Using Management Information in Broiler Supply Chains

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Thesis
submitted in fulfilment of the requirements for the degree of doctor
at Wageningen University
by the authority of the Rector Magnificus
Prof. dr. M.J. Kropff,
in the presence of the
Thesis Committee appointed by the Academic Board
to be defended in public
on Friday June 15, 2012
at 4 p.m. in the Aula.

The Dutch broiler supply chain involves several interdependent firms such as breeding and feed companies, rearing farms, breeder farms, broiler hatcheries and broiler farms. To stay competitive and sustain continuity, evaluation of production at each level of the chain is crucial. Good quality data and the use of management information systems (MIS) can facilitate this process. Firms in the Dutch broiler supply chain collect data as a routine practice. However, the data are not often analysed and not fully used to support management decisions. The focus of this thesis is on the broiler breeder farms, because eggs are the origin of broiler production. Thus, improving the management at broiler breeder farms could contribute to the improvement of the performance of subsequent firms and the whole supply chain. The objective of this research is, therefore, to develop MIS based on available data in the broiler supply chain to support management decisions at breeder farms. The thesis is composed of three parts.

In the first part, management factors at breeder farms that are related to the performance indicators at the subsequent levels of the broiler production chain are explored. For this, field data from three Dutch hatcheries of 2004, 2005 and 2006 were analysed. Hatchability and first week mortality (FWM) of chicks are considered as performance indicators as these are related to the performance at the breeder farms, hatcheries and broiler farms. A significant difference in hatchability and FWM among eggs from different breeder flocks was found. Furthermore FWM differ significantly between broiler farms. Hatchability and FWM are significantly related with breeder flock age, egg storage length, strain, feed company of the breeder farm, season, year, as well as hatchery. It is concluded that breeder farm management factors are related to the performance in the subsequent levels of the chain next to hatchery and broiler farm factors.

In the second part of this thesis, the availability and quality of data in the Dutch broiler supply chain was assessed. The data quality of the hatchery dataset (from part one) was assessed based on the intuitive approach whereby the quality attitudes are selected by the researcher intuitively. Results showed that the datasets had some fields with inaccurate, incorrect, inconsistent, non-uniform, incomprehensible, and/or incomplete data. In addition, a protocol was proposed and validated for standardization of data to improve the quality of data in the chain.

In the third part of this thesis, two management information systems were developed aiming to support decisions at broiler breeder farms. The first management information system evaluates the tactical management at broiler breeder farms using individual farm analysis combined with a deterministic simulation model (IFAS). With IFAS, the performance of a breeder farm is compared with an average of similar farms or other standards, and relevant deviations are determined based on economic and statistical importance. According to the relevance of the identified deviations the strong and weak management practices are indicated. The second management information system determines the economic optimal replacement age of the broiler breeder flock using the marginal net revenue approach. A well informed replacement decision for breeder flocks improves profitability, not only at the breeder farms but also at hatcheries and broiler farms.

Preface

"Dream lofty dreams, and as you dream, so shall you become. Your vision is the promise of what you shall at last unveil." **John Ruskin**

Since childhood, I was taught to follow my passions: to dream about things worth pursuing and then to go for them. Without this foundation I probably would not have dared to do a PhD while being a mother of three young children. Accomplishing a doctorate study is a dream come true for me. At the beginning of my study, my aspiration was to present a thesis that does not only make a small but significant contribution to scientific progress, but that also provides significant help to the end user in the field. And I gravely hope that I have succeeded in doing so.

This thesis has been kept on track and been seen through to completion with the support and encouragement of numerous people including my family, friends, colleagues and various institutions. I will be happy to remember and thank some of the people who have helped and supported along this long but fulfilling road.

First of all, my deepest gratitude is to my co-promoter and daily supervisor, Dr. ir. Annet Velthuis. I have been amazingly fortunate to have a supervisor who gave me the freedom to explore on my own, and at the same time the guidance to recover when my steps faltered. Annet, thank you for your initial faith, on-going patience, expert guidance and encouragement. Your good advice and friendship has been invaluable on both academic and personal level, for which I am extremely grateful. You are a good listener and always find the right words to keep me on track when I am lost.

I would like to express my heartfelt gratitude to Prof. dr. ir. Alfons Oude Lansink. Alfons, it was a wonderful experience to work under your supervision. Your way of analysis, prompt response, brief and to the point instructions, have impressed me.

I am heartily thankful to my second co-promoter Dr. Marleen Boerjan whose encouragement, guidance and support enabled me to develop an understanding of the subject. Marleen, thank you for providing me tremendous insight and guidance on a variety of topics within this thesis. The insightful comments and constructive criticisms were thought-provoking and they helped me focus on my ideas.

My deepest sense of gratitude goes to Gerard Giessen without whom I would never have been able to accomplish the last two chapters of my thesis. Gerard your critical and honest advices were a source of inspiration and encouragement for me. Thank you.

I also extend my special thanks to prof. Ruud Huirne for his guidance and critical comments during the first year of my PhD.

I would like to thank Henk Hulsbergen (Secretaris Stichting Fonds voor Pluimveebelangen) for his support and ideas during several workshops throughout my PhD.

I am very grateful to hatcheries Probroed & Sloot and Munsterhuis for generously providing me data and information needed for my research. Special thanks to hatchery personnel and managers and all breeder farms for their participation in surveys, discussions and for providing, through questions and feedback, thought provoking additional research insights to include in this thesis. Specially, I would like to thank Johan Kollenstart (hatchery Probroed & Slot) who actively and enthusiastically participated in this research. Many thanks

to Erwin Wilderink Poultry consultant in Ugchelen, The Netherlands for his contribution to this thesis.

I would like to thank my colleagues at the Business Economics Group. In particular, a special acknowledgement goes to my office mate Natasha Longworth. She was a true friend ever since we began to share an office in 2006. And I also thank Geralda and Koenraad, my other great office mates who have been supportive in every way. I owe many thanks to Anne Houwers for all her support and AH stickers.

I owe a lot to my parents, brothers and sisters who encouraged me at every stage of my personal and academic life, and longed to see this achievement come true. I am very much indebted to my husband Salih Zeinu, and my sons Rakin, Rami and Elim for their support and great patience at all times. They have given me their unequivocal love and encouragement throughout, as always, for which my mere expression of thanks likewise does not suffice.

Lastly, I offer my regards and gratitude to all of those who supported me in any respect during the completion of the PhD project.

Hurria Yassin
Utrecht, 14 April 2012

Contents

General Introduction

Hurria Yassin

Business Economics Group, Wageningen University

1.1 Introduction

The demand for poultry meat and consequently the broiler production is increasing rapidly throughout many regions of the world (FAO, 2010). Poultry meat production is a chain process that starts at a breeding company where pure line females and males produce grand grandparent and grandparent day-old breeder chicks. The day-old breeder chicks are then delivered to rearing farms where they are raised to pullets of an age of 18 to 20 weeks. Next, these pullets are delivered to breeder (parent stock) farms where they will produce broiler hatching eggs starting at an age of 23 to 25 weeks till the age of 55 to 65 weeks. These hatching eggs are picked up and delivered to broiler hatcheries where they are incubated for 21 days. The resulting day-old broiler chicks are then delivered to broiler farms where they are raised until they are ready for slaughter at the age of 39 to 42 days. Figure 1.1 shows the firms and farms in the broiler supply chain.
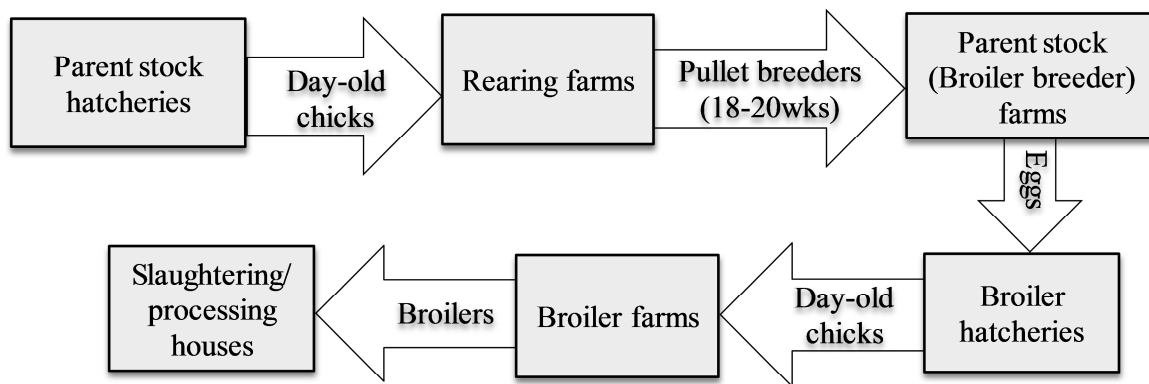

Figure 1.1 The broiler supply chain

During the last decades, the genetic potential of broilers and breeders has changed dramatically resulting in a highly productive but also a more fragile chicken (Robinson et al., 1993; Havenstein et al., 2003a). Breeder flocks need to be managed in a manner that maximizes the reproductive traits yet carrying the genetic material to have their offspring exhibit fast and efficient rates of growth (Decuypere et al., 2001; Rustad and Robinson, 2002). At the same time, poultry businesses are under increasing pressure from global competition and from retailers who expect to offer their customers safer, welfare-friendly food at cheaper prices. To achieve optimum bird performance and meeting profit expectations in a welfare friendly and socially responsible way, poultry producers need to rely their decisions on good quality information (Redman, 1995; Ballou and Tayi, 1999). Incorrect management decisions at one level of the chain may impact not only the overall performance at that level, but also the performance of the supply chain as a whole. Heier and Jarp, 2001; showed that optimization of breeder farm and hatchery management leads to improvement of the result throughout the broiler supply chain. Inter-organizational information sharing and collaboration among partners has been proven to improve performance and enhances the competitive advantage of a supply chain (Holland, 1995; Li et al., 2006). For inter-organisational information exchange to be effective, every firm in the chain should collect relevant and good quality data as the analysis of these data is crucial for good management. Management information systems (MIS) can facilitate this process significantly.

1.2 Management information systems

Management information systems (MIS) are used to collect, process, and store data which could be aggregated and disseminated in the form of information needed to carry out the functions of business (Davis & Olson, 1985). So, a MIS produces information that supports the management decision of an organization. The quality of the decision made however, is directly related to the quality of the information used (Wang and Strong, 1996; Redman, 1998; Ballou and Tayi, 1999). An improvement in the quality or quantity of available information will enhance the quality of the decision making, the productivity and competitiveness of an organization (Daft and Lengel, 1986; Keller and Staelin, 1987).

Information for decision making is derived from data that are analysed (Davis & Olson, 1985). As a result, there is a direct relationship between the quality of information and the quality of data. Data quality is a multidimensional concept (Redman, 1995; Wang and Strong, 1996; Ballou and Tayi, 1999), but the most commonly used definition is "fit for use by data consumers" (Juran and Godfrey, 1999). Data are of good quality if they are fit for their intended use in operations, decision-making and planning. Data should be free of defects and possess desired features such as relevancy, accuracy, interpretability and completeness. Data collection practices implemented by an organization determines the data quality within an organization (Redman, 1995; Ballou and Tayi, 1999).

1.3 Problem definition

In the broiler supply chain, data are collected as a routine practice. However, the data collection systems are not uniform. Each separate firm in the supply chain produces data according to its own specific format. Moreover, these data are not always used to support neither the tactical nor operational management, but are often used to find causes in case of derogations in production. This applies particularly to the Dutch poultry meat production.

This research focusses on the Dutch broiler supply chain. Unlike in many other countries, the Dutch chain is not, or to a small extent vertically integrated (van Horne, 2010). This implies that farms or firms within this chain act independently and are connected only by delivery contracts. However, the performance of an individual firm as well as the whole chain, is determined by management decisions at every farm or firm within the chain. For this reason, the flow of information to support the management at other levels in the chain is important.

The data generated in the Dutch broiler supply chain are not often analysed and not fully used to support management decisions. This research focusses, therefore, on the use of available data in the broiler supply chain to support the breeder farm management in particular. Breeder farms deliver the eggs which are the starting material for broiler production. Thus, improving the management at the breeder farms could contribute to the improvement of the performance of subsequent farms and firms in the broiler-production chain.

1.4 Research objectives

The objective of this research is to develop a MIS based on available data in the broiler supply chain to support breeder farm management.

To achieve this objective, first, it has to be shown that management factors at breeder farms are related to performance indicators at different levels of the broiler supply chain. For example, egg collection, and storage practices and feeding management at the breeder farms affect hatching egg quality (kirk et al.,1980; Wilson, 1997). The quality of hatching eggs in turn affects the quality of day-old chicks and the performance of broiler chickens (Tona et. al. 2005; Decuypere and Bruggeman, 2007). Second, the quality of the available field data in the broiler supply chain has to be assessed as it determines the quality of the MIS. Summarizing, to achieve the objective the following sub-objectives were defined:

1. To explore management factors that are related to hatchability;
2. To explore management factors that are related to first week mortality as an indicator for day-old chick quality;
3. To analyze the data quality in the broiler supply chain;
4. To develop a data collection protocol that standardizes the content and quality of data in the broiler supply chain;
5. To develop a management information system for breeder farms at tactical level;
6. To develop an on-farm management tool that supports the optimal flock replacement decision at breeder farms.

1.5 Outline of the thesis

The outline of this thesis is illustrated in Figure 1.2. The thesis is composed of three parts. In the first part, i.e. chapter 2 and 3, management factors that are related to hatchability (i.e. sub-objective 1) and first week mortality (i.e. sub-objective 2) are explored respectively. Hatchability and first week mortality of chicks are used as performance indicators as these are related to the performance of the breeder farms, hatcheries and broiler farms.
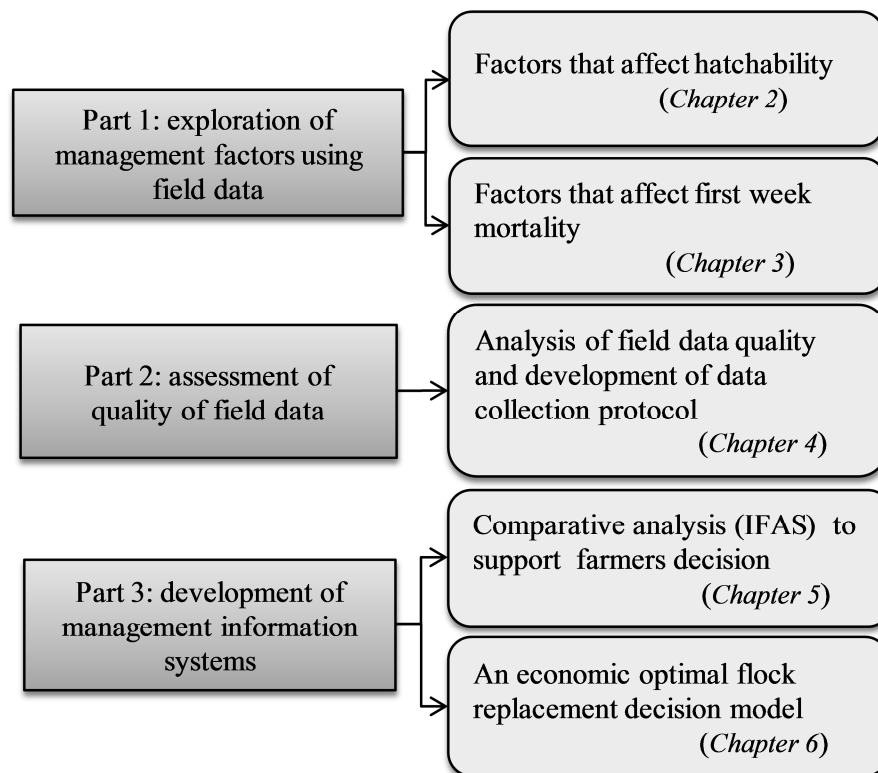
Figure 1.2 An overview of the chapters in the thesis

Hatchability, the percentage of eggs set that are hatched, is one of the most important performance indicator for the success of management at breeder farms and hatcheries. According to the literature, e.g. Kirk et al., 1980; Wilson, 1997; Tona et al., 2005; Decuypere and Bruggeman, 2007, reasons for low hatchability are improper management of the breeder flock, improper management of hatching eggs, an incorrect incubation procedure or a failure within any step between the breeder farm and the final hatch. Another important performance indicator for the success of the management at hatcheries is the quality of the day-old chicks, which means that they are healthy and vigorous. An indicator for the quality of the day-old chicks is the potential to survive the first week of life, which is not only a performance indicator for the hatchery but also of the broiler farm (Decuypere et al., 2001; Tona et al., 2005).

In the second part, i.e. chapter 4, the availability and quality of data in the field are assessed (sub-objective 3) and a protocol for standardization of data to improve the quality is proposed (sub-objective 4). The hatchery data that were analysed in chapters 2 and 3 is used for data quality assessment and the new protocol was validated with new data at 23 breeder farms, three hatcheries and 7 broiler farms.

If the relation of management factors at breeder farms and performance later in the chain is proven and if the quality of the field data is sufficient, a MIS can be developed to support decision making at tactical level (for example, by benchmarking the performance of a flock to another flocks) and subsequently operational level (for example to support the breeder flock replacement decision).

In the third part, on- farm decision support tools are developed for the breeder farms. In chapter 5, a MIS is presented for tactical management at the breeder farm using an individual farm analysis that is based on a deterministic simulation model, the so-called IFAS model (sub-objective 5). IFAS shows the strong and weak points of an individual breeder flock compared to the average of comparable breeder flocks.

Chapter 6 presents a breeder flock replacement model in which replacement decisions are based on economic optimal performance. The deterministic model uses the Marginal Net Revenue (MNR) approach to determine the optimal replacement moment which may vary between the hens age of 55 and 68 wks. The model deals with a forecast in production parameters of 25 wks to enable the planning, hatching and rearing period of the new flock.

In Chapter 7 (the general discussion) attention is given to integrated decision in the broiler supply chain, impact of the current study, recommendations for future research, and presents the main conclusions of the thesis.

Chapter 1

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Field Study on Broiler Eggs Hatchability

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Chapter 2

Abstract

The aim of this research was to explore factors that are related with hatchability in the field. Data from three Dutch hatcheries for the years 2004, 2005 and 2006 were analyzed using a random regression model with the method of restricted maximum likelihood (REML). In total 24,234 batches of 724,750,444 eggs, originating from 511 breeder flocks were included. Annually 241,583,481 eggs were set on average, which is 37% of the total annual eggs set in the Netherlands. A significant difference in hatchability among eggs from different breeder flocks was found. Hatchability was significantly related with flock age, egg storage length, strain, feed company, season, year, as well as hatchery ($P < 0.001$). There was also significant interaction between flock age and age at first delivery, egg storage length at hatchery, strain, feed company, and season. Other 3-way interaction terms were also significant. The was significant difference in hatchability among the breeder farms. The average estimated difference in hatchability among the hatcheries was 8%. The average estimated hatchability at 25 wk of age was 66%; it increased to 86% between 31 and 36 wk and decreased to 50% at 65 wk of age. On average, an extra day of storage until d 7 reduced hatchability by 0.2% and from d 7 to 14 by 0.5%. Eggs from older flocks were less sensitive to prolonged storage, whereas they were more sensitive to season. Hatchability was greater during late summer than during spring. The average estimated differences in hatchability among strains and feed companies of the breeder farms were 8 and 2%, respectively.

Based on the relations found, optimization of hatchery results depends not only on good management at the hatchery but also on the hatching egg quality and therefore on the breeder farm management. It can be concluded that production data that are collected by the hatcheries can be used to adjust the management decisions at hatcheries as well as breeder farms.

Key words

Broiler, hatchability, management

2.1 Introduction

Different production partners are involved in the Dutch broiler supply chain. Optimization of this chain depends not only on good management of every single business but also on business-to-business management and relations. The hatchery plays a central role in the breeder-hatchery-broiler supply chain. It hatches eggs from multiple breeder farms and delivers chicks to even more broiler farms. Optimization of hatchery and breeder farm management can lead to improvement of the result throughout the broiler supply chain (Heier and Jarp, 2001).

Generally, the success of hatchery management is monitored by the percentage of eggs set that are hatched (hatchability) and the number of chicks that are placed for grow out (saleable chicks). Reasons for low hatchability could be improper management of the breeder flock, an incorrect incubation procedure or a failure within any step between the breeder flock and the final hatch.

Breeder factors that affect hatchability include strain, health, nutrition and age of the flock, egg size, weight and quality, egg storage duration and conditions, egg sanitation, and season of the year (Kirk et al., 1980; Wilson, 1991 and 1997; Elibol et al., 2002; Tona et al., 2005 and 2007). Age of the breeders affect hatchability because it is related to the quality of hatching egg such as the "internal egg composition" or ratio, egg weight, shell quality whereby the incubation condition and the development of the chick embryo are influenced (Wilson, 1991;Vieira and Mora,1998 ; Tona et al. 2004; Joseph and Moran, 2005a). Hatchability is influenced by storage of eggs because the quality of the egg depreciates whereby the metabolic activity of the chick embryo is affected which in turn influences the embryonic development of the chick (Lapao et al., 1999; Christensen et al., 2001; Tonal et al., 2004; Decuypere and Bruggeman, 2007; Fasenko, 2007). Samli et al. (2005) also found an interaction between prolonged egg storage and high storage temperature with albumen pH and quality (Haugh), air cell size, specific gravity and egg weight loss, which are important characteristics of the quality of hatching eggs.

Additionally hatchery factors that are related with hatchability include, egg handling and storage condition, incubation conditions such as temperature, humidity, turning frequency, ventilation and egg orientation (Elibol and Brake, 2006; Decupere and Bruggeman, 2007).

Most Dutch hatcheries collect data about breeder flocks and hatching performance mainly for their own quality control system. However, these data are not often analyzed on routine basis to improve their daily management and thus their business performance. In contrast to previous studies, which were based on pre-designed experimental protocols that consider limited factors, the aim of this research was to study the relationship between several factors and hatchability in the field. The effects of management factors that are related to breeders and hatcheries were addressed in this study.

2.2 Materials and methods

2.2.1   Description of the data

Data of three commercial Dutch hatcheries were collected (Table 2.1). The data set includes hatchability records for the years 2004, 2005, and 2006. In total, 24,234 batches consisting of

724,750,444 eggs that are originated from 511 breeder flocks are included. Annually 241,583,481 eggs were set; that is, on average, about 37% of the total number of annual eggs set in the Netherlands, which was 648,000,000 in 2006 (PVE, 2007).

