>) (Gerber, 2006). A decrease in blood CO<sub>2</sub> levels increases blood pH and decreases Ca<sup>2+</sup> 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  $42.6N \pm 9.0SD$  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  $38.9N \pm 7.0SD$ .

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<sub>2</sub> 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<sub>2</sub>, 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

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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

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### 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-permaculture-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 Naked-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.

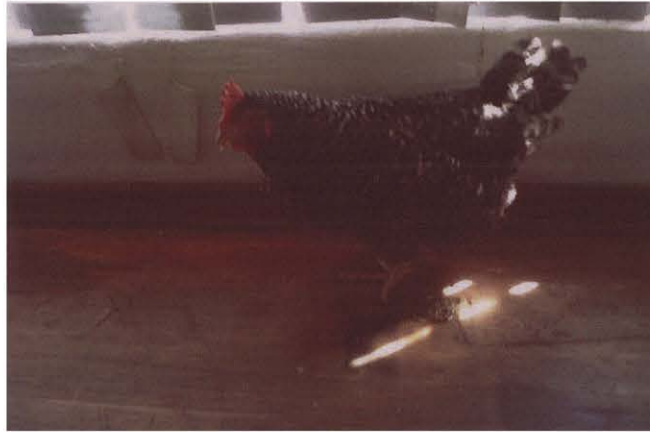


Figure 2.10 Potchefstroom Koekoek

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.