The observational unit is a batch of eggs, which is defined as the number of eggs from a group of hens housed in the same house that were delivered by a breeder farm to the hatchery at a single date and were set for incubation at single date and time. The data set included flock code, flock age (wk), length of storage at the hatcheries (d), number of eggs set, date of set, the age of the hens at first delivery, strain, feed company of the breeder flock, the year, the hatcheries and, the number of chicks sold to the broiler farm.

The dependent variable is hatchability which is the percentage of the total number of eggs set (i.e. hatch of eggs set) that result in good quality chicks (first grade chicks) to be sold to the broiler farms.

Table 2.1. Description of the data set

Independent variable	Unit	Range	Average	Total number	Missing/ unknown
Hatcheries involved	Code	(A, B and C)[1]	…	3	…
Breeder flock	Code	…	…	511	…
Strain	Code	(R1 to R12)[2]	…	12	110
Date of set	Date	01-01-'04 to 31-12-'06			11637
Days of the week	Days	Monday to Sunday			11637
Feed company	Code	(V1 to V16)[3]	…	16	112260
Flock age	Weeks	24 to 65	43	…	1112
Age at start delivery	Weeks	(19 to100)[a]	27	…	483
Egg- storage length	Days	2 to14	4		0
Number of batches in three years	Number	…	…	24234	
Hatchability of eggs set	Percent	40 to 99	77	…	…
Hatchability of eggs set after 18th day (candling)	Percent	40 to 99	87	…	…

[1, 2, and 3] Codes of the hatcheries, the strains and the feed companies respectively.
[a] 89% of the age at first delivery is between 21 and 28 wk.

2.2.2 Statistical Analysis

Before conducting the statistical analysis, observations were checked for unlikely values, and some restrictions were made. The data set was restricted to age of the hens between 25 and 65 wk to exclude molted flocks and hatchability between 40%, and 95 is included. The production date of the eggs was not in the data set, and therefore, the egg storage length refers to days of storage at the hatchery, which is restricted from 2 until 14 d. In the data set, 12 stains were recorded; of those, 8 are defined (Ross 308, Ross 508, Ross 708, Cobb, Cobb 500, Cobb 600, Hubbard, and Hybro) and 4 are not. Additionally, there were 16 feed companies recorded, and 1 is undefined. If no strain of the breeder flock or no feed company of the breeder farm is known, a variable (unknown) is included in the data set. One hatchery did not

register the date of set, because it uses set numbers to identify the batches. In this case, January 1, 2004 is used as the date of egg set.

The data analysis was conducted using the statistical programming language Genstat version 8 for Windows (VSN International, Hemel Hempstead, UK). The data structure was unbalanced. Each breeder farm usually delivers all the eggs of one flock to one hatchery and did so for subsequent years. In addition, the frequency distribution of the age at first delivery, strain, and feed company was skewed. Therefore, hatchability was tested using a random regression model with the method of restricted maximum likelihood. First, the random model was tested, and then individual traits were modeled, using a generalized linear model with a logit link function, so that they could also be examined for their relative importance to the hatchability. Flock age, age at first delivery, egg-storage length at the hatchery, days of the week, hatcheries, season, year, strain, feed company as well as their interactions were tested as explanatory variables in the model. For all variables, residuals were checked for homogeneity of variance based on residual plots.

2.2.3   Random model

The production of eggs as well as the quality of the eggs produced (which results in hatchability) per hen is age-dependent. This study therefore assumes that the hatchability of eggs per flock follows a probability curve with slopes and intercept, as does the lactation curve of dairy cows. Soysal et al. (2004) suggested different models to describe the lactation curve. In this study, the Wood curve is used to describe the hatchability curve (Wood, 1967):

$$\text{logit}(H) = FID_0 + FID_1 \cdot \ln(A+1) + FID_2 \cdot A + \varepsilon \tag{1}$$

Where H is the hatchability of eggs at flock age A, *FID* is the flock that supplies the hatching eggs at that specific date when the eggs where set and A the flock age at the date of production of the eggs. In other words, $FID_0 = \beta_0 + \underline{\varepsilon}_0$, $FID_1 = \beta_1 + \underline{\varepsilon}_1$ and $FID_2 = \beta_2 + \underline{\varepsilon}_2$ where $\beta_0, \beta_1, \beta_2$ are estimates for the intercept, ln(A+1) and A and $\underline{\varepsilon}_0 \sim N(0, \sigma_0^2)$, $\underline{\varepsilon}_1 \sim N(0, \sigma_1^2), \underline{\varepsilon}_2 \sim N(0, \sigma_2^2)$ are random effect of a flock at the intercept, ascending and descending slopes respectively.

2.2.4   Fixed model

For the fixed model, initially the full model was run containing all the variables and all four-way, three-way and two-way interactions between variables. Backwards stepwise elimination of non-significant interaction terms (P>0.05 Wald's test), starting with the four-way interactions and ending with the two-way interactions was carried out. Thereafter, non-significant variables were eliminated to end with the best-fit final model consisting of significant variables and interaction terms except for the variables season and age at first delivery where the whole effect is considered significant if an interaction term is significant and the single variables are not. For example, if one of the two season variables i.e. $\sin\left(\frac{2\pi}{365} \cdot d\right)$ or $\cos\left(\frac{2\pi}{365} \cdot d\right)$ is significant both the variables are included in the model (Grossman et al., 1986).

The final model is:

$$
\begin{aligned}
\text{logit}(H) = {} & C + \sin\left(\tfrac{2\pi}{365}\cdot d\right) + \cos\left(\tfrac{2\pi}{365}\cdot d\right) + \ln(A+1) + A + SA + FC + B + \\
& A\cdot SA + \ln(A+1)\cdot FC + A\cdot FC + \ln(A+1)\cdot B + A\cdot B + YR + HR + ES + ES^2 \\
& + HR\cdot YR + A\cdot\cos\left(\tfrac{2\pi}{365}\cdot d\right) + A\cdot ES + A\cdot ES^2 + \cos\left(\tfrac{2\pi}{365}\cdot d\right)\cdot HR\cdot YR + \\
& ES\cdot HR\cdot YR + A\cdot\sin\left(\tfrac{2\pi}{365}\cdot d\right) + \sin\left(\tfrac{2\pi}{365}\cdot d\right)\cdot HR\cdot YR
\end{aligned} \tag{2}
$$

Where C is the intercept, $\sin\left(\tfrac{2\pi}{365}\cdot d\right)+\cos\left(\tfrac{2\pi}{365}\cdot d\right)$ describes the seasonality based on the dth day of the year, A is used to calculate the effect of flock age, SA the age when the flock for the first time supplies the hatchery, FC is the feed company of the breeder farm, B is the strain, YR is the year, HR is the hatchery code and, ES is the egg storage length.

The following model choices were carried out. The flock age (FA) is calculated as a function of A and natural logarithm of (A+1) where $A = FA - 24$ which results in the defined hatchability curve with intercept and slopes. Furthermore, to check for an optimal storage length, both ES and ES^2 were included. To allow for smooth seasonality effects the summation of $\sin\left(\tfrac{2\pi}{365}\cdot d\right)$ and $\cos\left(\tfrac{2\pi}{365}\cdot d\right)$ was included and tested, using the date of egg delivery (i.e. subtracting the date at which the eggs were set from the storage length) and from this, the number of the dth day was calculated (Grossman et al., 1986).

2.3 Results

2.3.1   Random model

Results from the model using the chi-square test showed a significant difference in hatchability among breeder flocks in relation to the age of the hens. Estimates for the difference at the intercept and ascending slope are 2.58 and 0.97 respectively (Table 2.2).There is a significant difference in the peak hatchability among the flocks. Thus, there is a difference in the way the flocks reach the peak hatchability (rates of pre-peak ascending) and declines from the peak level (rate of post-peak decline). The significant model indicates that flocks with eggs of high initial hatchability at the intercept have a lower ascending rate and a relatively lower descending rate in contrast to those with lower initial hatchability. The variation in hatchability among flocks increases with flock age. The results indicate that flocks vary in persistency of hatchability. The model explains 91% of the difference in hatchability that occurred.

Table 2.2. Estimates, standard errors, t-values and p-values of the parameters of the random model

Parameter	Description	Estimate	s.e.	χ^2 prob
$Cov(\beta_{0,\,\beta1})^a$	$Cov(FID_0,(FID_1 \cdot \ln(A+1))$	-0.92	0.01	<0.001
$Cov(\beta_{0,\,\beta2})^b$	$Cov(FID_0,(FID_2 \cdot A))$	0.72	0.04	<0.001
$Cov(\beta_{1,\,\beta2})^c$	$Cov((FID_1 \cdot \ln(A+1)),(FID_2 \cdot A))$	-0.89	0.09	<0.001
$\varepsilon_0{}^d$	Difference among breeder flocks at the intercept	2.58	0.35	<0.001
$\varepsilon_1{}^d$	Difference among breeder flocks in ascending slope	0.97	0.13	<0.001
$\varepsilon_2{}^d$	Difference among breeder flocks in descending slope	0.004	<0.01	<0.001
Residual		0.12	<0.01	

[a] describes the relation between the initial hatchability at the intercept and the increase in hatchability i.e. the ascending slope;

[b] describes the relation between the initial hatchability at the intercept and the decrease in hatchability i.e. descending slope;

[c] describes the relation between the ascending slope and descending slope of the hatchability curve;

[d] ε_0 shows the variation in hatchability among flocks at the intercept and ε_1 and ε_2 show the variation in hatchability among flocks at the ascending and descending slope respectively in relation to flock age.

2.3.2 Fixed model

Table 2.3 shows the estimates of the final fixed model. The fixed model describes significant factors and interactions, which are related with hatchability. The model is described using a formula, which combines the main effects and interactions of the factors (formula 2).

Age at first delivery

The variable 'age of the hens at first delivery' was not significant. However, the interaction 'age of the hens at first delivery × flock age' was significant (P<0.001). The hatchability of eggs from hens that deliver earlier is higher than the hatchability of eggs that originate from hens that start at a later age (Figure 2.1, panel A).

Flock age

Flock age was significantly related with hatchability (P<0.001). At the age of 25 wk, the average estimated hatchability[1] was 66%. The average estimated hatchability increased to 86% between the age of 31 and 36 wk, where after it decreased to 50% at the age of 65 wk.

---

[1] Calculated based on the average situation.

Table 2.3. Estimates, standard errors and Chi-square probabilities of the fixed model.

Variables	Description	Estimates	(s.e.)	χ^2 prob.
C	Intercept	0.73	0.19	
$\cos\left(\frac{2\pi}{365} \cdot d\right)$	Cosine of the dth day of the year	0.12	0.04	0.504[a]
$\sin\left(\frac{2\pi}{365} \cdot d\right)$	Sine of the dth day of the year	-0.04	0.04	0.765[a]
ln(A+1)	Ln (Flock age + 1)	1.03	0.08	<0.001
A	(Flock age)	-0.10	0.01	<0.001
SA	Age at start delivery	-0.02	0.00	0.424[a]
FC	Feed company	(-0.97 ; 0.22)[b]	0.60	<0.001
B	Strain	(-1.46 ; 0.86)[b]	0.56	<0.001
$A \cdot SA$	Flock age * age at start delivery	0.00	0.00	<0.001[a]
$\ln(A+1) \cdot FC$	Ln (Flock age + 1) * feed company	(-0.05; 0.80)[b]	0.37	0.038
$A \cdot FC$	Flock age * feed company	(-0.06 ; 0.00)[b]	0.03	<0.001
$A \cdot B$	Flock age * strain	(-0.10; 0.08)[b]	0.02	<0.001
YR	Year			<0.001
2004		0.00	0.05	
2005		-0.03	0.05	
2006		-0.08	0.05	
HR	Hatchery			<0.001
A		0.00	0.07	
B		0.05	0.07	
C		-0.21	0.07	
ES	Egg storage length	0.02	0.01	<0.001
$(ES)^2$	(Egg storage length)^2	-0.01	0.00	<0.001
$\ln(A+1) \cdot B$	Ln (Flock age + 1) * strain	(-1.07 ; 1.12)[b]	0.33	<0.001
$HR \cdot YR$	Hatchery * year	(-0.06 ; 0.01)[b]	0.07	0.019
$A \cdot \sin\left(\frac{2\pi}{365} \cdot d\right)$	Flock age * $\sin\left(\frac{2\pi}{365} \cdot d\right)$	-0.01	0.00	0.444[a]
$A \cdot ES$	Flock age *egg storage length	-0.01	0.00	<0.001
$A \cdot (ES)^2$	Flock age * (Egg storage length)^2	0.00	0.00	<0.001
$HR \cdot YR \cdot \sin\left(\frac{2\pi}{365} \cdot d\right)$	Hatchery * year * $\sin\left(\frac{2\pi}{365} \cdot d\right)$	(0.00 ; 0.06)[b]	0.04	0.721[a]
$HR \cdot YR \cdot ES$	Hatchery * year * egg storage length	(-0.01 ; 0.01)[b]	0.01	<0.001
$A \cdot \cos\left(\frac{2\pi}{365} \cdot d\right)$	Flock age * $\cos\left(\frac{2\pi}{365} \cdot d\right)$	-0.01	0.00	<0.001[a]
$HR \cdot YR \cdot \cos\left(\frac{2\pi}{365} \cdot d\right)$	Hatchery * year * $\cos\left(\frac{2\pi}{365} \cdot d\right)$	(-0.09;0.00)[b]	0.03	0.006

[a] if an interaction term is significant and the single variables are not (like the age at first delivery), the variable will be included in the model. Additionally, if one of the two season variables is significant both the variables are included in the model.

[b] because this factor includes more varieties, more estimates are calculated. To restrict the size of the table the minimum and the maximum estimates are given respectively.

Egg storage length at hatchery

Egg storage length at the hatchery and the interaction 'egg-storage length × flock age' were significantly related to hatchability (P<0.001). If eggs are stored hatchability decreased with different rates in relation to the age of the flock at egg production. Hatchability of eggs of young breeders is affected more by prolonged (8 to 14 days) storage than that of old breeders (0.8% vs. 0.4% per day of storage) for age group 25-30 and 51-60 wk respectively (Table 2.4 and Figure 2.1, panel B). The negative effect of storage increases with storage length. On average, each extra day storage of eggs before the 7th day reduced hatchability by 0.2% and after the 7th day by 0.5%. Furthermore, the effect of egg storage length on hatchability was significantly different among the hatcheries (P<0.001). Storage affected hatchability more at hatcheries A and C than at hatchery B.

Table 2.4. Effect of egg storage length at hatchery for different age classes

Age of hens (wk)	Decrease in hatchability per day of storage at hatcheries (%)	
	3rd–7th day	8th–14th day
25-30	-0.2	-0.8
30-35	-0.1	-0.6
36-45	-0.1	-0.5
46-50	-0.2	-0.5
51-60	-0.2	-0.4
61-65	-0.2	-0.3

Strain and feed company

There was a significant difference in hatchability of eggs from different strains (P<0.001) (Table 2.3). The interaction 'flock age × strain of the breeder flocks' showed also a significant effect on hatchability. There was a difference in initial hatchability among the strains, the peak hatchability, the ascending rate to the peak, and the descending rate from the peak hatchability. (Figure 2.1, panel C).

There was also a significant effect of the feed company (of the breeder farm) and the interaction 'flock age × feed company' on hatchability (P<0.001 and P<0.05 respectively) (Table 2.3). Estimates show that feed companies contribute to a variation in the initial hatchability, the peak and post-peak hatchability decline (Figure 2.1, panel D).

Hatchery, year, and seasonality

There was a significant difference in hatchability among the hatcheries and within the hatcheries in different years (P<0.001) (Table 2.3 and Figure 2.1, panel F). The hatcheries had different best and worst years. However, only hatchery A performed consistently during all three years.

Season had significant effect on hatchability, but the effect is also related to the age of the breeder at egg production and the 'hatchery x year' interaction (P<0.001 and P=0.006) respectively (Table 2.3). Hatchability was higher during late summer than during spring, whereas the effect was greater for eggs from older hens than for those from younger hens

(Figure 2.1, panel E). Furthermore, the effect of season was more prominent at hatchery A than hatchery B (Figure 2.1, panel E) and for year 2006 than for the years 2005 and 2004.
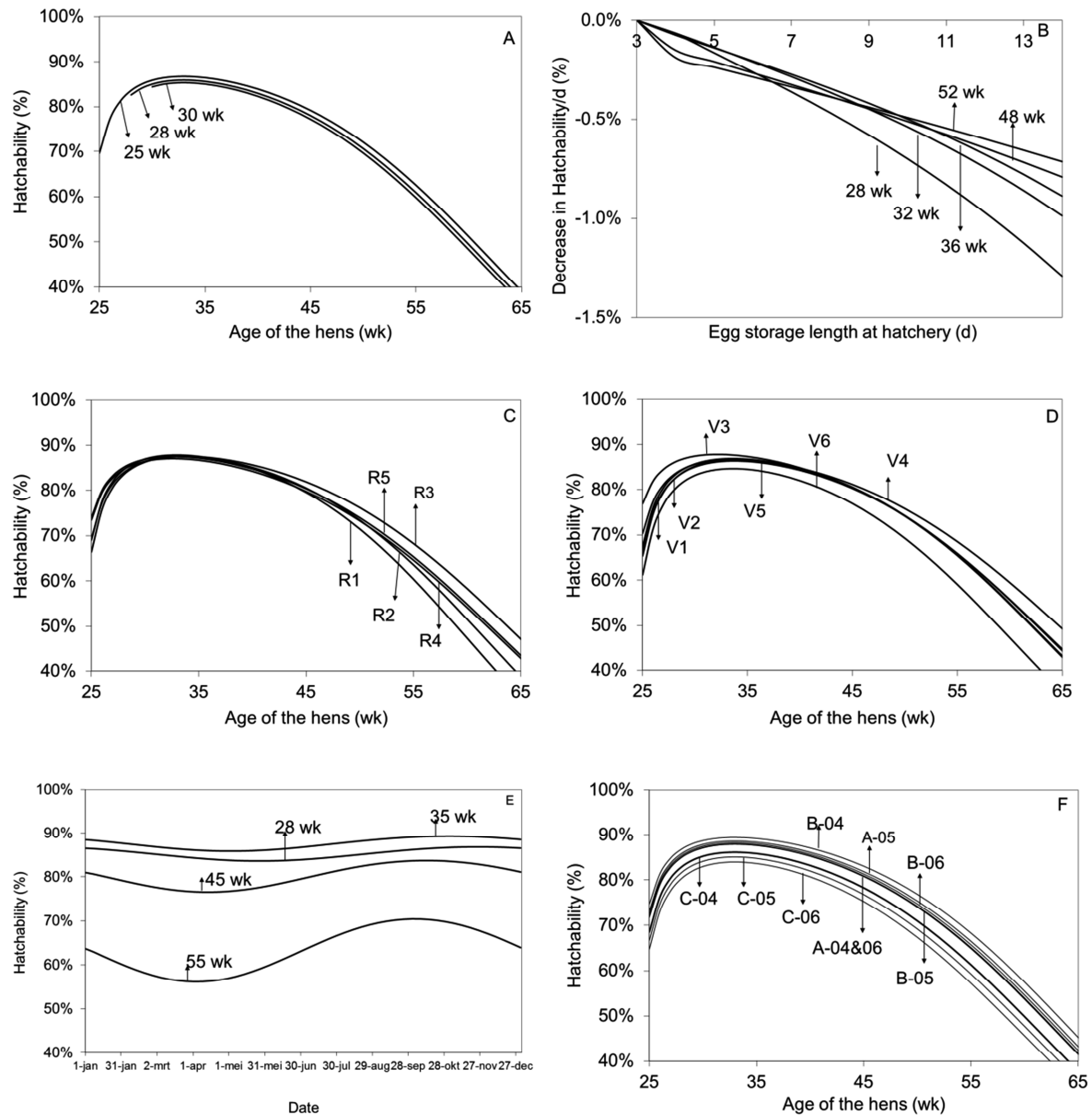
Figure 2.1. Panel A, shows the hatchability and the difference in hatchability between hens at different age at first delivery to the hatcheries (25, 28, and 30 wks). Panel B, shows the decrease in hatchability in relation to egg storage length at hatchery. Panels C and D, show the hatchability and the difference in hatchability between flocks of different strains (R1 to R5 are example of the strains that represent more than 500 batches) and feed companies (V1 to V6 are example of feed companies that represent more than 250 batches) respectively. Panel E, shows the seasonality of hatchability and the relation of season with ages of the breeders. Panel F, shows the difference in hatchability among hatcheries A, B, and C and its interaction with year (2004, 2005, and 2006).

2.4 Discussion

For better decision making, hatchery management should have information on factors that influence hatchability and chick quality. Mostly, hatchability is related to egg fertility and embryonic mortality throughout the hatching processes. Therefore, all factors that affect the fertility of the egg and cause embryonic mortality during the incubation process should be better understood before making any management decision.

This study is based on field data that were collected by hatcheries. These data were not collected for scientific reasons and therefore, can be less accurate. However since the data are (partly) collected for financial system the accuracy should be high. Furthermore, there is the advantage of a large data set with which this study deals and which tend to counteract the effect of errors. Analyzing field data, results in finding relations without being able to test the causality. Therefore, the found relations will be discussed in the light of experimental literature to suggest causality and to indicate where knowledge is lacking.

In this study, hatchability is based on total eggs set, thus discrimination between losses due to infertility or embryonic mortality could not be made. From the management point of view, specific knowledge of the cause of low hatchability is essential, because good management of the cocks and hens at the breeder farm could improve poor fertility, whereas a high level of embryonic mortality may be the result of poor management of hatching eggs at the farm and at the hatchery.

Variation was found in hatchability patterns among breeder flocks. Similar to the findings of Tona et al. (2007), the differences in hatchability among flocks increase with flock age. This variation, especially as the flock ages, indicates room for improvement of the management at the breeder farm level.

The variation in hatchability among the breeder farms might be caused by different management factors, such as housing system, nest type, egg handling, egg collection system, storage management, genetics, nutrition, health, male to female ratio and other related factors (Meijerhof, 1992; Wilson, 1997; Heier and Jarp, 2001). The housing systems (Reu et al., 2005) and the type of laying nest used (Godard et al., 2007) for example; determine the level of microbial contamination of the hatching eggs whereby hatchability could be affected.

Age at first delivery

Hatchability was influenced by age at first delivery to the hatcheries. High hatchability was found in hens that start at an early age. The high hatchability of eggs from early matured hens (25 rather than 28) could be related to rearing management (i.e., the feeding and photostimulation programs during rearing). Sometimes flocks are late maturing due to late and slow light stimulation, underfeeding at the onset of lay, and uneven uniformity of the flock, which consequently affect the reproductive performance of the flocks. The age at first egg can be affected by the age at first photostimulation, which in turn is dependent on the photoresponsive characteristics of birds (Lewis et al., 2007). Body weight of the hens at first egg affects the egg weight (Lewis and Morris, 1998), which in turn is related to hatchability (Wilson, 1991). Therefore, at the onset of lay, feed intake should be adjusted along with light stimulation to achieve a mature physical state. Moreover, feed allocation regime during rearing affects hatchability. According to Wilson et al. (1995), the number of chicks hatched

per hen for the period from 28 to 58 wk of age was greatest in the early fast than the standard and early slow regimes.

Flock age

Results of this research confirm that the age of the breeder flocks plays an important role in the management practice of the breeder farms as well as the hatcheries. Similar to the review of Wilson (1991), lower hatchability was seen at both young and old ages. Until the hens reached the age of 30 wk, there was a slightly lower hatchability. This could be related to the less fertility and greater incidence of nonviable germs of eggs of young breeders (Wilson, 1991; Pedroso et al., 2005). As described in the literature, eggs from young breeders have thick shells and produce smaller chicks that may have less physical strength to break the shell during hatching, resulting in embryo mortality after pipping (Pedroso et al., 2005). Moreover, the lower eggshell conductance of young breeders results in inadequate movement of water vapor and respiratory gasses during the incubation process (Christensen et al., 2005). Furthermore, according to Noble and Yafei (1988), the low hatchability of eggs of young broiler breeders is associated with the fatty acid composition of the yolk and the ability of the chick embryo to mobilize the yolk lipids to be used for embryonic development.

For eggs of older breeders, hatchability decreases because of change in egg quality and failure to adjust the incubation condition according to the requirement. As the hen ages, the albumen quality deteriorates (Lapao et al., 1999; Tona et al., 2004), the yolk cholesterol content increases (Dikmen and Sahan, 2007), and the thickness of the eggshell decreases (Bennett, 1992).

Additionally, though different incubation condition is required for different age classes, in practice, eggs of different age classes or eggs with different sizes are incubated together with an average incubation temperature. However, eggs from older breeders are known to hatch earlier and suffer more from postemergent holding in the hatcher than those from younger breeders (Vieira and Mora, 1998; Joseph and Moran, 2005a). Eggs from older breeders are larger with larger embryos; thus, they produce more heat during incubation (Lourens et al., 2006). Besides, the larger egg size of older flocks results in little space between the eggs during the incubation process, thus reducing the air velocity over the eggs (French, 1997). If eggs of different age classes are to be incubated together, adjustments should be made to the incubation condition accordingly. For example, the machine temperature should be reduced earlier or the airflow around the eggs should be increased more for the larger eggs than for smaller eggs, or both (Lourens et al., 2006).

In this study, most of the hatchery as well as breeder management factors were significantly related with the age of the hens. In accordance to the result of Creel et al. (1998) and Tona et al. (2007), the age of the breeders could be an important indicator for management decisions made by breeder farms as well as the hatcheries.

Egg storage length

For different reasons, eggs are not usually incubated immediately after laying, but they are stored both at the breeder farms and at the hatchery. In this research, only the length of storage period at the hatcheries was considered. Therefore, the real egg storage length is at least 1 to 4 d longer due to the storage at the breeder farm.

Egg storage at the hatcheries decreased hatchability significantly. The effect of egg storage differed significantly among the hatcheries. In addition to storage conditions at the hatchery, storage conditions at the farm and handling during transportation might also have contributed to the difference found.

Though different maximum limits were given for egg storage before it affects hatchability, the negative effect of storage was also found in other studies (Reis et al., 1997; Lapao et al., 1999; Tona et al., 2004; Samli et al., 2005). During storage, the length of storage period, temperature, humidity, gaseous environment, and the orientation of the eggs (Meijerhof, 1992; Fasenko, 2007) influence hatchability. Egg storage depresses albumen quality, affects embryonic viability in all flock ages, and results in less percentage of good quality day-old chicks (Lapao et al., 1999; Tona et al., 2004). Long and improper storage temperatures decrease the albumen Haugh unit and increase the air cell size of the eggshell, which results in low hatchability (Samli et al., 2005).

In this study, the decrease in hatchability due to storage differed for different age classes, and the variation was bigger among the young flocks. The result shows that eggs from younger breeders were more sensitive to prolonged storage than eggs from older breeders, which is contrasting with the findings of Reis et al. (1997), Tona et al. (2004), and Samli et al. (2005). According to Brake et al. (1997), during storage, the temperature, relative humidity, and the gaseous environment of storage interact with the fertile egg and affect certain components of the egg, of which the albumen is the most detrimental portion for the time- and environment-related effect of storage. However, the albumen quality and percentage is affected by age (Lapao et al., 1999; Tona et al., 2004) and strain (Suarez et al., 1997) of a flock. Therefore, in addition to the storage duration, during storage, the age and strain of a flock should also be considered while adjusting the storage conditions. However, in practice, changing storage conditions for each flock, from different breeder farms and different age classes at hatchery level, might be more difficult than altering egg storage conditions per specific flock at farm level. Besides, it is assumed that hatchery conditions for egg storage are given much more attention than on-farm egg storage conditions, mainly because of better knowledge of storage conditions and relatively well-maintained climate of the hatchery.

The found relation of egg storage with hatchability is confirmed in the literature. However, complete and accurate information about storage duration at the breeder farm and storage condition at the breeder farm as well as hatcheries is required in order to know the point of improvement.

Strains and feed company

The difference in hatchability among strains was highly significant and was related to the age of the parent flock. Management at the breeder farm as well as at the hatchery should be adjusted according to the strains, because every strain responded differently to hatchability. Fertility of an egg and embryonic mortality during the hatching process are the most important characteristics to determine hatchability, and it is known to be different for different strains. As the flock ages, for example, there was more infertility and early embryonic mortality in eggs from Ross 308 compared with Cobb 500 (Deeming and Van Middelkoop, 1999). Among different strains, difference was also found in egg weight and components like the yolk and albumen percentage, yolk: albumen ratio, shell percentage, and incubation time

(Suarez et al., 1997; Joseph and Moran, 2005b). As revised by Decuypere and Michels (1992), there is a significant difference in the tolerance limits for temperature fluctuation during incubation not only between strains but also within strains. Besides, genetic strain and parent flock age influence daily embryonic metabolism during the early and latter days of incubation, which coincides with the incidence of greater embryonic mortality during this period of incubation (Hamidu et al., 2007).

The above-mentioned findings suggest that different strains require different management at the breeder farms as well as at the hatcheries. The management of the breeder farms and the hatcheries should use recommendations that are applicable to each strain in making decisions, and adjustments should be done by assessing the performance of the strain at a specific time.

A difference in hatchability among the feed companies of breeder farms was found, and the variation was larger as the flock aged. The difference might be caused by variation in nutritional values of the feed, feed processing system, feed storage system, and the relation of the breeder farm with the feed company, which determines the advice provided to the breeder farm. Because embryonic development depends on the supply of nutrients within the egg, which is transferred from the maternal nutrition, inadequate, excessive, or imbalanced levels of nutrients may decrease hatchability (Wilson, 1997; Decuypere and Bruggeman, 2007).

Hatchery, year, and season
Difference in hatchability was observed among the hatcheries. This difference could be caused by the level of communication with their business partners, location and size of the hatcheries, level of personnel qualification, incubator quality, choice of breeder farms, and the strains. Hatchability was also different within the hatcheries in the three yr. Hatchery A performed relatively consistent during the three yr.

Hatchability was significantly affected by seasons. Generally, high hatchability was found during summer, although the greatest and lowest hatchability varied with season in different hatcheries.

In contrast to the result of this study, Chowdhury et al. (2004) and Tona et al. (2007) found high hatchability in fall and winter and lower hatchability in the summer using data from broiler flocks in Belgium and data from a duck-breeding farm in Bangladesh, respectively. However, the effect of season was not related to the flock age in both studies as it is in this study. The statistical method used to calculate seasonality in this study allows for the seasonal fluctuation that occurs. To justify the result of this study, seasonality was analyzed in relation to daylight and market price, but no association was found. Future research is recommended to find an adequate explanation.

The results revealed room for improvement at the hatcheries as well as the breeder farm level. Variation in hatchability among the hatcheries as well as the breeder farms is substantial quantity. Different reasons may cause this variation (e.g., the size and standard of the businesses, the level of communication with the business partners, and training and experience of the personnel). In agreement with the results of many experimental studies, the result showed that hatchability depends not only on the management factors at the hatcheries (e.g., egg storage length and seasonality) but also on flock age, age at first delivery, the strain, and the feed companies.

What starts at the breeder farms with a fertile egg ends at the hatchery with a chick. The history of the eggs and feedback about the performance of the chicks at the broiler farm are important decision parameters for the hatchery management. Therefore, collecting and analyzing relevant data and exchanging information at the right moment could reduce losses to maximize chick production or sales.

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Field Study on Broilers First Week Mortality

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Chapter 3

Abstract

In the Dutch broiler supply production chain, first week mortality (FWM) of the chicks is an important measure to quality and is therefore highly related to the price of the chicks that the broiler farm has to pay to the hatchery. Therefore, next to the total number of broiler eggs produced per hen and hatchability, this figure is often used as a measure of efficiency in the breeder-hatchery-broiler supply chain. In this study, factors that are related to chick mortality in the first week at broiler farms were investigated. Field data obtained from 2 commercial Dutch hatcheries, for which 482 broiler farms voluntarily recorded FWM of 16,365 flocks of broiler chicks over the years 2004, 2005, and 2006, were analyzed. These represented 79% of the total number of day-old chicks delivered to separate broiler farms. First week mortality was significantly related to breeder age, egg storage length at the hatchery, season, strain, feed company of the breeder farm, year, and hatchery. Furthermore, FWM differed significantly between chicks originating from eggs of different breeder flocks and which were kept for grow-out at different broiler farms.

Key words

Broiler, first week chick mortality, management

3.1 Introduction

In the broiler supply chain, the production of high quality day-old chicks that are healthy and vigorous is crucial and is the hinge that determines the economic efficiency of the chain process. Poultry production in general and broiler production in particular, are very important in the Dutch economy. In 2006, 590 million broilers were produced for slaughter, 19.2% of which were exported, with a value of approximately 84 million Euros (PVE annual report, 2007). Mortality in broilers means a loss in income to broiler farms as well as to the hatcheries.

In addition to the above-mentioned economic importance, there are 2 main reasons to focus on first week mortality (FWM) in the Dutch broiler chain. The first reason is that FWM is an important measure for quality and is related with the price of the chicks that the broiler farm has to pay to the hatchery. The second reason is the new European Union directive, which aims to increase the welfare of broilers. Chick mortality is used as one of the indicators of the occurrence of welfare problems (European Union, 2007). The members of the European Commission agreed that high welfare standards at the broiler farm are conditional on the achievement of low mortality rates and guides to good management practice. Accordingly, to justify increased stocking density at the broiler farm, the daily cumulative mortality rate in at least 7 consecutive flocks should be below 1% + 0.6% × slaughter age of the flocks per day. When mortality rates are often too high, the broiler farmer should reduce the number of chicks in the next round.

At the broiler farm, the weekly mortality rate changes through time. According to Heier et al. (2002), the average weekly cumulative mortality during the first week was 1.54 and 0.48% a week during the remainder of the grow-out period.

The first week life of broiler chicks is important because modern broiler chicks grow faster than ever in their early days, resulting in a short lifetime at the broiler farm. In addition, the first few days of the chick's life are a transitional period from a very conditioned life at the hatchery to a more independent life at the broiler farm. A major change occurs in the morphophysiology of the digestive, immune, and the thermoregulatory systems of the posthatch chicks. Furthermore, in the posthatch chick, the source of nutrients is replaced with an exogenous diet and the hatchlings switch from utilizing a yolk nutrient-based diet to a solid external feed diet. These changes require an adaptation period for the entire physiological system of the chick (Vieira and Moran, 1999).This means that there is more stress on management during the first week, which has to be able to establish a healthy appetite with good feeding and drinking behavior quickly to maximize their opportunity for growth. Therefore, the mortality rate during the first week can be an indicator of the performance of the flock during the rearing period.

Different factors affect the survivability and performance of broiler chicks at the broiler farm. The performance of a chick at the broiler farm depends on quality of the chick that is delivered, the daily management, and the housing environment at the broiler farm. Vigorous and healthy day-old chicks are the basis for a broiler flock to perform efficiently. Sick, underweight, dehydrated, stressed, or weak chicks will not perform to their genetic potential (Wilson, 1991, 1997; Joseph and Moran, 2005; Tona et al., 2005; Decuypere and Bruggeman, 2007). Breeder age affects the performance of a broiler flock differently throughout the grow out period (Peebles et al., 1999). Furthermore, incubation condition, which is mostly related

to breeder age (Joseph and Moran, 2005), and egg storage length (Tona et al., 2004) affect the performance of the chicks at the broiler farm. Lourens et al. (2005) mentioned the importance of controlling the eggshell temperature during the incubation period because it affects the rectal temperature (body temperature) of the chick during the first week.

Additionally, the potential of a chick to survive the first week is directly related to the quality of the day-old broiler (Goodhope, 1991). The day-old chick quality depends on the genetic line of the breeders, breeder age, egg weight, egg storage conditions and duration, and incubation conditions such as temperature, humidity, gas levels, and altitude (Wilson, 1991; Peebles et al., 1999; Vieira and Moran, 1999; Decuypere et al., 2001; Tona et al., 2004, 2005; Decuypere and Bruggeman, 2007). Moreover, according to the result from a field study using data of commercial Dutch hatcheries (Yassin et al., 2008), a good hatch result depends on flock, breeder age, the age at first delivery of hatching egg, strain, feed-providing companies of the breeder farms, storage length at hatcheries, season, and the hatchery.

Factors such as rearing season (Imaeda, 2000), shipping distance and delivery route (Chou et al., 2004), stocking density, flock size, feeding management, drinking system, ventilation, and floor insulation at the broiler farm (Heier et al., 2002) are related to FWM. According to Heier et al. (2002), for example, the mortality of large flocks and flocks with a high stocking density was significantly lower than in small flocks and flocks with small density. In addition Chou et al. (2004) found the lowest cumulative FWM in broiler chicks raised in rooms with open-curtain ventilation (1.30%) than those raised in rooms with negative-pressure ventilation (1.42%) and water-cooled ventilation (1.37%).

In contrast to previous studies, which were based on pre-designed experimental protocols, the aim of this research was to study the relationship between several factors and FWM at the broiler farm, using field data from Dutch hatcheries. The effects of management factors that are related to breeders and hatcheries were addressed in this study.

3.2 Materials and methods

3.2.1 Description of the data

First week mortality data, which were collected by two commercial Dutch hatcheries (Table 3.1), were analyzed. The data included 482 broiler farms, who voluntarily recorded FWM of 16,365 flocks of broiler chicks over the years 2004, 2005, and 2006. This covered 79% of the total number of day-old chicks delivered to separate broiler farms.

The statistical unit used is a broiler flock (i.e., a flock housed in one barn and that originates from one breeder flock or from a mixture of breeder flocks at a specific date and time). Note that it is possible that chicks from one breeder flock can be housed in different barns (at one or different broiler farms). Additionally, chicks originating from different breeder flocks can be housed in 1 barn (31% of the data set).
In this case, more records (multiple origins breeder flocks per barn) were included but, in the model, a variable percentage of chicks delivered per breeder flock per barn was calculated for correction.

The data set included the following: flock code, breeder age (wk), length of storage at the hatcheries (d), number of eggs set, date of set, the age of the hens at first delivery, strain, feed company of the breeder farm, year, hatcheries, number of chicks sold to the broiler farm,

broiler farm code, date of chick delivery, barn number, percentage of chicks delivered per breeder flock per barn, feed company of the broiler farm, and number of dead chicks in the first week.

First week mortality is calculated as the total number of chicks that died in the first week after housing (Dead chicks) as the numerator and the number of chicks housed (Housed chicks) at the start as the denominator:

$$FWM = \frac{\# Dead\ chicks}{\# Housed\ chicks} \cdot 100\% \qquad\qquad (1)$$

Table 3.1. Description of the data set on FWM

Independent variable	Unit	Range	Average	Total number	Missing
Hatcheries involved	Code	A & B[1]	…	2	…
Breeder flock	Code	…	…	511	…
Broiler farms	Code			482	…
Strain	Code	R1 to R11[2]	…	11	7
Date of delivery at the broiler farm	Date	22-01-'04 to 01-12-'06	…		7
Feed company of breeder farms	Code	V1 to V16[3]	…	16	7
Feed company of broiler farms	Code	MV1 to MV8[3]	…	8	7
Age of hens(Breeder age)	Week	24 to 65	41	…	34
Egg- storage length	Days	2 to14	5		0
Number of broiler flock in three years	Number	…	…	16,365	…
Total number of chicken delivered per year		…	…	99,430,748	…
Response rate on FWM	Percent	79%[a]	…	…	…
Mortality rate 5th, 50th and 95th percentile	Percent	0.0%, 0.9%, 3.3%	…	…	…

[1, 2, and 3] Codes of the hatcheries, the strains and the feed companies respectively

[a] Percentage of voluntarily reported FWM from the total number of flocks delivered by the hatcheries, which was 100% from hatchery A and 43% from hatchery B.

3.2.2 Statistical Analyses

Data were analyzed using Genstat version 8 for Windows (VSN International, Hemel Hempstead, UK). The data structure was interdependent. Each breeder farm usually delivers all eggs to one hatchery and most of the time, a broiler farmer asks for chicks that are originating from a specific breeder farm. However, because a broiler farm uses the all-in-all-out system and a breeder farm delivers eggs to the hatchery on average twice a week, a hatchery might be forced to deliver a flock to another broiler farm that it does not usually deliver to. Therefore, FWM was tested using a generalized mixed model with the method of restricted maximum likelihood (Harville, 1977), where the logistic (logit) transformation was

used. Effects of breeder flock and broiler flock per barn were included in the random part of the model.

Some restrictions were made in the data set. The breeder age was restricted between 25 and 65 wk to avoid molted flocks and the egg storage length between 2 and 14 d. In the data set, 12 strains were recorded, 8 of which were defined (Ross 308, Ross 508, Ross 708, Cobb, Cobb 500, Cobb 600, Hubbard, and Hybro) and 4 were not. Additionally, 16 feed companies of the breeder farm and 8 feed companies of the broiler farm were recorded, and 1 from both was undefined. If no strain of the breeder flock or no feed company of the breeder farm was known, a variable "unknown" was included in the data set.

The independent variables in the random part of the model were breeder farms and broiler farms, whereas age at start delivery to the hatchery (wk), breeder age (wk), egg storage length at hatchery (d), strain, feed company of the breeders, feed company of the broilers, hatcheries, and season were taken as explanatory variables in the fixed part of the model.

3.2.3 Statistical model

Initially, all of the variables and interaction terms until the 4-way interactions were included in the so called full model. A stepwise selection procedure was applied, starting to exclude non-significant 4-way interaction terms ($P < 0.05$, Wald's test), then excluding the 3-way interactions, 2-way interactions, and single factors to come to the final model. Therefore, the final model included only significant single factors and interactions.

The final model is described as follows:

$$\text{logit}(FWM) = C + \varepsilon_{bf} + \varepsilon_{brf} + \varepsilon_{brfs} + \beta_1 H + \beta_2 A + \beta_3 \ln(A+1) + \beta_4 ES + \beta_5 B +$$
$$\beta_6 YR + \beta_7 B \cdot YR + \beta_8 FC + \beta_9 \left(\sin\left(\tfrac{2\pi}{365} \cdot d\right)\right) + \beta_{10} \left(\cos\left(\tfrac{2\pi}{365} \cdot d\right)\right) + \quad (2)$$
$$\beta_{11} H \cdot YR + \varepsilon$$

Where C is the intercept, ε_{bf} is the random effect of a breeder flock ($\varepsilon_{bf} \sim N(0, \sigma bf^2,)$), ε_{brf} is the random effect of a broiler flock ($\varepsilon_{brf} \sim N(0, \sigma bf^2,)$), and $\varepsilon_{brf.s}$ is the random effect of a broiler flock in a barn[1] ($\varepsilon_{brf.s} \sim N(0, \sigma brf.s^2,)$). H is the hatchery, A is the breeder age (number of weeks - 24), ES is the egg storage length at the hatcheries (d), B is the strain, YR is the year, FC is the feed company of the breeder farm, and d the dth day of the year in the seasonality function: $\sin\left(\tfrac{2\pi}{365} \cdot d\right) + \cos\left(\tfrac{2\pi}{365} \cdot d\right)$.

The following model choices were made. To allow for a (non-linear) curve of FWM with breeder age, $A + \ln(A+1)$ was included where A is the breeder age minus 24 wk. Furthermore, to allow for smooth seasonality effects, the function $\sin\left(\tfrac{2\pi}{365} \cdot d\right) + \cos\left(\tfrac{2\pi}{365} \cdot d\right)$ was included and tested, using the date of chick delivery to calculate the dth day of the year (Grossman et al., 1986).

3.3 Results

The FWM in broiler chick flocks ranged from 0.0% (5th percentile) to 3.3 % (95th percentile) with an average of 1.5%. Furthermore, the results of the random model showed that there was a significant difference in FWM between flocks originating from different breeder farms and

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[1] As some reported FWM were at barn level this variable was included.

between flocks kept at different broiler farms (Table 3.2). The model explains 66% of the variation that occurred in FWM.

In the fixed model, a lot of variables and interactions were tested to be significantly related with FWM (Table 3.2).

First, breeder age was related to FWM of the chicks at the broiler farm (P<0.002) (Table 3.2). On average, 1.82% of the broiler chicks died, if the breeder age was 25 wk. In breeder flocks aged between 38 and 44 wk, mortality was 1.02% and mortality increased to 1.20%, if the breeder flock was 60 wk. This hyperbolic curve is called the mortality curve (Figure 3.1 panels B to E).

Second, the egg storage length at the hatcheries was negatively related with FWM of broiler chicks at the broiler farms (P < 0.005) and its effect depended on breeder age (Figure 3.1; panel A). However, the difference between the different storage lengths was not large. The average increase in FWM per extra day storage at hatchery was 0.0018% (Figure 3.1; panel A). The effect of storage on FWM was related to the hatcheries; the increase in FWM for hatchery A was 0.0015% and for hatchery B 0.0022%.

Third, there was a significant difference in FWM among the broiler chick flocks, which originated from the two hatcheries. For breeder flocks that were 25 wk of age, the average difference in FWM between the two hatcheries was 1.13%. For breeder flocks that were between the ages of 37 and 44 wk, the average difference was 0.64%, and for 60-wk-old breeder flocks, the average difference was 0.75%.

Fourth, there was a significant difference in FWM in the different years. The average SD in FWM among the years was 0.21%, in which the lowest mortality was found in 2004 and the highest in 2006. Furthermore, the interaction hatchery × year (Figure 3.1; panel B) was also significant (p<0.002), indicating that the difference SD among the years was much smaller for hatchery A, which was on average 0.16%, than 0.29% for hatchery B.

Fifth, FWM in broiler chick flocks was related to the dth day of the year or in other words to the season (P < 0.001). The highest mortality (on average 1.18%) was found from mid-March until mid-April, whereas the lowest mortality (on average 1.08%) was found from mid-September to mid-October (Figure 3.1 panel F).

Sixth, a difference in FWM was found among the strains (P < 0.001; Figure 2.1; panel C). The difference in SD in FWM among the strains was 0.40% if the strains were 25 wk of age. If the strains were between 37 and 44 wk, the difference was 0.23%, and if the strains were 60 wk, the difference was 0.26%. Furthermore, there was a difference in FWM within the strains in different years (P < 0.001; Figure 3.1; panel D). The difference among the strains and within the strains was breeder age-dependent.

Finally, the feed company of the breeder farms was significantly related to FWM (P < 0.029; Figure 3.1; panel E). The effect of the feed company of the breeder farm on FWM of the broiler flocks was also breeder age-dependent. If breeder age was 25 wk, the difference in SD in FWM was 0.46%, and if the breeder flock had an age between 37 and 44 wk, the difference decreased to 0.26%, whereas it increased to 0.31% if breeder age was 60 wk.

Table 3.2. Estimates, standard errors and Chi-square probability of the fixed model.

Variables	Descriptions	Estimates	(s.e.)	χ^2 prob
$\varepsilon_{bf}{}^a$	Breeder flock	0.0304	0.0068	0.001
$\varepsilon_{brf}{}^a$	Broiler flock	0.5452	0.0408	0.001
$\varepsilon_{brf.s}{}^a$	Broiler flock * Barn	0.0000	bound	…
C	Intercept	-4.38	0.2	
$\beta_1 * H$	Hatchery		0.12	0.001
A	A	Ref.		
B	B	0.62		
$\beta_2 * Age$	Breeder age	0.03	0.003	0.002
$\beta_3 * ln(Age+1)$	ln(Breeder age+1)	-0.46	0.04	0.001
$\beta_4 * ES$	Egg storage length	0.002	0.004	0.005
$\beta_5 * B$	Strain	(-0.14 ; 0.89)[b]	0.43	<0.001
$\beta_6 * YR$	Year		0.21	<0.001
2004		Ref.		
2005		0.29		
2006		0.34		
$\beta_7 * B*YR$	Strain ·Year		0.45	<0.001
2004		Ref.		
2005		(-0.29 ; 1.18)[b]		
2006		(-0.88 ; 0.49)[b]		
$\beta_8 * FC$	Feed company	(-0.38; 0.64)[b]	0.2	0.029
$\beta_9 \cdot SIN\left(\frac{2\pi}{365} \cdot d\right)$	sine of the dth day of the year	0.04	0.02	<0.001
$\beta_{10} \cdot COS\left(\frac{2\pi}{365} \cdot d\right)$	cosine of the dth day of the year	0.11	0.01	<0.001
$\beta_{11} * H*YR$	Hatchery · Year		0.11	0.002
A-2004		Ref.		
A-2005		Ref.		
A-2006		Ref.		
B-2004		0.00		
B-2005		-0.36		
B-2006		-0.31		

[a] where $\varepsilon_{bf,}$ $\varepsilon_{brf,}$ and $\varepsilon_{brf.s}$ are the variation components of the model and Ref. is the reference used to calculate the estimates.
[b] because this factor includes more varieties, more estimates are calculated. To restrict the size of the table the minimum and the maximum estimates are given respectively.
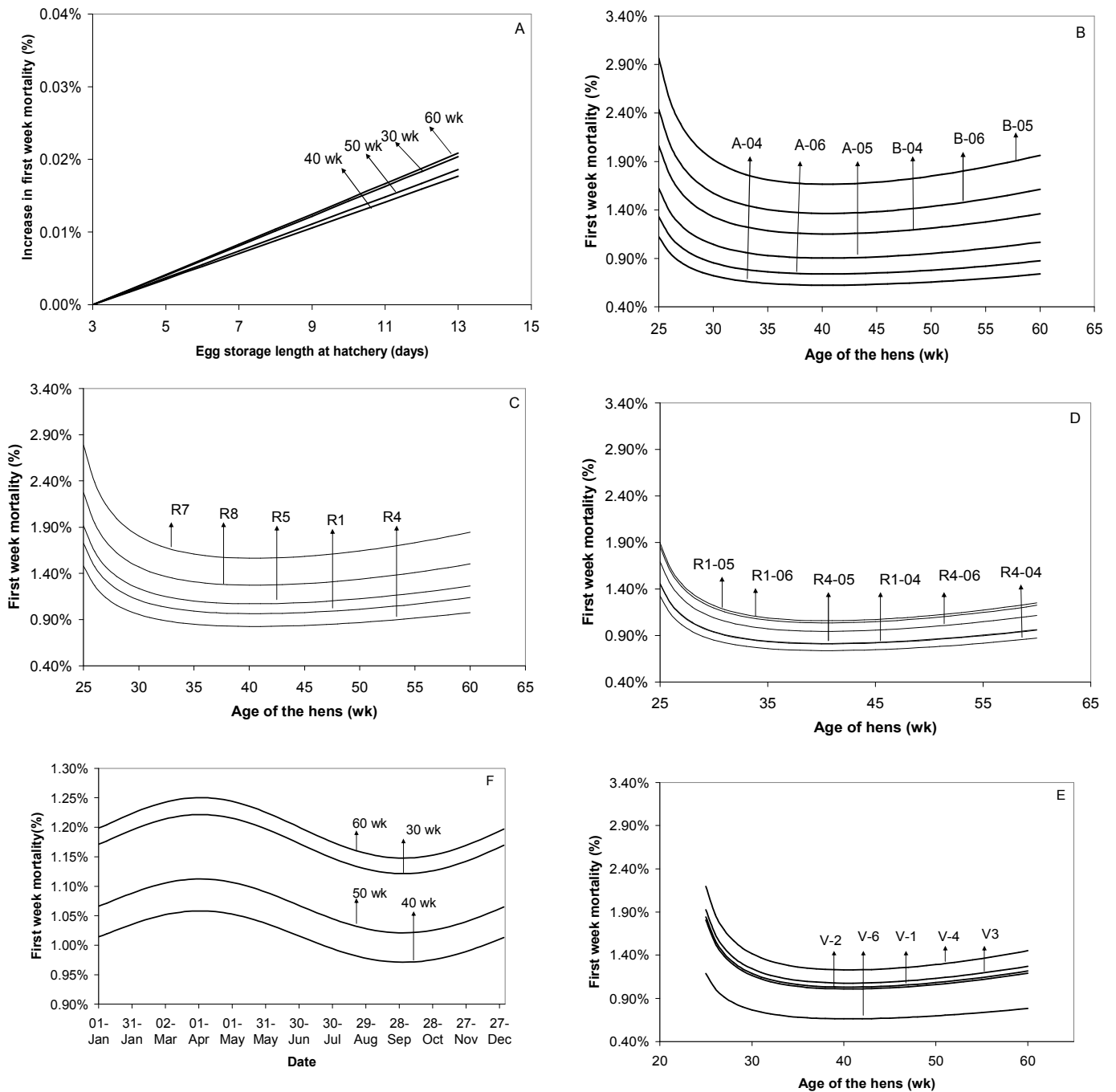
Figure 3.1. Panel A, increase in FWM in relation to egg storage length at the hatchery. Panel B, difference in FWM between chicks originating from two hatcheries in years. Panel C, the difference in FWM among Strains. Panel D, the difference in FWM within strains in years. Panel E, the difference in FWM in relation to different feed-providing companies of the, breeder flock. Panel F, the seasonality of FWM.

3.4 Discussion

In this study, FWM was analyzed from data collected by commercial Dutch hatcheries. The data were collected based on voluntary reports on FWM at the broiler farms. Generally, the price of the day-old chicks is corrected for FWM, when mortality is higher than an agreed level, which is written down in the contract between the hatchery and the broiler farm. This economic incentive might have affected the motivation of the broiler farmer to report FWM and thus the reported level of mortality.

Furthermore, this study has the advantage of utilizing an extremely large field-based data set, with conclusions being based on significant relationships discussed in the light of experimental literature to suggest causality and to indicate where knowledge is lacking.

First week mortality is, in addition to other production criteria, an important performance measurement of the broiler farm. The potential of the chicks to survive the first week is directly related to the quality of the day-old broilers (Goodhope, 1991). Therefore, in this study, it was tested whether factors that have been shown to be related to hatchability and day-old chick quality such as breeder age, egg storage length, incubation condition, strain, and feed (Decuypere et al., 2001; Yassin et al., 2008) are also related to FWM.

Confirming the results of Heier et al. (2002), there was difference in FWM among flocks originating from different breeder farms. The difference in FWM may indicate the different management protocols followed at the breeder farms, which influence the performance of the chicks at the broiler farms. These management protocols concern nutrition and growth profiles related to photo stimulation (Renema et al., 2008). The significant influence of breeder management suggests that the broiler farmer needs information about the origin of the chicks to optimize management at the farm.

In addition, a significant difference in FWM was found among broiler farmers. This can be due to the difference in chick management upon arrival (especially floor temperature) and during the first week, which is mostly related to feed and water provision, housing environment (i.e., insulation and ventilation systems), stocking density, as well as health management.

First week mortality was highly related to breeder age following a negative hyperbolic shape. Increased FWM in broiler chicks was found more often for young breeders (Wilson, 1991; Peebles et al., 2004; Pedroso et al., 2005). Younger breeders produce smaller eggs with a larger proportion of albumen DM, a smaller proportion of yolk DM, and a thick shell, due to which the weight of the live chicks and the yolk sac content is smaller (Vieira and Moran, 1998a). There is a direct relationship between the nutrients provided by yolk sac and the subsequent performance of the chicks (Vieira and Moran, 1999). Generally, yolk sac content is high in fat and protein and low in carbohydrate, which is a direct source of energy. However, chicks of young breeders have a reduced yolk lipid mobilization and a reduced lipoprotein transfer to mobilize the energy for their development. This is usually associated with reduced viability of the chicks during the first week (Latour et al., 1998). Moreover, chicks from young broiler breeders have lower feed intake and BW during the first week compared with chicks from older breeders (Maiorka et al., 2004). Therefore, special management of chicks of young breeders is required during the first week. Adjustments of the temperature (house and floor) and height of drinking nipples; provision of required feed nutrients, especially energy source; as well as good health control are important measures.

The increased FWM for chicks from older breeders could result from bad navel and navel-yolk sac infections more often found in chicks from older flocks. Another reason for an increased mortality of chicks of older breeders is that eggs from older breeders hatch earlier (Suarez et al., 1997) and therefore the risk of dehydration of chicks increases with breeder age if management in the hatchery with respect to the time of collecting chicks is not adjusted. Because breeder age affects broiler performance throughout brooding to maturity phase (Peebles et al., 1999), breeder age should always be taken into consideration during any production management decision.

Storage length of eggs at the hatchery increased FWM at the broiler farms significantly. Merritt (1963) also found increased FWM with increased length of storage time, which was 2.2 and 2.9% for storage length of 1 to 7 and 8 to 14 d, respectively. It is also known that storage of eggs affects egg quality (Decuypere and Bruggeman, 2007; Fasenko, 2007), which subsequently affects the quality of the chick and depresses the relative growth during the first week at the farm (Tona et al., 2004).

First week mortality differed between broiler flocks that originated from the two hatcheries. Heier et al. (2002) also found a significant difference in mortality between flocks originating from various hatcheries in Norway. It was interesting to notice that the hatchery that had higher hatchability during the first study (Yassin et al., 2008) also showed higher FWM. The difference between hatcheries might be explained but needs further investigation, by a difference in egg sanitation practice, climate conditions during incubation and chick handling, transportation conditions, and the transport time to the broiler farms.

First week mortality was significantly different among the three years: 2004, 2005, and 2006. Similarly, Heier et al. (2002) found difference in FWM in different years.

Seasonality of FWM in this study could be related to weather because of the temperate climate in the Netherlands. In addition, fluctuation in the market might have played a role. For example, in case of high market demand, the hatcheries mostly buy eggs from the free market to fulfill the extra need. These eggs, however, are mostly of varied quality and therefore might result in low-quality day-old chicks. Additionally, weather conditions, especially the temperature of the barn (floor and house), and ventilation are very critical and vary between seasons. From this result, it is concluded that breeder farms, hatcheries, and broiler farms should make adjustments of management practices on the season to maximize profit.

From the large-scale data analysis, difference of FWM was observed among the different broiler strains. This observation is in accordance with results from small-scale experiments. Some of the strain-related factors that influence chicks' quality are the difference in egg weight (Vieira and Moran,1998b) and embryo metabolic activity during incubation (Hamidu et al., 2007). A significant difference in mortality between strains after brooding stage through maturity was also found before (Awobajo et al., 2007).

The different feed-providing companies of the breeder farms caused a significant difference in FWM of the broiler chicks. It is well known that the nutrition of the parent is transferred to the chick embryo through the egg content (Wilson, 1997) and that the nutrition of the breeder hens affects the progeny viability and early growth (Kidd, 2003; Enting et al., 2007). Therefore, any aspect that reduces the quality and quantity of the required diet and results in undernourishment of the breeder hen could affect the chick's viability at the farm.

In summary, there is interrelation between FWM at the broiler farms and management factors at the breeder farms (like the breeder age, strain, and feed company of the breeder farms) and at the hatcheries (like egg storage management, hatching management, and season). On-time information exchange and analysis of the production result and feedback from each chain participant to the partners is crucial. Therefore, a good information exchange system is recommended for the chain to take timely measures and avoid probable management mistakes to result in a maximal chain profit. For this to be realized, good quality production data should be kept, analyzed, and interpreted to support a better management decision at each level of the chain.

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Standardized Data in the Broiler Value Chain

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Chapter 4

Abstract

In the Dutch broiler chain, data are collected as routine practice. However, there is a wide range of variation in the content of data collected and data collection systems. This variability hampers the use of field data in management information systems to support decisions. The objective of this study was to analyse data quality and standardize the content of data sets in the broiler supply chain. To evaluate data quality, data sets from three Dutch hatcheries, of 23,637 batches of eggs, were assessed. Data quality was assessed intuitively based on seven quality attributes. To standardize the content of the data set, a protocol was proposed and validated. The protocol was validated at 30 breeder farms, three hatcheries, and 104 broiler farms using three quality attributes: consistency, uniformity, and completeness.

Results of the data quality analysis of the three Dutch hatcheries showed that the data sets had a few inaccurate, incorrect, inconsistent and incomprehensible fields and some non-uniform, relevant but missing fields and incomplete fields.

Results of protocol validation were as follows: feedback was obtained from 23 (77%) breeder farms, three (100%) hatcheries and seven (7%) broiler farms. Of all the questions, on average 88% were answered on breeder farms; 57, 65, and 82% were answered at each of the three hatcheries, respectively; and 79% were answered on the broiler farms. Data collected at two hatcheries were more consistent than those collected at the third hatchery. Hatchery data were less consistent than breeder farm data, but the number of data entries at hatcheries far exceeded the number at the farm level. Data from the hatcheries, breeder farms, and broiler farms were not always uniform, possibly because of differences in management strategies. This protocol enables the listing of relevant and standard contents of a data set whereby information exchange along the chain can be simplified. However, it is recommended that the protocol be supplemented with some rules for data collection and management, for example, that variables must be recorded in the provided fields, and that a variable must have one and only one name or code, the same unit of measurement, and the same definition.

Key words

Broiler chain, Standardised data, Data quality, Information exchange

4.1 Introduction

Broiler production is a chain process that combines the movement of products with the flow of operational and financial information between the chain partners. This technical and economic interdependence may give the broiler chain a complexity that can make individual decisions difficult. For example, the performance of the chicks on broiler farms is affected by the management at the breeder farms and hatcheries (Yassin et al., 2008, 2009). Management information systems based on the exchange of relevant information can simplify such complexity and help managers make better decisions (Davis and Olson, 1985). The advantage of farmers using management information systems in the decision-making process has been demonstrated on dairy farms (Lazarus et al., 1990) and on sow farms (Verstegen et al., 1995). Achieving a competitive advantage by using such a system, however, is a challenge because the quality of decisions depends on the quality of data used to make them (Redman, 1995; Ballou and Tayi, 1999).

In a previous field study, data from three Dutch hatcheries were used to perform statistical analysis on broiler egg hatchability (Yassin et al., 2008) and first week mortality (Yassin et al., 2009). The statistical analysis revealed that, within the data set, some important indicators that could support and explain hatchability and mortality results were missing. For example, information related to hatchability, such as the BW of breeder flocks, egg weight, and egg storage conditions (Wilson, 1991; Meijerhof, 1992; Fasenko, 2007), was lacking. In addition, information on the quality of the day-old broilers was missing, which is related to the first-week performance of the chicks (Vieira and Moran, 1999; Decuypere et al., 2001; Tona et al., 2003). Furthermore, the data set had missing values in some categories. From these studies, it was concluded that the quality of data complied with the definition "fit for use by data consumers," as described by Juran and Godfrey (1999). In this definition, the notion of data quality depends on the actual use of data by the data consumer. However, what may be considered good data for one specific application or use may not be sufficient in another situation.

Hence, the objectives of this study were, first, to assess the quality of Dutch broiler hatchery data based on field data; second, to develop a protocol for the standardization of data sets within the broiler production chain; and third, to validate the protocol developed.

4.2 Assessing the quality of Dutch hatchery data

Different quality attributes are used in the literature to assess data quality, such as accuracy, completeness, consistency, relevance, accessibility, comprehensibility, reliability, and timeliness (Ballou and Pazer, 1985; Wang et al., 1995; Wang and Strong, 1996; Pipino et al., 2002). Wang and Strong (1996) suggested 3 approaches to selecting quality attributes: the intuitive approach, the theoretical approach, and the empirical approach. The intuitive approach means that the selection of quality attributes is based on researchers' intuition or experience with attributes that are important for a specific application and context. The theoretical approach focuses on how data may become deficient during the data manufacturing process, and the empirical approach uses data consumers to determine the quality attributes.

Data quality of the Dutch broiler chain was assessed based on the intuitive approach (Wang and Strong, 1996). The data quality attributes selected for data quality analysis and

their definitions are given in Table 4.1. To assess the quality of data, the data sets of three commercial Dutch hatcheries were used. The data sets included information from breeder farms, hatcheries, and broiler farms. The information at the farm level was limited because centrally collected information about farms was not available. The hatchery data sets gave an indication of the quality and availability of farm-level data. The three hatcheries together covered 38% of the annual chick production in the Netherlands. The data set included 23,637 batches of hatching processes for the years 2004, 2005, and 2006. Data were judged as inaccurate, incorrect, inconsistent, not uniform, incomprehensible, or relevant, or a combination of these, based on expert knowledge and information from the literature. Values are recorded as percentages, which were calculated by counting the number of records that were inaccurate, incorrect, inconsistent, not understandable, irrelevant, or missing. If no relevant information was available, 100% was recorded. The relevance of information in the data set was measured in relation to hatchability and first-week mortality.

Table 4.1. Data quality attributes selected to evaluate the Broiler chain data

Data quality attribute	Definition
Accuracy	Proximity of measured values to real or true values
Correctness	Extent to which data are correct
Consistency	Representation of data value is the same at all times
Uniformity	Definitions of data values are uniform for all data users
Comprehensibility	Extent to which data are easily comprehended
Relevance	Data items can be used as inputs in the user's decision making
Completeness	All data items are recorded and stored for use

4.2.1   Results of Data Quality Analysis of the three Hatcheries
Results of the quality analysis of the combined data set of the three hatcheries are given in Table 4.2. The contents of the data sets of the hatcheries differed significantly. Generally, data were recorded accurately, except in rare cases for the age of breeders and egg storage length. For example, egg storage length was occasionally recorded as 99 d, which is impossible. Strain names were rarely recorded incorrectly, but there were, for example, a few records in which the strain name Kant was entered, which was not recognizable. Fewer than 1% of the names of strains and feed companies were recorded inconsistently. The information used by hatcheries was often, but not always, uniform. The traceability of information from egg to chick was difficult in some cases.

Table 4.2. Data quality analysis of data set of three Dutch broiler hatcheries

Variables	Inaccurate	Incorrect	Inconsistent	Not uniform	Incomprehensible	Relevant but not included	Missing
				Quality attributes			
Strain	-[1]	2%	-	Yes[2]	≈0%	-	-
Age of breeders	1%	-	≈0%	No[3]	-	-	2%
Feed company used by breeder farms	-	-	≈0%	Yes	-	-	52%
Feed intake	-	-	-	-	-	100%[4]	-
Health information on breeders	-	-	-	-	-	100%	-
Egg weight	-	-	-	-	-	100%	-
Body weight	-	-	-	-	-	100%	-
Egg transportation date	-	-	-	No	-	-	73%
Egg transportation conditions	-	-	-	-	-	100%	-
Batch number	-	-	-	Yes	-	-	-
Start of incubation: date or number	-	-	-	Yes	-	-	-
Age of eggs	1%	-	-	No	-	-	-
Egg storage conditions	-	-	-	-	-	100%	-
Candling information	-	-	-	No	-	-	15%
Hatch results	-	-	-	No	-	-	≈0%
Chick transport conditions	-	-	-	-	-	100%	-
Floor temperature at chick delivery	-	-	-	-	-	100%	-
Feed intake by chicks in first week	-	-	-	-	-	100%	-
Feed company used by broiler farms	-	-	-	No	-	-	93%
Weight of chicks after first week	-	-	-	No	-	-	82%
Date of weighing	-	-	-	No	-	-	80%
First week mortality	-	-	-	No	-	-	42%
Health information on chicks/broilers	-	-	-	No	-	-	87%

[1] 0% is indicated by '-'
[2] Yes indicates data were available but not uniform
[3] No indicates that data were uniform
[4] 100% indicates that the information is relevant but not included in the data set

4.3 Indication of data needs

Data needs were indicated based on a literature review and expert opinion. The literature showed that broiler performance, whereby profit of all the involved partners is affected, is related to flock and egg management at the breeder farms and incubation management at the hatcheries (Wilson, 1991; Bennett, 1992; Hocking, 1996; Robinson and Wilson, 1996; Vieira and Moran, 1999; Decuypere et al., 2001; Hazary et al., 2001; Tona et al., 2001, 2003; Elibol and Brake, 2006; Decuypere and Bruggeman, 2007; Yassin et al., 2008, 2009). Given these

relationships among flock management, egg quality, incubation management, and the quality of posthatch performance of day-old chicks and broilers, the need for an exchange of relevant information in the breeder-hatchery-broiler chain is inevitable. Because hatcheries play a central role, they are in a position to monitor the whole process and provide necessary information to support management decisions at each link of the chain.

Therefore, the hatchery data sets should include data that could be made available to breeder as well as broiler managers. The data set should include data on the operational management of breeder farms, such as feed quality information, feed intake, BW and egg weight, egg collection time, egg collection frequency, egg storage conditions, and egg cleaning procedures. In addition, the data sets should include data from the operational management of broiler farms, such as feed intake, health conditions, BW, and daily mortality.

Data quality analysis of the three hatcheries, however, showed that the data sets were incomplete and lacking information on the management of the breeders, eggs, and chicks. Moreover, there was a difference in data collection systems at hatcheries and farms, whereby the information recorded varied. For example, not all broiler farms provided information on first-week mortality and chick BW.

Hence, although it is not currently integrated, information exchange in the Dutch broiler chain is of great importance to support individual decision making at each link of the chain (Davis and Olson, 1985; Lazarus et al., 1990; Verstegen et al., 1995). Accordingly to sustain successful business-to-business communication and collaboration, data sets of the breeder-hatchery broiler chain should be uniform, be complete, and carry the same meaning across all participating organizations. However, data quality analysis of the three hatcheries showed that the data sets had different contents and that the hatcheries had different systems for collecting and recording information. Additionally, the data set had missing values and lacked relevant information on management at other stages of the chain. A standardized data set containing all relevant variables and complete information may provide opportunities to improve the current data collection process; for this reason, a protocol was developed to standardize the data sets in the broiler value chain.

4.4 Standardisation of data sets in the Broiler Value Chain: Protocol Formulation

Standardization is a process by which all elements in a data field (or a set of related data fields) are forced to conform to a standard. A standardized data set enables the collection of uniform, relevant, accurate, and consistent data. With today's growing interest in electronic communication, the use of standards for the names and contents of each data element in a data set improves information exchange in a chain organization (Donnelly et al., 2009). Moreover, when data are recorded using standard codes and definitions along the chain levels, traceability of product information can be simplified and facilitated (Donnelly et al., 2008), which in turn serves as a foundation for effective decision making at each level of the chain.

To standardize data sets in the broiler value chain, a protocol is proposed. The protocol was formulated based on information needs for management at breeder farms, hatcheries, and broiler farms at the tactical and operational levels. The protocol included 4 steps.

In step one, critical success factors (CSF) were determined. Critical success factors are performance factors or activities that are required to ensure the success of a business (Rockart, 1979; Huirne et al., 1997). To identify possible CSF, the mission and objectives of the

business are examined. For example, the revenues of breeder farms, hatcheries, and broiler farms depend largely on the production of a maximal number of high quality day-old chicks, which in turn depends, among other factors, on the quality of hatching eggs (Wilson, 1991; Tona et al., 2003; Yassin et al., 2008). Thus, CSF of the breeder farms could be production of the maximal number of high-quality hatching eggs per production round of a flock.

In step two, indices were determined. Indices are management processes or mechanisms that should be fulfilled to reach the management objectives regarding the CSF. For example, within the management category "flock management," maintaining good egg quality is an index.

In step three, indicators were determined. An indicator is a concrete management decision that has to be practiced on a continuous basis to reach the main objective (Goodger, 1984). A single index can have several associated indicators (Goodger, 1984; Scholl et al., 1992). For example, some indicators related to maintaining good egg quality are BW, daily feed intake, and fertility control (Wilson, 1991; Hocking, 1996; Robinson and Wilson, 1996; Hazary et al., 2001; Richards et al., 2010).

In step four, data set questionnaires were formulated. After listing all indices and indicators, draft data set questionnaires were prepared using Microsoft Access (Microsoft Corporation, Redmond, WA). First, relevant question types and expected responses were determined for breeder farms, hatcheries, and broiler farms. The type of question depended on the information sought, and questions were categorized as open-ended, closed (yes/no), or multiple choice. Second, it was determined at what level of the chain or within an organization the information would be available. For this, it was important to know who would be responsible for collecting and organizing the information, and how often it should be collected. When the necessary information involved measurements, it was important to determine the sample size, how to perform measurements, when to take measurements, and with what frequency they should be taken. Third, questions were formulated and organized together with their expected responses. Effort was made to ensure the traceability of information from the egg to the chick. Accordingly, the data at each level of the chain included specific codes that related individual batches of eggs from breeder farms to each flock of chicks that arrived on the broiler farms. The protocol was pilot tested at hatcheries and breeder farms to determine the practical applicability, feasibility, accuracy and completeness of the standardized data set.

Accordingly, consideration was given to the economic value and practicality of the indices and indicators included in the standardized data set. For example, on breeder farms, egg characteristics such as eggshell structure or thickness, eggshell membrane, internal egg quality, and egg weight are indicators related to an index of incubation conditions and hatchability (Bennett, 1992; Tona et al., 2001). However, measurement of eggshell or albumen thickness is not economical and is not routinely done in practice and was therefore excluded from the standardized data set.

The final data set questionnaires included questions that were practical and economical to answer. The questionnaires for the managers of breeder flocks were categorized into flock management and egg management. At hatcheries, the questionnaires were categorized as egg management (i.e., before the egg had been set in the setter), incubation management (i.e., in the setter), hatching management (i.e., in the hatcher), and chick management. A

questionnaire was developed for transporters because transportation management can affect egg and broiler quality. On broiler farms, management was categorized into management during the first week and management during the rest of the period. During this study, it was focused on the management of chicks during the first week because the demands on management are greater during this period, which is a transitional period from the conditioned environment at the hatchery to an independent life at the broiler farm. Additionally, the performance of a chick during its first week is closely related to the quality of the day-old broiler, as demonstrated by Goodhope (1991). The quality of the day-old chick in turn depends on the genetic line of the breeder flock, flock age, egg weight, egg storage conditions, and incubation conditions at the hatcheries (Wilson, 1991; Vieira and Moran, 1999; Decuypere et al., 2001; Tona et al., 2003).

Table 4.3 shows the selected CSF for breeder farms, hatcheries, and broiler farms and provides examples of some indices and indicators at each level of the chain. Thus, the protocol was used to develop a standardized data set for the breeder-hatchery-broiler chain. The protocol allowed the identification of priority data that are important to the broiler chain, especially data that are shared along the organizations.

Table 4.3. Critical success factors and examples of some indices and indicators for breeder farms, hatcheries, and broile

Location	CSF	MCI	ND
		Chain level	
Breeder farm	Production of maximal number of highquality hatching eggs per production year of a flock	Flock management to maintain egg fertility	Daily feed intake
			BW of birds
			Percentage of egg production
			Health conditions
			Percentage of fertile eggs
			Hen-to-cockerel rati
		Egg management to maintain egg quality	Egg collection frequency
			Number of floor eggs
			Egg storage duration
			Egg storage temperature
			RH
		Egg transport management to maintain egg quality	Transport environment
			Transport duration and route
Hatchery	Maximal hatchability of total eggs set with vital day-old chicks	Egg handling process to maintain egg quality	Egg storage duration
			Egg storage temperature and RH
			Fumigation duration and temperature
		Incubation and hatching management to maintain the quality of embryos and chicks	Date and time of incubation
			Incubation temperature
			RH
			Embryo temperature
			Ventilation (CO2)
			Candling results
			Date and time of hatching
			Hatching results
			Chick temperature
		Chick transport management to maintain chick quality	Transport temperature
			RH
			Transport distance
			Transport route
Broiler farm	Production of maximal number of marketable broilers with good slaughter yield	Chick management to maintain chick performance	Daily feed intake
			BW of chicks
			Health conditions
			Percentage of first-week mortality
			Floor temperature

[1]CSF = critical success factors; MCI = management categories and indices; IND = indicators.

4.5 Protocol validation

The protocol was validated at three hatcheries using data set questionnaires. Each hatchery chose 10 breeder farms, each with one flock, and 104 broiler farms. The three hatcheries cover 38% of the annual chicken production in the Netherlands, and 12% of the number of breeder farms and 13% of the number of broiler farms in the Netherlands are included in this study. On the breeder farms, information related to the production, collection, storage, and sale of eggs was collected. Four rounds of eggs per flock were delivered to the hatcheries in two wk. The hatcheries collected data starting from the purchase of the eggs and ending with chick delivery on the broiler farms. On the broiler farms, information related to the first week of chick performance was collected.

At breeder farms and hatcheries, data were collected via telephone, site visits, postal mail or e-mail. On the broiler farms, data were collected via postal mail. Quality of data was assessed based on completeness, consistency and uniformity (Table 4.1). Response percentage (completeness) was calculated by quantifying the percentage of missing records.

The collected data were presented and discussed with the hatchery managers and thereafter during two workshops, to which hatchery managers and all delivering breeder farms of the hatcheries were invited. During these workshops, results were presented as variations in data among the breeder farms, whereby, for each result, a 10-min period was used to discuss the differences and usefulness of the information.

Breeder Farms

The standardized data set questionnaire for the breeder farms included four main categories of questions. These requested information on: farm personnel and farm management rules, farmhouse (barn), flock, and daily egg production.

Of the 30 breeder farms approached, 23 (77%) gave feedback. Information on farms, barns, and flocks was provided by all 23 farms. Complete two-week information on daily egg production was provided by 16 farms and one-week information by three farms. One flock was culled, and no information on egg production was provided by 2 farms (Table 4.4).

Table 4.4. Percentages of information provided by the 23 breeder farms

Information available	Completeness	Explanation
General farm information	100%	
General barn information	100%	
Specific flock information	96%	One flock was culled
Information of daily egg production	86%	16 flocks two weeks and 3 one week information

The standardized data set enabled the collection of extra data on the breeder farms. For example, information was obtained on storage duration and conditions, egg collection time and frequency, BW of the birds, and time taken to load eggs for transportation. Moreover, data were registered consistently, and feedback was provided within the given time schedule. Additionally, results of this study revealed a possible difference in management strategies among breeder farms. Information collected on the farms varied in type and frequency. There

were differences in sample size, frequency, and time of weighing among farmers. For example, of 23 breeder farms, 7 farms weigh eggs daily, 3 farms weekly and 13 never. The number of eggs weighed also varied among farms: some farms weigh the whole batch of eggs; others weigh 720, 900, or 150. Moreover, weighting mechanisms differed among breeder farms: out of 23 breeder farms, 1 farmer gave no information, 7 weigh automatically, 10 weigh manually and 5 use a combination of automatic and manual weighing. Furthermore, the frequencies of weighing hens differed among breeder farms (Figure 4.1). The breeder farms were also asked how frequently the barn-registration form is used to record routine management procedures like egg production and mortality. These forms are provided by feed companies and/or grandparent farms. The type and frequency of information registered, though, differs among breeder farms. Table 4.5 provides an indication of the types and frequencies of data registration on such forms.

Table 4.5. Registration of information on production calendar

	Breeder farms out of 23 (%)			
	Always	Frequently	Seldom	Never
Egg production	100	0	0	0
Mortality	100	0	0	0
Egg weight	30	9	39	22
Feed provision	78	9	13	0
Special husbandry (e.g., worm treatment)	72	14	14	0

In two workshops, farmers discussed among themselves and with the hatchery managers the variations in data collected. They shared ideas about their management strategies and presented their opinions on why certain information was more important to them than other information. For example, some farmers preferred to use both egg and BW measurements for feeding management, whereas others preferred to use only BW measures thinking that egg weight measures consumed time and added no extra value. Furthermore, the breeder farmers acknowledged the importance of collecting and sharing relevant information and expressed the need for detailed information from the hatcheries, rather than only hatching results. For example, the breeder farmers indicated they preferred to have information on storage conditions, hatching conditions, and specific candling information, such as number of clear eggs or unknowns. The hatchery managers indicated that they would investigate the possibility of providing more information on the hatching results and chick quality.
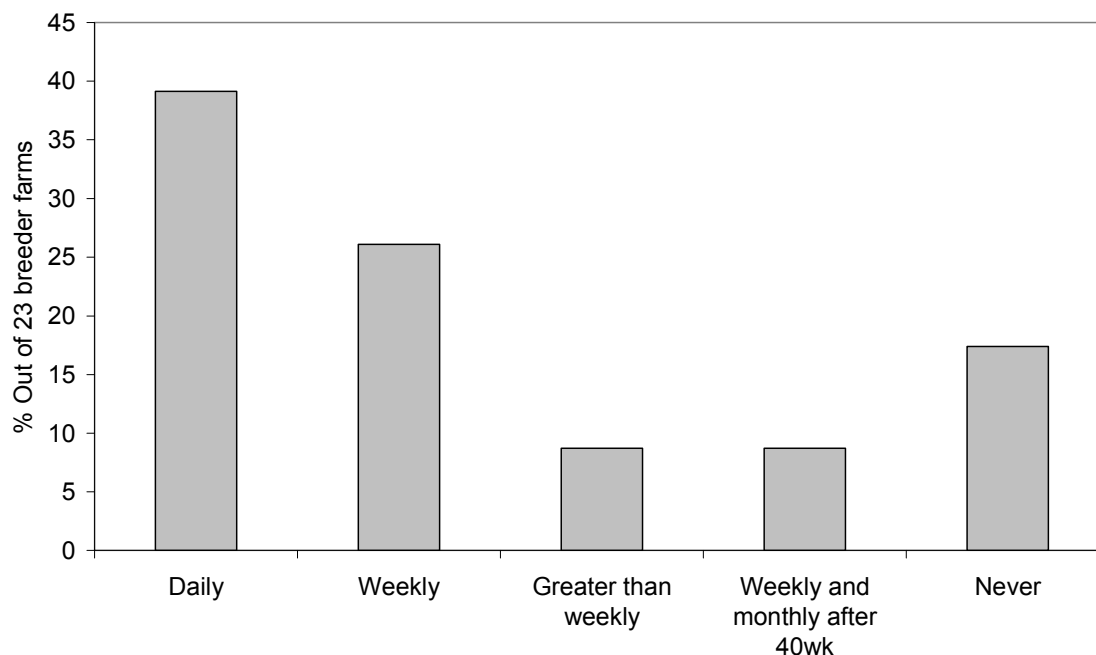
Figure 4.1. Differences in hen weighing intervals among breeder farms

Hatcheries

The data set questionnaires prepared for hatcheries were organised in 7 categories. These included information on personnel, hatcheries, incubators and hatchers; egg buying and transportation; egg handling and pre-incubation preparation; incubation process until day 18; hatching process day 19 to day 22; chick handling, chick transportation and delivery at broiler farms.

Three hatcheries (100%) provided feedback (Table 4.6). It was possible to collect new information at the hatcheries by using the standardized data set, especially information about egg and chick transportation, such as the transportation environment, transportation duration, and barn environment at the time of chick delivery to the broiler farms. Moreover, tracing of egg to chick information was facilitated because specific codes were introduced in the standardized data set.

Table 4.6. Completeness of data set questionnaires at the three hatcheries

Information available	Hatchery A	Hatchery B	Hatchery C
Information on egg transportation and delivery	35%	78%	87%
Information on egg setting	86%	81%	100%
Information on incubation and candling	64%	45%	90%
Information on hatching	50%	49%	63%
Information on chick collection	63%	56%	77%
Information on chick transportation and delivery	43%	83%	76%
Total	57%	65%	82%

Although the hatchery managers were interested in a standardized data system, given the short time period of the experiment, they indicated that the data they provided were registered anyway and that additional data would be provided only if the collection would be

easy to implement in their routine procedures. Thus, the percentage of questions answered was an indicator of the extent to which a hatchery data set did not comply with the data set suggested by our protocol. The data set questionnaires were, accordingly, incomplete, not uniform, and inconsistent among hatcheries (Table 4.6). Additionally, this result could be partly explained by the nature of the hatching process, during which several people are involved in collecting and registering data. Furthermore, some information could not be provided because the necessary measures were impractical to implement, for example, storage conditions and measurements that indicated the hatch window. Most hatcheries used one storage room where all eggs of different origins and dates were stored. Accordingly, hatching decisions were made based on averages of storage duration and conditions that were not related to a specific batch of eggs.

Results of the protocol validation were discussed with the hatcheries, whereby comparisons of the collected data were made. The hatcheries indicated that they would work towards improving their data systems, include in-depth information from partners, and play a role in improving information exchange within the chain.

Broiler Farms

Information requirements at broiler farms were categorised into two parts: general information on the farm, personnel, individual barns, and chick management; and specific information on chicks' first-week performance.

Chicks from four rounds of eggs of 23 breeder flocks were delivered to 104 broiler farms, but feedback was provided by 7 (7%) broiler farms. Complete information on farm, personnel, individual barns, and general chick management was provided by all 7 broiler farms (100%). Information on first-week performance, however, was provided by 4 (57%) broiler farms.

Questionnaires on the data set were recorded consistently and uniformly. The response percentage on broiler farms was low (7%) compared with the result from a previous study (Yassin et al., 2009), in which 79% of the broiler farms reported first-week mortality to the hatcheries, although not all relevant information was complete in the data set.

4.6 Discussion

In the broiler chain, management information systems can help managers make better decisions. However, the data that underpin management decisions should be of good quality and kept according to a standard method using similar codes and definitions that are understandable to all chain participants. High-quality data can provide considerable information that can be used to correct or amend past decisions and improve future decision making (Davis and Olson, 1985; Redman, 1995; Wang and Strong, 1996). Hatcheries are bridges between the breeder and the broiler farms. To ensure successful and sustainable production, it is in the interests of hatcheries to collect and transfer all relevant information on egg production and chick performance among the partners. However, as shown in this paper, the existing data collection system at Dutch broiler hatcheries varies significantly in terms of data quality, data content, and the systems used to collect and record data. Additionally, the data sets had missing values and lacked relevant information on the management of the breeders, eggs, and chicks. Results of data quality analysis of the data sets indicated that the

existing data system needed improvement to include all relevant information. Moreover, to simplify communication and allow better traceability, individual variables in the data set should have no duplicates and have one, and only one, name (code) and definition. The fact that the methods of data collection at breeder farms, hatcheries, and broiler farms are mainly developed to be used in individual links of the chain is the main reason for the variability in data quality among the hatcheries. In addition, a protocol for standardization is lacking.

A protocol for standardizing the data set was proposed and validated. The steps in the protocol were based on the formulation of CSF, indices, and indicators. When determining the indicators in a data set, it is recommended that the practical applicability and economic value of the indicators included or excluded be considered. Accordingly, some indicators were excluded from the data set. For example, questions about egg quality were excluded because on breeder farms, egg characteristics are not measured routinely.

Another situation is one in which an indicator may be included at one level but could never be used at another level of the chain. For example, decision making on breeder farms is mostly related to flocks within an individual farmhouse (barn), which could result in differences in performance of the flock between barns. However, at hatcheries, eggs from different barns of a flock are mostly hatched together. Decision making at hatcheries is therefore related to flock-level information. Accordingly, although barn-level information is preferred for decision making on the breeder farms, information on hatching results is provided at the flock level.

With the standardized data set, on breeder farms, data were registered consistently and most of the farmers recorded data completely. However, to ensure uniform results of data that need measurement, extra attention should be paid to predefining the time, frequency, and method of measurement. In the current situation, for example, farmers can weigh birds or eggs daily, weekly, or never. However, if the protocol were applied, the frequency of weighing could be predefined in the data set to allow comparison of similar information.

Considering the short time period given for the experiment, the hatcheries were not able to introduce the standardized data set in their systems, which affected the protocol validation. However, with the protocol, it was possible to collect extra information about egg and chick transportation. To facilitate information sharing among the partners, the hatcheries have expressed interest in standardizing their data content and having a complete and standardized data set from all associated partners. A standardized data set would enable the hatcheries to compare results by using uniform and relevant data content to allow improved decision making. If hatchery data were standardized and included relevant information from breeder farms as well as broiler farms, they could play an important role in facilitating information exchange among the partners. The managers of breeder farms would benefit from receiving feedback on the performance of their eggs at hatcheries and broiler farms. In addition, the managers of broiler farms would benefit from information about the hatching process and origin of their chicks.

The low response percentage on the broiler farms might be related to the method of information collection, which was via post. De Leeuw (1999) found the lowest response percentage for a survey conducted via post, rather than face to face or by telephone, as was done at the breeder farms and hatcheries. Additionally, increased reluctance of the broiler farmers to share information, compared with breeder farms and hatcheries, might have

influenced the response percentage. Because performance of the chicks on broiler farms is affected by the management on the breeder farms and hatcheries (Wilson, 1991; Vieira and Moran, 1999; Tona et al., 2003; Yassin et al., 2009), the broiler farms should consider collecting and exchanging relevant information with associated partners.

Furthermore, results of the protocol validation indicated that data quality depends on the individuals responsible for recording the data. On breeder farms, one person is generally responsible for administrative jobs and data recording. However, at hatcheries, information is collected at different stages of the process and is most likely collected by several people, resulting in an inconsistent and non-uniform data set. For example, when transporting eggs from breeder farms and chicks to broiler farms, drivers are given the responsibility of recording information, and there appear to be differences among individuals in the consistency, correctness, and comprehensibility of data recording.

Although there was variation in the contents of the data collected, the advantages of data registration and information exchange were clear to the chain partners, especially for the hatchery and breeder farm managers [J. Kollenstart (Probroed & Sloot hatchery, Groenlo, the Netherlands) and B. Munsterhuis (Munsterhuis hatchery, Saasveld, the Netherlands), personal communication]. Application of the protocol and adoption of a standardized data set at each chain level, however, takes time because the chain participants must first realize the economic gain of having a complete and uniform data set. In addition to uniform data content, the protocol can be of use and ensures good data quality along the chain only if the standardized data set uses the same definitions, names, and codes of variables for all users.

4.7 Conclusion

Broiler production is a chain process in which the exchange of information is the basis for the continuity and success of each entrepreneur in the chain. The results of a data quality analysis of the data sets of three Dutch hatcheries showed that the quality of the data sets requires improvement if information is to be used further along the chain. If the protocol recommended herein were implemented, it could permit the development of a standardized data set in which the contents would be uniform, minimizing variability along the chain. Moreover, the stepwise development of a data set considering CSF, indices, and indicators would allow the inclusion of relevant information in the data set. The standardized data set allows comparison of similar and different types of systems based on directly comparable information. Standardization of the existing data collection systems in the Dutch broiler chain, however, requires a commitment by all chain partners, and this costs time, money, and energy. Moreover, effort should be made to explain and quantify the value of high-quality data, and thus good information, at each chain level. Only the availability of high-quality data, accessible to all chain partners, ensures a reliable network in the long term and thus provides competitive advantages.

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Comparative Analysis as Management Tool for Broiler Breeder Farms:

Simulated Individual Farm Analysis (IFAS)

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Chapter 5

Abstract

The objective of this study was to develop a management information system to evaluate the tactical management of a breeder flock using Individual Farm Analysis with a deterministic simulation model (IFAS). Individual farm analysis is a method that evaluates performance of individual farms by comparing them with standards. In the first step of IFAS a farm accounting system is used to compare performance indicators of a flock with the same performance indicators of the average of a group of flocks that produced in the same time period. In the next step, a deterministic simulation model is used to determine the factors causing the traced deviations in performances. Then relevant deviations are determined based on the economic and statistical importance of each traced deviation. Finally the deviations are identified by relevance to give farmers an indication of their strong and weak management practices.

Key words

Boiler breeders; Management information system; Individual Farm Analysis

5.1 Introduction

Although intensive genetic selection over the past years has contributed to improvements in broiler breeder production, managing the flocks has become challenging leading to big differences in performance among flocks of even the same strains (Yassin et al., 2008 and 2009). Therefore, to improve and maintain farm income, improving farmers' management is also important. Management information systems can play an important role in this context whereby farmers make better decisions by integrating data into usable information, enhancing management skills, altering production systems, and reducing costs of production (Davis and Olson, 1985). The quality of decisions depends on the quality of data used to make them (Ballou and Tayi, 1999). Therefore, establishing and using an effective farm record-keeping system is a prerequisite to aid in farm planning, informed decision-making and analysis of both production and financial records.

Several models have been suggested as decision tools in the broiler supply chain. These decision tools are directed to individual farms. Most of them are related to decisions on stocking density, feed allocation, nutrient utilization, profitable feeding programmes and selection of traits for genetic improvements (Shalev and Pasternak, 1983; Fisher, 1998; Feddes et al., 2002; Sakomura, 2004; Sahman, 2009). Groen et al. (1998) developed a deterministic model whereby profitability of the broiler production system per level is analysed by comparing the economic value of genetic improvement of a particular performance trait. The model compares the profitability or cost price of a performance trait with the profitability or cost price after a marginal change in genetic merit before that particular performance trait was made.

As mentioned by Kay et al. (2007), a farm manager has three basic tasks: planning, implementation, and control. The controlling function of the farm management is important (Davis and Olson, 1985). It involves collecting farm information and comparing it to standards to help track the progress of a business toward attaining its goals. Individual farm analysis is a decision tool that compares an individual farm's performance information to a set of standards in order to evaluate the farmer's management practices. Huirne et al. (1992) described this system in detail for sow farming. Depending on the standards used, individual farm analysis can be applied to make internal or external comparisons. If the standards are derived from the farm itself, then internal farm analysis is done. Trend analysis is done if the objective of the individual farm analysis is to evaluate the development of the farm over time, and the standards in this case are derived from multiple years of the farm itself. If the standards are derived from other similar farms or a group of similar farms, then external or comparative analysis is done. External analysis is done to determine the relative position of a farm compared to other similar farms.

Individual farm analysis allows farmers to be aware of the strong and weak elements in their farm management (Huirne et al., 1992). As to our knowledge, there is not such a system developed for the broiler breeder farms. Hence, the objective of this study was to develop a management information system for broiler breeder farms in order to evaluate the tactical management of a broiler breeder flock by individual farm analysis using a deterministic simulation model (IFAS).

5.2 Materials and Methods

5.2.1   IFAS Basic Concepts

As in any other farm organization the management at the broiler breeder farm involves three management levels: strategic, tactical, and operational (Kay et al., 2007). Strategic management determines long term objectives to be pursued by the broiler breeder farm and identifies the ways and means of achieving these objectives. Tactical management is concerned with planning and control for individual organizational functions for improving performance in short or medium term. For example, tactical management for broiler breeder farms are planning of marketing and production, defining stocking density, selection of strain, feed provider and hatchery. Operational management ensures that the day to day operations of the organization are carried out effectively and efficiently. For example, at broiler breeder farms operational management will concentrate on daily or weekly egg production, feed consumption, weight control, and egg and flock health management.

5.2.2   Description of IFAS

For individual farm analysis of broiler breeder farms, a deterministic simulation model, called IFAS is developed. IFAS uses flock performance, technical and financial data from a farm accounting system. IFAS compares the performance of an individual broiler breeder flock with the averages of a group of similar flocks within same time period.

   The first step in the evaluation of broiler breeder farms' tactical management is comparing various flock performance parameters (F_P) with average flock performance parameters (A_P) (Figure 5.1). These parameters include technical and economic performances such as: the number and price of parent stock bought, the number of hatching eggs produced and sold, the number of parent stocks died and the amount and price of feed. Farm evaluation is done based on the differences in performance (D_{total}):

$$D_{total} = F_p - A_p \qquad\qquad\qquad (1)$$

   A part of D_{total} can be explained by known factors and is simulated with a simulation model. This part of D_{total} is called D_{model}. The remaining D_{total} which cannot be explained is called D_{rest}. So, the second step is to evaluate the broiler breeder farm using a deterministic simulation model. This model will be explained later under the heading simulation model.

   The simulation model uses input variables from a farm accounting system. The model calculates performance values, that is, model flock performance (F) and model average flock performance (A) of input variable j (Figure 5.1) and the deviations between the performance values D_{model}:

$$D_{model} = F_j - A_j \qquad\qquad\qquad (2)$$

   The deviation D_{model} *is* caused due to differences in input variables (*j*) that affects the performance results. To identify the most important input variables that caused the deviations,

D_{model} is further analyzed by calculating the economic importance (EI_j) and statistical importance (SI_j) of the deviations of input variable j.

The EI_j is calculated as follows. First, all input variables of an individual flock (F_i) are introduced into the simulation model, which results in a gross margin per day per 100m^2 (GM_d). Then, each input variables of the individual flock (F_{ij}) are consecutively replaced by the corresponding input variables of the average flock (A_j) which results into a new gross margin (GM_{dj}). Therefore, the marginal impact of each input variable (j) on gross margin is analysed assuming no change is made on the other input variables. Thus EI_j of each input variable equals to the difference between GM_d and GM_{dj}.

$$EI_j = (GM_d) - (GM_{dj}) \tag{3}$$

The SI_j is calculated as a ratio of the traced deviation of input variable j (TD_j) and its standard deviation (SD_j). The traced deviation is calculated as a difference between the input variables F_{ij} and A_j. The standard deviation is calculated using the input variables of F_i which are used to calculate the input variables of A. SI_j greater than 1.96 (significance level of 95%) means that F_{ij} uses more input than A_j and that the difference is statistically relevant.

$$TD_j = F_{ij} - A_j \tag{4.1}$$

$$SD_j = \sqrt{\frac{\sum\left(F_{ij} - A_j\right)^2}{N}} \quad ; \text{where N is the number of broiler breeder flocks} \tag{4.2}$$

$$SI_j = \frac{TD_j}{SD_j} \tag{4.3}$$

The relevance of a deviation (RD_j) is calculated by multiplying the economic importance of a deviation with the absolute value of the statistical importance of the deviation. Positive RD_j indicates positive contribution of an input variable to the GM_d whereby the larger the number the more relevant the input variable is to the GM_d earned. Positive RD_j can be related to the strength of the farm management practices. On the other hand a negative RD_j indicates the negative contribution of an input variable to GM_d and can be related to the weakness of a farm management practices.

$$RD_j = EI_j \times \left|SI_j\right| \tag{5}$$

Finally, D_{rest} (Figure 5.1) indicates the deviations which are not explained by the simulation model. In other words, D_{rest} is the deviation of performance of the farm from the Farm Specific Average (FSA). The FSA is a calculated average that includes those characteristics which are specific to a farm or flock (Hennen, 1995). It is calculated as a summation of the average farm performance (A_p) and the difference between model farm performance and model average performance D_{model}:

$$FSA = A_p + D_{model} \tag{6}$$
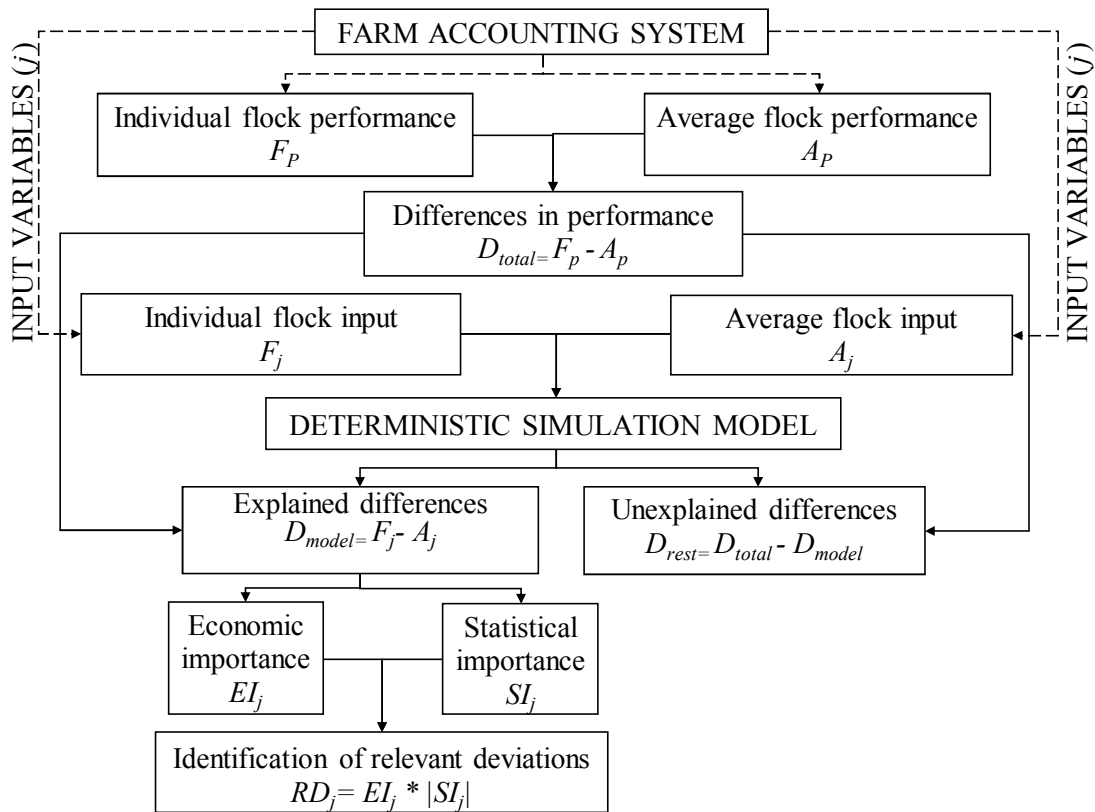
Figure 5.1. Conceptual framework of IFAS

5.2.3   The simulation model

The simulation model is a deterministic model that calculates the gross margin based on underlying causal relationships between performance parameters. The model calculates gross margin per 100 m^2 per day (revenue minus variable costs). Steps used to calculate feed cost during the rearing and laying periods are adapted from (Groen et al.,1998).Table 5.1 shows the definitions of the abbreviations of input variables used in the simulation model.

Basic assumptions made to do the calculations. The number of hen pullets purchased (*HPP*) depends on the barn size (*S$_l$*) and the allowable number of hens per m^2 (*NHP$_{Sl}$*):

$$HPP = NHP_{Sl} \times S_l \tag{9}$$

The number of young males purchased (*MPP*) depends on the number of hen pullets purchased (*HPP*) and the pre-decided hen to male ration (*RPS$_{MF}$*):

$$MPP = HPP \times RPS_{MF} \tag{10}$$

The length of rearing period (*LRP*) is the time period from date of purchase of a flock until the hens are housed to start laying eggs. In this study, the age at which hens are housed (*AHH*) is set to 154 days which is 22wks. *LRP* is calculated from birth(hatch) date (*BD*), date when hens of a specific flock are housed (HD) and the assumed age when the hens are housed to lay eggs (AHH):

$$LRP = AHH - (HD - BD) \tag{11}$$

Hen housed (*HH*) is the number of hen parent stock alive at the end of the rearing period at the broiler breeder farms and depends on hen mortality during the rearing period (*DH_{RP}*):

$$HH = HPP - (HPP \times DH_{RP})$$ (12)

Male housed (*MH*) is the number of male parent stock alive at the end of rearing period at the broiler breeder farms and depends on male mortality during the rearing period (*DM_{RP}*):

$$MH = MPP - (MPP \times DM_{RP})$$ (13)

Average number of available hen and male parent stock per day during the rearing period (*AHM_{RP}*) is the average of the starting and end number of parent stock during the rearing period:

$$AHM_{RP} = \frac{HPP + HH + MPP + MH}{2}$$ (14)

The length of laying period (*LLP*) is the time period from start of egg production till the flock is sold for slaughter. The *LLP* is calculated from the date when hens are housed (*HD*), date of slaughter (*DS*) and length of rearing period (*LRP*):

$$LLP = (DS - HD) - LRP$$ (15)

Average number of available hen parent stock per day during the laying period (*AH_{LP}*) is calculated as an average of the start and end number of parent stock hens during the laying period:

$$AH_{LP} = \frac{HH + (HH - HH \times DH_{LP})}{2}$$ (15.1)

Average number of available male parent stock per day during the laying period (*AM_{LP}*) is calculated as an average of the start and end number of parent stock males during the laying period. To do the calculation the number of males houses *(MH)*, the number of male replaced per hen housed *(MR)* and male mortality *(DM_{LP})* are considered.

$$AM_{LP} = \frac{MH + (MR \times HH) + (MH + (MR \times HH) - (MH + (MR \times HH) \times DM_{LP}))}{2}$$ (15.2)

Average number of available parent stock per day during the laying period (*AHM_{LP}*) is calculated as an average of the start and end number of parent stock hens and males during the laying period:

$$AHM_{LP} = AH_{LP} + AM_{LP}$$ (15.3)

The total number of parent stock hens (*HE_{LP}*) and males (*ME_{LP}*) at the end of laying period depends on the mortality of hens (*DH_{LP}*) and males (*DM_{LP}*) during the laying period:

$$HE_{LP} = HH - (HH \times DH_{LP})$$ (16.1)

$$ME_{LP} = MH - (MH \times DM_{LP})$$ (16.2)

The length of cleaning period (*LKP*) is the time period when the barn is left empty for cleaning. This is calculated from date of slaughter (*DS*) and the planned date when the next flock will be purchased (*PD*):

$$LKP = PD - DS$$ (17)

Flock life time *(FLT)* is the period of time from date of purchase of the parent stock till the last date at the broiler breeder farm. This includes the lengths of rearing period (*LRP*), laying period (*LLP*) and cleaning period (*LKP*) at the broiler breeder farm:

$$FLT = LRP + LLP + LKP \tag{18}$$

The rearing period at the breeder farms (RPBF). This is a period of time at the broiler breeder farms between the date of purchase of a broiler breeder flock from a grandparent farms and the date when hens start laying eggs. During this period there is no income for the breeder farm except for cost.

Costs during the rearing period at the broiler breeder farm. Cost of parent stock pullets purchased (*CPSP*) depends on the number of parent stock purchased and the price per hen (*PHP*) and male (*PMP*) parent stock:

$$CPSP = (HPP \times PHP) + (MPP \times PMP) \tag{19}$$

Feed cost during rearing period at the breeder farm (*CF_RP*) depends on the daily feed consumption in grams (*FC_RP*), the average available number of parent stock per day (*AHM_RP*), the price per 100kg of feed (*PF_RP*) and the length of rearing period at the broiler breeder farm (*LRP*):

$$CF_{RP} = \left(\frac{FC_{RP} \times AHM_{RP}}{1000} \right) \times \left(\frac{PF_{RP}}{100} \right) \times LRP \tag{20}$$

Variable costs during the rearing period at the broiler breeder farms (*VC_RP*) includes housing costs (HC), miscellaneous costs (MC), hired labour costs (HLC) and interest (R). *HC_RP* depends on housing cost per total m^2 per day (*HUC_RP*), the total barn size (*S_t*) and the length of rearing period (*LRP*), MC depends on miscellaneous cost per hen housed (*CMS_RP*), the number of hens housed (*HH*) and the length of rearing period (*LRP*), HLC depends on hired labour cost per year per hen housed (*HLC_RP*), the number of hens housed (*HH*) and the length of rearing period (*LRP*) and R is calculated with interest rate of *I* per year from purchasing costs and miscellaneous costs made during the rearing period:

$$HC_{RP} = S_t \times HUC_{RP} \times LRP \tag{21.1}$$

$$HLC = \frac{HLC_{RP} \times HH \times LRP}{365} \tag{21.2}$$

$$MC = CMS_{RP} \times HH \times LRP \tag{21.3}$$

$$R = \left((HPP \times PHP) + \frac{(CMS_{RP} \times HH)}{2} \right) \times \frac{(I \times LRP)}{365} \tag{21.4}$$

$$VC_{RP} = HC + HLC + MC + R \tag{21.5}$$

Purchasing and rearing cost of parent stock (*TC_RP*) are all the costs incurred excluding the value of culled, lost or sold parents stock (*CCPS_RP*) during the rearing period:

$$TC_{RP} = (CPSP + CF_{RP} + VC_{RP}) - (HH \times CCPS_{RP}) \tag{22}$$

The laying period (LP). This is the period of time from the start till end of laying eggs. During this period, the breeder farmers get revenue from sale of eggs, culled parent stock during the laying period and sale of parent stock at the end of laying period. Extra revenue can also be acquired from other sources such as compensation.

Revenue during the laying period. Revenue from hatching eggs (*RHE)* depends on the number of hatching eggs delivered to the hatchery (*HED*) and agreed price per hatching egg (*AP*). The number of hatching eggs is calculated per average number of available hens per day during the *LP*. During the production cycle of a flock, most farmers follow the management and performance guidelines given by the breeding companies. Farmers use breed-specific egg production curves to analyse the production potential of their flock. In this study, the number of hatching eggs delivered to the hatchery is replaced with a normative number of hatching eggs produced by a specific strain during a specific length of the *LP* (*HENO*) to compare the egg production potential of a flock with the normative value of the same strain. In addition to the number of hatching eggs delivered to the hatchery, revenue from hatching eggs depends on the percentage of fertility (*F*) or hatchability (*H*) of the eggs delivered to the hatchery. In the Dutch broiler production system, there is a contract signed between the broiler breeder farmer and the hatchery that, among others, mentions the target F or H for the eggs delivered during the lifespan of a flock (NOP, 2008). Accordingly, if a flock performs better or worse than the targeted fertility (*RF*) or hatchability (*RH*), then the broiler breeder farmer is paid more or less per each higher or lower chick hatched, respectively . The revenue that is acquired due to higher or lower F or H is calculated based on the average number of available parent stock hens per day during the *LP* (*AHLP*), the normative number of hatching eggs (*HENO*) produced per available hen during the *LP*, flock *H* or flock *F*, agreed price per hatching egg, targeted hatchability or targeted fertility, and bonus price (*B*):

$$RHE = \left(AH_{LP} \times HENO \times AP\right) + \left(AH_{LP} \times HENO \times 100 \times (H - RH) \times B\right) \quad \text{or} \qquad (23.1)$$

$$RHE = \left(AH_{LP} \times HENO \times AP\right) + \left(AH_{LP} \times HENO \times 100 \times (F - RF) \times B\right) \qquad (23.2)$$

Revenue from other eggs (*ROE)* is revenue earned from eggs sold for consumption and for industries (small eggs). The revenue depends on the number of consumption (*CEP*) and small eggs (*SEP*) produced per hen housed and the price per consumption (*PCE*) and small eggs (*PSE*):

$$ROE = \left(HH \times CEP \times PCE\right) + \left(HH \times SEP \times PSE\right) \qquad (24)$$

Revenue from eggs (*RE*) equals then:

$$RE = RHE + ROE \qquad (25)$$

Revenue from sale of parent stock at the end of laying period and from culling during the laying period (*RSA*) depends on the number of parent stock hens and males remained at the end of the laying period HE_{LP} and ME_{LP} respectively, the average weight of a parent stock hen (WT_H) and male (WT_M) at the end of the laying period, slaughter price per kg parent stock hen (PH_{LP}) and male (PM_{LP}) and revenue acquired from the sale of culled parent stock (*RS*) during the laying period:

$$RSA = \left(HE_{LP} \times WT_H \times PH_{LP}\right) + \left(ME_{LP} \times WT_M \times PM_{LP}\right) + \left(HH \times RS\right) \qquad (26)$$

Other revenue (*RO*) is revenue acquired from other sources (*RVO*) such as compensation.

$$RO = HH \times RVO \qquad (27)$$

The total revenue during laying period TR_{LP} is the revenue from eggs, sales of parent stock during and at the end of the laying period and other revenues (*RO*):

$$TR_{LP} = RHE + ROE + RSA + RO \qquad (28)$$

Revenue excluding the purchasing and rearing cost of parent stock (RR_{LP}) is the total revenue during the laying period excluding the cost during rearing period and cost of males replaced (*CMR*) during the laying period:

$$RR_{LP} = TR_{LP} - \left(TC_{RP} + CMR\right) \qquad (29)$$

Costs during the laying period. Cost during the laying period includes cost of feed and other variable costs. Cost of feed during the laying period CF_{LP} includes costs of main feed (CFE_{LP}) and other feed supplements (CFO_{LP}). Cost of main feed (CFE_{LP}) depends on the amount of feed consumed during the laying period and the price per 100kg feed (PF_{LP}). The amount of feed consumed during the laying period is calculated from the amount of feed consumed by male (*FCM*) and hen (*FCH*) parent stock. The amount of feed consumed by male parent stock (*FCM*) is calculated from the amount of feed consumed per male per day (FCM_d), the average number of males per day (AM_{LP}) and the length of laying period (*LLP*). In the simulation model, the amount of feed consumed per male per day (FCM_d) is replaced with a normative value (*FMN*) which considers the relationship between the amount of feed consumed per day with kg weight gain.

The amount of feed consumed by hen parent stock (*FCH*) is calculated from the amount of feed consumed per hen per day (FCH_d), average number of hens per day (AH_{LP}) and the length of laying period (*LLP*). Similarly, the amount of feed consumed per hen per day (FCH_d) was replaced with a normative value (*FHN*) which considers the relationship between the amount of feed consumed per hen per day with body weight gain and egg production.

The cost of other feed supplements includes the cost of grain, limestone, and other supplements. The cost of other feed supplements depends on the number of hens housed, amount consumed per day per hen housed, and the price per 100 kg of supplement. The *FG*, *FLS*, and *FOS* variables are the amounts of grain, limestone, and other supplements, respectively, and the *PG*, *PLS*, and *PS* variables are for the price per 100 kg of grain, limestone, and other supplements, respectively.

$$FCM = FMN \times AM_{LP} \times LLP \qquad (29.1)$$

$$FCH = FHN \times AH_{LP} \times LLP \qquad (29.2)$$

$$CFE_{LP} = \left(FCM + FCH\right) \times PF_{LP} \qquad (29.3)$$

$$CFO_{LP} = \left(HH \times FG \times PG\right) + \left(HH \times FLS \times PLS\right) + \left(HH \times FOS \times PS\right) \qquad (29.4)$$

$$CF_{LP} = CFE_{LP} + CFO_{LP} \qquad (29.5)$$

Cost of purchasing male replacements (*CMR)* depends on the number of hens housed; the percentage of male replaced per hens housed (*MR*) and the price per male replacement (*PMR*):

$$CMR = HH \times MR \times PMR \tag{30}$$

Interest during laying period (*R_{LP})* is calculated for the total length of laying period (*LLP*). It includes total purchasing and rearing cost of parent stock during the rearing period (*TC_{RP}*), cost of male replacement (*CMR*), revenue from sale of parent stock at the end of the laying period (*RSA*) excluding the revenue obtained from sale of selected or culled parent stock (*RS*) and the interest rate (*I*):

$$R_{LP} = \frac{TC_{RP} + CMR + \left(RSA - \left(HH \times RS\right)\right)}{2} \times \frac{I \times LLP}{365} \tag{31}$$

Other variable costs during laying period (*OVC_{LP})* include costs of electricity (*CET*), heating gas and oil (*CHT*), health care (*CHC*), hired labour (*CHL*), bedding and litter (*CBLT*), manure removal (*CPR*) miscellaneous variable costs (*CMS*), cost of male replaced (*CMR*) and interest calculated for the flock (*R_{LP}*). To calculate total costs of electricity, heating and bedding and litter underlining relationships are constructed in the model. For each hen housed 1KWH electricity, $0.8m^3$ gas for heating and 1kg litter is needed and *CE, CH* and *CBL* are costs per KWH electricity, $0.8m^3$ gas and kg litter respectively (KWIN, 2008).

$$CET = 1KWH \times HH \times CE \tag{32.1}$$

$$CHT = 0.8m^3 \times HH \times CH \tag{32.2}$$

$$CBLT = 1kg \times HH \times CBL \tag{32.3}$$

$$OVC_{LP} = \left(CHC + CHL + CPR + CMS + CMR\right) \times HH + CET + CHT + CLBT + R_{LP} \tag{32.4}$$

The total variable cost during the laying period (*TVC_{LP})* is:

$$TVC_{LP} = FC_{LP} + OVC_{LP} + CMS \tag{33}$$

Housing and other costs during the laying and cleaning period (HC_{LKP}): depends on housing cost per total m^2 per day (*HUC_{LKP}*) during the laying and cleaning period, the total barn size (*S_t*) and the length of laying (*LLP*) and cleaning period (*LKP*):

$$HC_{LKP} = \left(LLP + LKP\right) \times HUC_{LKP} \times S_t \tag{34}$$

Measurement of overall performance of a flock. Gross return (*GR*) is return during the laying period after deducting the purchasing costs of parent stock and male replacement, rearing costs and feed cost during the laying period. In other terms it is the rest revenue (*RR_{LP}*) minus feed cost during the laying period CF_{LP}:

$$GR = RR_{LP} - FC_{LP} \tag{35}$$

Gross margin during the laying and cleaning period (*GM_{LKP})* is:

$$GM_{LCP} = RR_{LP} - OVC_{LP} \tag{36}$$

Return to labour (*RL*) is the gross margin earned during the laying and cleaning period excluding housing cost:

$$RL = GM_{LCP} - HC_{LCP} \tag{37}$$

Gross margin per 100m^2 per day (GM_d) is calculated per 100m^2 of the total barn size (S_t) per day throughout the flocks' life time (FLT). The daily gross margin includes the gross margin obtained during the laying and cleaning periods (GM_{LKP}) and variable costs made during the rearing period excluding the interest:

$$GM_d = \left(\frac{GM_{LCP} + (VC_{RP} - R)}{S_t} \right)^{-FLT} \times 100 \qquad (38)$$

Because of lack of adequate performance data, the model does not include all underlining relationships between variables. For example, not all breeder farms weigh their birds (Yassin et al., 2011), therefore to calculate daily feed consumption of parent stock, the relationship between daily feed consumption and body weight gain cannot be calculated from a data set . Instead, daily feed consumption of parent stock is calculated with a normative value which considers the relationship between feed intake, BW gain and egg production. In the model, the normative value of egg production or average daily feed intake is calculated for a specific length of laying period. Therefore, if the length of laying period is shorter or longer, the normative number of egg produced or the average daily feed intake can change accordingly. This way, analysis can be made if a flock is producing or fed over or under the norm. Additionally, the model does not include the effect of topography and environmental factors on a flock's performance.

5.2.4 Analysis Scheme of IFAS

An analysis scheme (Figure 5.2) is used to interpret results from IFAS and to determine which factors can cause the deviations and which management categories to consult for future improvements. The analysis scheme is developed based on the gross margin. It consists of two parts: the basic scheme and management categories. The basic scheme includes logical linking of important factors that affect the gross margin. Furthermore, part of the basic scheme is explained in four parts; that is, revenue from hatching eggs, revenue from sold parent stock at the end of the LP, purchasing costs of the parent stock, and feed costs. The management categories are management practices at the rearing farms, at broiler breeder farms, during transportation, and at hatcheries that related to the performances of a flock.

Interpretation of results of IFAS can be done as follows: suppose that the gross margin of broiler flock F_i is different from that of average broiler farm A, then one has to look at the factors that affect the costs and revenue during the life time a flock. For example, interpretation of the revenue can be done as follows: a great part of revenue at a broiler breeder farm comes from sales of hatching eggs.

Firstly, revenue from hatching eggs depends on the number of eggs delivered to the hatcheries. The number of eggs delivered during the laying period depends on the number of eggs delivered per hen, number of available hens during the laying period and the length of laying period. Number of eggs produced per hen depends on hen's reproductive capacity. On the other hand the number of hens present during the laying period depends on the number of dead hens during this period. Both hen's reproductive capacity and number of dead hens

during the laying period are related to the management of parent stock at the breeder farm which is again related to the management of parent stock at the rearing farm. Management at the rearing farms determines flock's uniformity which is an important factor that affects the performance of a flock (North, 1980; Costa, 1981). Management of parent stock at the breeder farm is categorised to different sub-managements: feeding, health, fertility and housing management. For example, if the number of eggs produced per hen is lower than that of average farm, the breeder farm management should consult his management practices on feeding, health, fertility and housing because all these management practices can affect the hen's reproductive capacity (Giambrone, et al. 1991; Rosales, 1994; Lopez and Leeson, 1994; Wilson et al., 1995; Robinson and Wilson, 1996; Hazary et al., 2001; Ingram et al., 2007; Torshizi et al., 2008).

Secondly, revenue from hatching eggs depends on the price earned per hatching egg which includes the agreed price during contract with the hatcheries and bonus price which is earned because of extra hatched chicks. The bonus price depends on percentage fertility or hatchability. The percentage fertility or hatchability is determined by the number of fertile or hatched eggs respectively which in turn are dependent on male fertility and quality of hatching eggs (external and internal). Male fertility is related to parent stock management at the rearing and breeder farm. Internal and external quality of the eggs is related to egg management at the breeder farm, during transportation and at hatchery (Kirk et al., 1980; Wilson, 1991 and 1997; Vieira and Mora, 1998; Tona et al., 2004 and 2005; Elibol and Brake, 2006; Decuypere and Bruggeman, 2007; Yassin et al., 2008).

Chapter 5

A HH is the number of hens housed to start laying eggs
B PS is parent stocks
C HE is hatching eggs
D NHE is non-hatching eggs
E LP is laying period

F RP is rearing period at the breeder farms
G RF is rearing farm
H BF is breeder farm
I H is hatchery
J SM is simulation model

A) Basic Scheme

Not included in the SM[J]

Gross Margin per HH[A]

Revenue per HH
Variable costs per HH

Revenue from sold eggs
Revenue from sold PS[B]
Revenue from other sources

Individual animal costs
Flock costs

Revenue form HE[C] (1)
Revenue from NHE[D]
Revenue sold PS at end of LP[E] (2)
Revenue culled PS during LP
Purchasing cost of PS (3)

Feed costs (4)
Other variable costs

Hired labour cost
Electricity cost
Cost of heating gas and oil
Cost of bedding and litter
Miscellaneous costs
Interest

Cost of health care
Cost of water
Cost of manure removal
Miscellaneous costs

# of NHE
Price per NHE
# of culled PS
Price per culled PS

HE external quality
Age and weight of hens
Fertility and conditions of PS

PS management BF[H]
Egg management at BF

PS management BF

1)

Revenue form HE

# of HE delivered
Price per HE

Egg laying percentage
# of hens per day
Duration of LP

Agreed price per HE
Bonus price per extra hatchability

% hen mortality during LP

% hatchability or fertility
Target hatchability or fertility

Egg laying potential of hens
Condition of PS at purchase
Egg laying potential of hens
Male fertility
Quality of egg (external and internal)

PS management at RF
PS management at RF[G]
PS management at BF

PS management at BF
Egg management at BF
Transport management
Egg management at H
Hatching management

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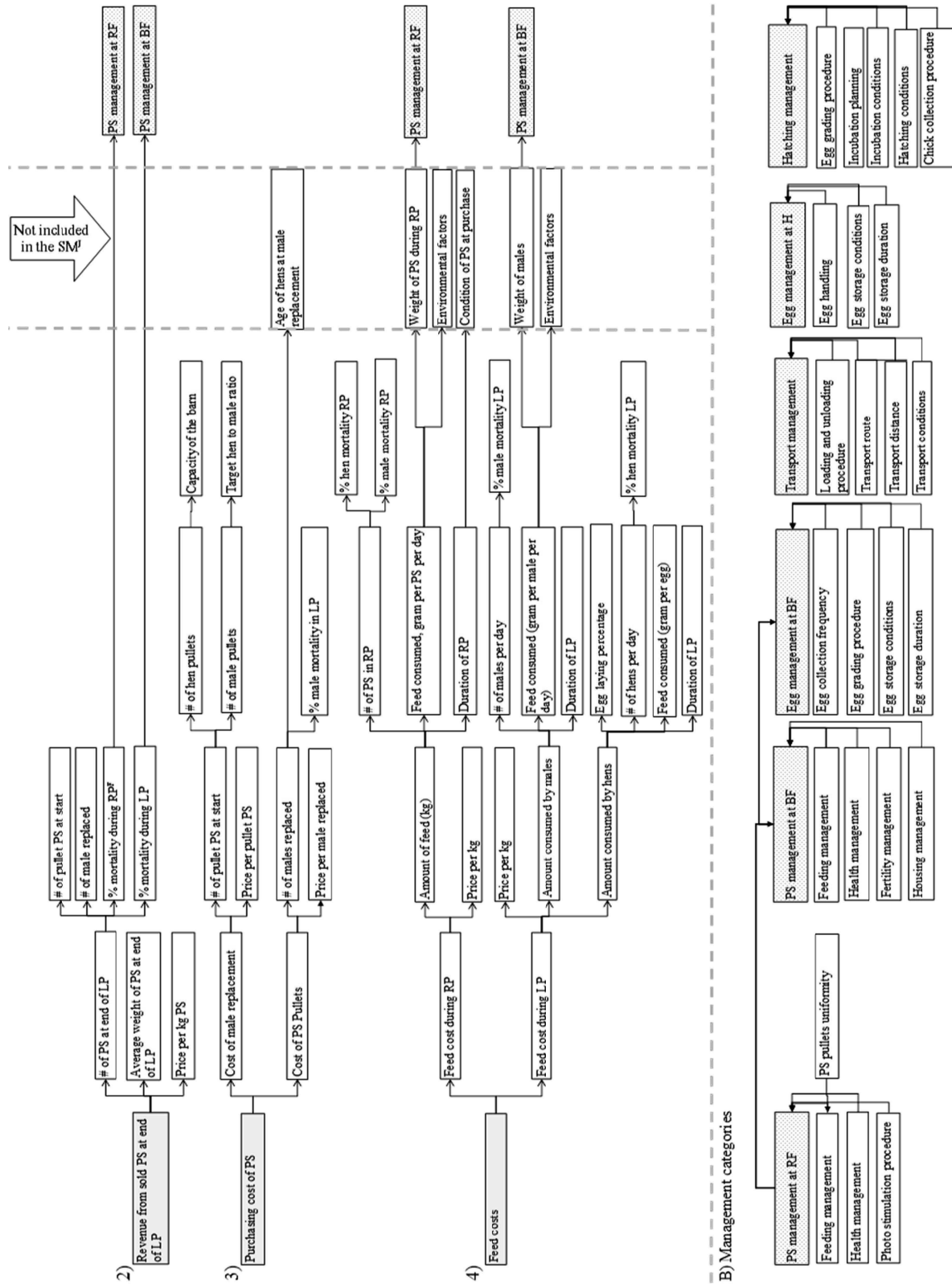# Comparative Analysis as Management Tool for Broiler Breeder Farms

Figure 5.2. Analysis Scheme of the simulation model

5.3 Demonstration of IFAS

In this demonstration, input variables of the average flock (A) (Table 5.1) were calculated as weighted averages of input variables of 20 broiler breeder flocks. The hatch dates of the flocks varied between 14-09-2006 and 14-11-2007 with SD of 146 d. The flocks consisted of fourteen Ross 308 and six Cobb500.

Table 5.1. Performance and price data of the average breeder flock (A) and individual flock (Fi) used to demonstrate IFAS.

Input variables	Unit	Descriptions	Parameter values		$SD(A_j)$
			A_j	F_{ij}	
S_t	m^2	Total space	2,894	3,070	1,097
S_l	m^2	Liveable space	2,758	2,840	1,227
NHP_{st}	#	Number of hen pullets per m²	7.40	7.38	1.00
PHP	€/bird	Price per PS hen pullet	9.92	10.45	0.55
PMP	€/bird	Price per PS male pullet	0.00	0.00	0.00
RPS_{MF}	%	PS young males to PS hens at purchase	9.49	10.08	1.03
AHH	days	Age of hens housed	154	154	0
LRP	days	Length of rearing period	14	10	5
LLP	days	Length of laying period	279	263	12
AS	days	Age at slaughter	433	417	12
LKP	days	Length of cleaning period	48	56	21
FC_{RP}	gr./bird/day	Feed consumption PS in rearing period	115	106	14
PF_{RP}	€/100kg	Price of feed during rearing period	24.43	29.93	3.06
CMS_{RP}	€/HH[1]	Miscellaneous costs during rearing period	0.00	0.00	0.00
$CCPS_{RP}$	€/HH	Cost of culled or sold PS during rearing	0.00	0.00	0.02
DH_{RP}	%	PS hens died during rearing period	0.39	0.26	0.62
DM_{RP}	%	PS males died during rearing period	2.96	2.42	3.93
HED	#/hen	Number of hatching eggs delivered	171	173	8
$HENO$	#/hen	Number of hatching eggs delivered (norm)	167	173	0
LAP	Egg/day	Laying percentage	64.40%	69.52%	0.03
EP	HE[3]/hen/week	Number of hatching eggs	4.61	4.30	0.20
RH	%	Reference hatchability	78.00	78.00	0.00
RF	%	Reference fertility	83.00	83.00	0.00
F	%	Flock fertility[2]	84.09	0.00	5.19
H	%	Flock hatchability	79.88	80.90	3.80
B	€/egg	Bonus price	0.001	0.001	0.00
AP	€/egg	Agreed price per hatching egg	0.192	0.189	0.01
CEP	#/HH	Number of consumption eggs produced	5	7	2
PCE	€/egg	Price per consumption egg	0.015	0.010	0.007
SEP	#/HH	Number of small eggs produced	3	2	1
PSE	€/egg	Price per small egg	0.09	0.08	0.029
WT_H	kg	Weight of PS hen end of LP[4]	3.67	3.90	0.21
WTH_N	Kg	Weight of hens (norm) end of LP	3.66	3.64	0
WT_M	Kg	Weight of PS male end of LP	4.84	4.90	0.39
WTM_N	kg	Weight of males (norm) end of LP	4.35	4.32	0

PH_{LP}	€/kg	Price per PS hen end of LP	0.55	0.40	0.09
PM_{LP}	€/kg	Price per PS male end of LP	0.48	0.46	0.13
DH_{LP}	%	PS hens died during LP	7.97	5.75	2.53
DM_{LP}	%	PS males died during LP	38.63	31.79	9.74
MR	%/HH	Male replaced	2.22	1.91	1.18
PMR	€/bird	Price per male replacement	6.04	6.56	1.68
RS	€/bird	Revenue from culling per HH	0.027	0.010	0.08
RVO	€/HH	Other revenue per HH	0.102	0.00	0.69
FCM_d	gr./bird/day	Feed consumed per male during LP	162.16	168.17	6.05
FMN	gr./bird/day	Feed consumed per male (norm) during LP	140.34	140.85	0
FCH_d	gr./bird/day	Feed consumed per hen during LP	165.64	168.71	11.48
FHN	gr./bird/day	Feed consumed per hen (norm) during LP	157.45	157.92	0
FCR_H	gr./egg	Feed conversion ratio	273.17	264.14	12.10
FCR_N	gr./egg	Feed conversion ratio (norm)	252.04	248.27	0
PF_{LP}	€/100kg	Price of main feed during LP	25.71	27.16	2.57
FG	gr./HH/day	Grain supplement used during LP	2.79	0.00	6.47
PG	€/100kg	Price of grain	23.19	0.00	9.90
FOS	gr./HH/day	Other supplements used laying period	0.21	0.00	0.28
PS	€/100kg	Price of other supplement feed	182.47	0.00	121.98
FLS	gr./HH/day	Limestone used during LP	0.44	0.00	0.23
PLS	€/100kg	Price limestone	11.81	0.00	0.00
I	%	Interest rate	6	6	0
HLC_{RP}	€/HH/year	Hired labour cost in rearing period	2.00	2.00	0.00
HUC_{RP}	€/m²/day	Housing cost in rearing period	0.066	0.066	0.00
HUC_{LKP}	€/m2/day	Housing cost in laying and cleaning period	0.066	0.066	0.00
CE	€/KWH	Cost of electricity per KWH	0.15	0.15	0
CEL	€/HH	Cost of electricity during laying period	0.54	0.48	0.12
CH	€/0.8m³ gas	Cost of heating per 0.8m³ gas	0.42	0.42	0
CHT	€/HH	Cost of heating during laying period	0.03	0.10	0.04
CHC	€/HH	Cost of health care during laying period	0.38	0.68	0.17
CHL	€/HH	Cost of hired labour during laying period	0.44	1.00	0.18
CBL	€/Kg	Cost of bedding and litter per kg litter	0.05	0.05	0
$CBLT$	€/HH	Cost of bedding and litter laying period	0.04	0.13	0.04
CPR	€/HH	Cost of manure removal laying period	0.42	0.34	0.17
CMS	€/HH	Miscellaneous costs during laying period	0.38	0.30	0.07

[1]HH is hen housed, [2] Fertility is calculated from the number of hatching eggs left after candling at day 18 of incubation, [3]HE is hatching eggs, [4]LP is laying period.

5.3.1 Farm performance

In this example, most input variables used in the simulation model (Table 5.1) are calculated from the farm accounting system using exogenous independent variables. Only feed intake during the laying period, cost of electricity, heating and bedding and litter were calculated considering underlining relationships. The strain of F_i is Ross308, therefore, all normative values used in this demonstration are taken from the management guideline of Ross308 (Ross management guide, 2007).

Table 5.2 shows performance results of flock F_i and the average flock A. The gross margin per 100m² per day (GM_d) for flock F_i was lower than the average flock, which was

F_p= €15.03 versus A_p= 18.40 from the farm accounting system and F_j = €14.52 versus A_j=20.07 from the simulation model respectively. The value D_{total} under the farm accounting system indicates that flock F_i produced less than flock A with €3.37 per 100m^2 per day. To explain this difference, further analysis was done using the simulation model. Accordingly, the difference between F_m and A_m i.e. D_{model} = €5.55 per 100m^2 per day. The difference between the results of the farm accounting system and the simulation model is mainly caused due to the relationships included in the simulation model to calculate egg production, feed intake, use of electricity, heating and bedding and litter during the laying period. This can be seen by looking at Table 5.2 which shows that the total revenue of flock F_i was reduced by €1.23per 100m^2 per day which is mainly attributed to the revenue obtained from hatching eggs (34.27 -33.04 = 32.36 - 31.13) (Table 5.2). This is because the number of hatching eggs produced by flock F_i during the laying period was higher than the normative value for the same length of laying period i.e. 171 versus 167 respectively (Table 5.1). Additionally, feed cost of flock F_i and the average flock A from the farm accounting system was €12.74 and €12.42 respectively with D_{total} = €0.32. This is attributed to the price of feed and the amount of feed consumed per day (Table 5.1). When feed intake per day is simulated using relation with egg production and body weight gain, feed cost of F_i becomes €11.85 which is €0.89 less. Since the price of feed is set to a constant, this indicates that F_i used more feed per day compared to the norm for the same length of laying period. Increase in daily feed consumption is related to egg production and or body weight gain. No difference is shown when egg production of F_i is compared to the norm. However, compared to the norm, flocks of F_i had higher body weight at the end of the laying period which was an increase of 26 and 58 gram for females and males respectively i.e. (3.90 – 3.64 and 4.90 – 4.32) (Table 5.1).

Generally, looking at the results of the farm accounting system in Table 5.2, breeder farmer of flock F_i can assume that the causes for the lower GM$_d$ were: the higher total variable costs (+€0.82) during the laying period, higher purchasing and rearing costs (+€0.39), and feed costs (+€0.32) and lower revenue (-€0.06) which is largely attributed to the lower revenue earned from sale of parent stock at the end of the laying period (-€0.32). However, to evaluate the performance of flock F_i, the breeder farmer needs to look into specific management decisions made during the flock's life time. By analyzing D_{model}, the simulation model allows to find out the underlying factors which caused the deviations and shows how much each factor affects the GM$_d$.

Table 5.2. Comparison of performance results of broiler breeder flock F_i with the average broiler breeder flock A using the farm accounting system and the simulation model

Performance variables	Unit	Farm accounting system			Simulation model			D_{rest}	FSA
		F_p	A_p	D_{total}	F_m	A_m	D_{model}		
Overall performance									
Gross margin per day	€/100m^2	15.03	18.40	-3.37	14.52	20.07	-5.55	2.18	12.85
Gross margin during (LP and KP)^2	€/HH^1	7.11	8.71	-1.59	6.93	9.55	-2.61	1.02	6.09
Gross return	€/HH	10.41	11.18	-0.77	10.06	11.95	-1.89	1.11	9.29
Revenue excluding purchasing and rearing costs	€/HH	23.15	23.60	-0.45	21.91	23.92	-2.01	1.56	21.59
Return to labour	€/HH	4.02	5.64	-1.62	3.84	6.48	-2.64	1.02	3.00
Revenue									
Total revenue	€/HH	34.27	34.33	-0.06	33.04	34.66	-1.62	1.56	32.71
Total revenue from eggs	€/HH	32.60	32.22	0.38	31.37	32.54	-1.18	1.56	31.04
Revenue from hatching eggs	€/HH	32.36	31.92	0.44	31.13	32.24	-1.12	1.56	30.80
Revenue non-hatching eggs	€/HH	0.24	0.30	-0.06	0.24	0.30	-0.06	0.00	0.24
Total revenue from sale of PS^3	€/HH	1.67	2.01	-0.34	1.67	2.01	-0.34	0.00	1.67
Revenue from sale of PS end of LP	€/HH	1.66	1.99	-0.32	1.66	1.99	-0.32	0.00	1.66
Revenue from culling PS during LP	€/HH	0.01	0.03	-0.02	0.01	0.03	-0.02	0.00	0.01
Other revenues	€/HH	0.00	0.10	-0.10	0.00	0.10	-0.10	0.00	0.00
Costs									
Total costs during rearing period	€/HH	11.00	10.60	0.39	11.00	10.60	0.39	0.00	11.00
Total costs during LP	€/HH	16.03	14.89	1.14	14.98	14.37	0.61	0.53	15.50
Total feed cost during LP	€/HH	12.74	12.42	0.32	11.85	11.97	-0.12	0.44	12.30
Total variable costs during LP	€/HH	3.29	2.47	0.82	3.13	2.40	0.73	0.09	3.20

[1] HH is hens housed, [2] Lp & KP are laying and cleaning period respectively, [3] PS is parent stock

5.3.2 Identification of causes of deviations

Table 5.3 shows causes of deviations and their relevancies using the statistical and economic importance of input variables and Figure 5.3 shows the strong and weak management elements of F_i based on the economic importance of input variables.

The results in Table 5.2 show that F_i performed lower than the average flock A because of higher total variable costs, purchasing and rearing costs, feed cost during the laying period and lower revenue. Analyzing the results using the simulation model gives specific indication of why the costs of F_i were higher and the revenue was lower compared to A. The most important factors that caused the higher total variable costs during the laying period were costs of hired labour and healthcare which reduced the GM_d with €1.14 (RD=-3.77) and €0.61(RD=-1.10) respectively. The higher purchasing and rearing costs was largely caused by the purchasing price of the hens which reduced the GM_d with €1.11 (RD=-1.07). The amount of feed consumed per egg (feed conversion ratio) of F_i contributed positively to the GMd by €0.71 (RD=0.44).

Therefore the higher cost of feed during the laying period is mainly caused by the price of feed which reduced the GM_d with €1.39 (RD=-0.79). F_i produced a higher number of hatching

eggs per hen compared to the average flock A which increased the GM_d with €0.43 (RD=0.15). Furthermore, the average hatchability of eggs of flock F_i was higher than A which increased the GM_d with €0.36 (RD=0.10). However, F_i had lower revenue compared to A. This is largely attributed to the agreed price per hatching eggs and revenue earned from the sale of parent stock at the end of the laying period. Revenue from sale of parent stock is related to mortality of the parent stock during the laying period, body weight of the parent stock at the end of the laying period and the salvage value of the parent stock. The result in Table 5.3 shows that the main cause was the salvage value of the hens which reduced the GM_d with €0.83 (RD=-0.75). F_i had lower hen mortality during the laying period compared to A which increased the GMd with €0.53 (RD=0.46).
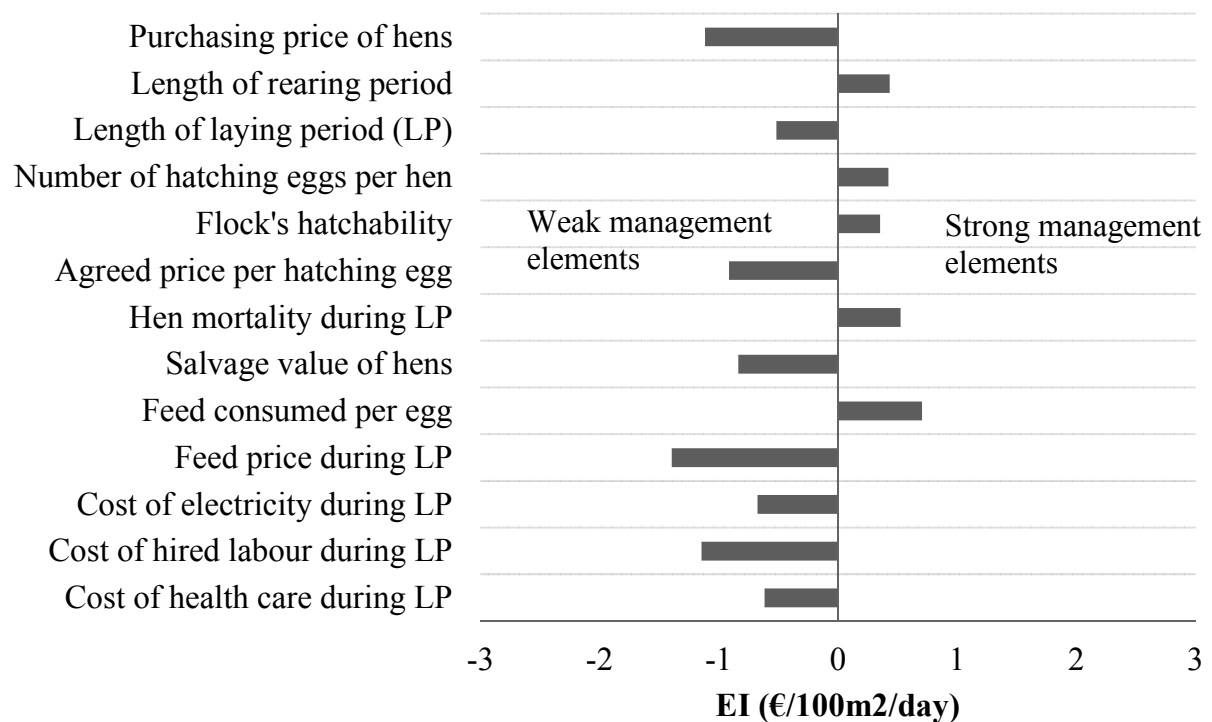

Figure 5.3. The strong and weak management elements of breeder farmer of Fi in relation to the Economic Importance (*EI*) of input variables.

Table 5.3. Performance variables and their statistical importance (SI), economic importance (EI) in GM_d €/100m²/day and relevance of deviation (RD)

Performance variables	SI	EI	RD
Number of hens per m² at purchase	0.03	-0.05	0.00
Purchasing price of hens	0.96	-1.11	-1.07
Feed consumption in RP[1]	0.66	0.07	0.04
Price of feed during RP	1.80	-0.13	-0.24
Hen mortality during RP	0.21	0.05	0.01
Male mortality during RP	0.14	0.01	0.00
Length of RP	0.72	0.44	0.31
Length of LP[2]	1.38	-0.53	-0.71
Length of KP[3]	0.39	-0.37	-0.14
Number of hatching eggs per hen	0.36	0.43	0.15
Flock's hatchability	0.27	0.36	0.10
Agreed price per hatching egg	0.36	-0.91	-0.33
Price of consumption egg	0.70	-0.07	-0.05
Price of small egg	0.19	-0.02	0.00
Hen mortality during LP	0.87	0.53	0.46
Salvage value of hens	0.90	-0.83	-0.75
Male mortality during LP	0.70	0.04	0.03
Salvage value of males	0.30	0.06	0.02
Percentage of male replaced per HH[4]	0.26	0.04	0.01
Price of male replacement	0.31	-0.02	-0.01
Feed consumed per egg	0.63	0.71	0.44
Feed price during LP	0.57	-1.39	-0.79
Cost of electricity during LP	0.51	-0.67	-0.34
Cost of heating during LP	1.56	-0.13	-0.21
Cost of hired labour during LP	3.30	-1.14	-3.77
Cost of health care during LP	1.65	-0.61	-1.01
Cost of bedding and litter during LP	2.23	-0.18	-0.41
Cost of manure removal during LP	0.48	0.17	0.08
Miscellaneous costs during LP	0.58	0.08	0.04

[1] RP is rearing period, [2] LP is laying period, [3]KP is cleaning period, [4]HH is hen housed

5.3.3 Analysis of relevant deviations

In addition to the analysis scheme given in Figure 5.2, to analyze the results of IFAS expert opinion is needed.

The F_i had lower GM_d compared to A. This means that, broiler breeder farmer of F_i needs to either increase the revenue earned or decrease cost of production in order to perform above the average flock A.

At a broiler breeder farm, the main sources of revenue is the sale of hatching eggs which is a function of the number of hatching eggs produced per hen, its hatchability and the price per hatching egg. The F_i produced higher number of hatching eggs which had higher

hatchability, although the length of laying period of F_i was shorter compared to A. As a broiler breeder farmer earns more for each percentage of extra hatchability the high hatchability contributed to increased income of F_i. However, the initial agreed price per hatching egg was lower which was again disadvantageous. Furthermore, although F_i purchased a small number of hens per m^2 at start, the lower mortality of hens throughout the laying period was also advantageous.

Nonetheless, feed (quality and quantity) is one of the most important factors that affect performance of a broiler breeder flock (Lopez and Leeson, 1994; Wilson et al., 1995; Hocking, 1996; Torshizi et al., 2008); the main source of cost at the broiler breeder farms is feed. Broiler breeders require feed mainly for maintenance, growth and production. Maintenance needs have priority since breeders must firstly maintain their body to survive. However, growth needs especially of hens during post-peak egg production do not contribute greatly to the daily requirement. Since overweight hens produce fewer eggs than trimmer hens (Robinson et al., 1993; Robinson and Wilson, 1996), the attempt of a broiler breeder farm management is to feed the hens to maximize egg numbers and keep body weight on target. The F_i had a higher cost of feed compared to flock A which is a function of the amount of feed consumed and the price per kg feed. Breeder farmer of F_i paid more per 100kg (€27.161) compared to A (€25.709) (Table 5.1). The lower feed conversion ratio of F_i i.e. gram feed per egg (264.14 versus 273.17) (Table 5.1) indicates that F_i used feed efficiently compared to flock A.

The F_i produced a higher number of eggs than flock A. Additionally; there was no significant difference in body weight of the parent stock of F_i compared to A. This indicates that broiler breeder farmer of F_i managed to produce higher number of hatching eggs keeping body weight on target. Accordingly, broiler breeder farmer of F_i should not be advised to reduce the amount of feed consumed but to focus on the feed price.

Additionally, considering the higher variable costs made by F_i, extra caution should be made especially on purchasing price of hens, costs of hired labour and healthcare.

5.3.4 Field validation of IFAS

The IFAS was validated in the field, during a workshop and a presentation whereby poultry advisors and experts, hatchery managers, and about 30 broiler breeder farms participated. The result of field validation showed that the model is simple and comprehensible to be used in the field. It allows comparison of the performances of a flock with other flocks. The model provides the strong and weak management practices during the flock lifetime and gives a clear picture of the points of improvement to support future management decisions of a broiler breeder farmer. However, for the model to be practical, a complete and good quality data set is needed. Standardization of the data system of the broiler breeder farms is a prerequisite whereby all names, codes, contents, definitions, and formats of the input variables are standardized (Yassin et. al, 2011). Additionally, there should be a responsible, in dependent, and trusted organization that secures the continuity of the use of the model. The organization is responsible for collecting data and calculating the average to be used as a standard for the comparison of a flocks' performances.

5.4 Discussion

The IFAS is a system that evaluates a broiler breeder farm's tactical management. It allows computing of the influence of production parameters, technical and financial inputs, on the overall performance of a flock. The model compares the performance of an individual broiler breeder flock with an average flock. It calculates costs made and revenues acquired during a flock's lifetime whereby analysis can be made as to the economic status of an individual broiler breeder farm. The IFAS calculates the statistical and economic importance of input variables relative to a flock's performance and identifies relevant deviations. Additionally, to support management decisions of a broiler breeder farmer, IFAS gives an indication of the strongest and weakest management practices during the flock's lifetime.

Interpretation of the results of IFAS should be done with care. Recognition of model assumptions on relationships between input variables is required. An input variable can have a negative effect on the overall performance of the flock while contributing positively to a specific performance factor. For example, increased veterinary costs can lower the gross margin while reducing the parent stock mortality rate. Another example is that a broiler breeder farmer can have high feed costs. This can be caused by a high feed price or higher amounts of feed consumed during the flock's lifetime. If the high cost is attributed to the amount of feed consumed, further analysis of the factors that are related with feed consumption, such as the number of hatching eggs produced and BW gain of the parent stock is needed (Robinson et al., 1993; Wilson et al., 1995; Hocking, 1996; Torshizi et al., 2008).

The analysis scheme in Figure 3 can be used as a basis for interpretation of the results of IFAS. The analysis scheme gives an indication of underlining relationships among input variables and performance factors. It shows logical links of the performance factors to the gross margin. Additionally, it gives an indication of the management categories at other levels of the broiler chain that affect the performance of a flock at a broiler breeder farm.

It is recommended to expand and develop IFAS in future studies, taking into account more interaction effects of input variables and the effect of management activities at other levels of the broiler production chain on the performance of a broiler breeder flock.

5.5 Conclusion

The result of IFAS enables broiler breeder farmers to get a good impression of the performance of their flock relative to other flocks. The information gained from IFAS can be used to amend previous weak management practices and maintain the strong management practices for the next flock. The results of IFAS should, however, be interpreted carefully, taking all relationships of input variables and performance factors into account. Analysis of the results by ranking relevant deviations allows specifying input variables that are most economically important related to the overall performance of a flock.

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A model for an Economic Optimal Replacement of a Breeder Flock

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Chapter 6

Abstract

A deterministic model is developed to support the tactical and operational replacement decisions at broiler breeder farms. The marginal net revenue approach is applied to determine the optimal replacement age of a flock. The objective function of the model maximizes the annual gross margin over the flock's production cycle. To calculate the gross margin, future egg production, fertility or hatchability of the eggs, revenues and variable costs of a flock were estimated.

For tactical decisions, the optimal laying length is the age at which the average gross margin of an average flock is maximal. For operational decisions, a flock should be replaced when the marginal gross margin of a replaceable flock is less than the average gross margin of an average flock. To demonstrate the model, a broiler breeder flock from a Dutch breeder farm was used. A sensitivity analysis showed that the optimal replacement decision, for both tactical and operational management, is sensitive to variation in the descending slope of egg production and the prices of feed and hatching eggs. The effect of the slope of fertility on the replacement decision is related to the payment system for hatching eggs.

Key words

On-farm decision support tool, Flock replacement decision, Marginal net revenue approach, Broiler breeder farms.

6.1 Introduction

At broiler breeder farms, farmers' major target is achieving economic profit from their flocks. The optimal replacement policy is known as an important factor affecting farm profitability (Renkema and Stelwagen, 1979; Van Arendonk, 1985a; Huirne and Dijkhuizen, 1993). This decision involves the replacement of a less productive flock with a more productive one at the economically most optimal moment of a production life.

Several methods are described in literature to address the replacement problem in livestock production. Dynamic programming is one of the first methods applied to solve on-farm replacement decisions on flocks of laying hens (White,1959). Dynamic programming is a mathematical technique which solves sequential interrelated decision problems. In this method, changes occurring over time like price fluctuation, and genetic improvement are taken in to consideration. Dynamic programming is the most commonly applied method to solve replacement problems in livestock production (Kristensen, 1987; Azzam and Azzam, 1991; Smith and Wetzstein, 1992; Huirne and Dijkhuizen, 1993 and others).

The marginal net revenue approach (MNR) is another method that is applied to find an optimal replacement policy in livestock production systems. In the early 60th the MNR approach was explained in detail for three types of enterprises, namely enterprises with short production periods with revenue being realized by the sale of the asset, enterprises with long production periods with revenue being realized by the sale of the asset, and enterprises with long production periods with revenue being realized throughout the life of the asset (Faris,1960). Thereafter, the MNR approach was suggested to solve the replacement problem of dairy cows in dairy farming (Renkema and Stelwagen, 1979; Dijkhuizen et al., 1985; Groenendaal et al., 2004) and swine farming (Giesen et al. 1988). The MNR approach relies on the production function approach in which both revenues and variable costs that could be influenced by farmer decisions are modeled during a given production cycle. In other words, the MNR approach refers to the gross margin, i.e. revenue minus variable costs. Therefore, the optimal replacement time is determined based on comparison of marginal gross margin of a replaceable item with the average gross margin of the replacement item. A replaceable item of a particular age should be kept in production as long as its expected marginal gross margin is higher than that of the expected average gross margin of a replacement item during a particular production cycle.

The MNR approach has a limitation compared to the dynamic programming approach. In the MNR approach no consideration is made of the effect of genetic improvements and seasonal variation. However, the limitation has been reported to have smaller consequences for the reliability and accuracy of results from the MNR approach vis-à-vis the dynamic programming approach (Van Arendonk, 1985c; Groenendaal et al., 2004). Where dynamic programming models are usually large and complicated, the MNR approach is simple and can be modeled in computer programs that are familiar and easily available to the end users (Groenendaal et al., 2004).

In this study, the MNR approach is applied to broiler breeder farms. Broiler breeder farms produce eggs that are delivered to hatcheries to be hatched to day-old broiler chicks. In general, during the production cycle of a breeder flock, egg production and quality can be varied from day to day and is affected by factors such as age of the breeder flock, feed consumption (quality and quantity), water intake, intensity and duration of light received,

health status, management and environmental factors (Williams and Sharp,1978; Robbins et al., 1988; Joseph et al., 2002; Pereira et al., 2007; Gibson et al., 2008;Yassin et al., 2008 and 2009; Lewis et al., 2010).

Several models focusing on optimal replacement policy for layer farms have been developed and described in the literature (White, 1959; Low and Brookhouse, 1967; McClelland et al., 1989; Smith and Wetzstein, 1992). These models applied the dynamic programming technique considering stochastic and non-stochastic formulations of performance and price variables. Generally, those models considered infinite time horizons and deal with the decision to rejuvenate (forced molting) or replace a flock with new pullets.

Replacement models for broiler breeder farms are lacking. Hence, the goal of this study is to develop an on-farm decision support tool for replacement decisions at operational and tactical level at broiler breeder farms. The model is based on the MNR approach where flocks are held for fine time horizon of a period of one year and where the farmer's objective is maximizing the annual gross margin.

6.2 The broiler breeder flock replacement model

The breeder flock replacement model is developed in the following order. First, mathematical models are developed to predict egg production and fertility or hatchability of eggs. Second, an economic performance model is developed to calculate the gross margin from a breeder flock. Finally, a model that optimizes the gross margin from a flock is developed to support the replacement decision at the breeder farms. Figure 6.1 shows a schematic representation of the model items. The broiler breeder flock replacement model supports questions concerning: (1) the optimal length of the laying cycle of a replaceable flock and thus (2) the optimal housing date of the replacement flock. The model calculates the weekly gross margin of a breeder flock based on the egg production and egg fertility or hatchability. The model allows the user to adjust input parameters easily to farm-specific production and economic conditions. Fixed price is assumed in the model, i.e. the breeder farm knows beforehand the price of his product.
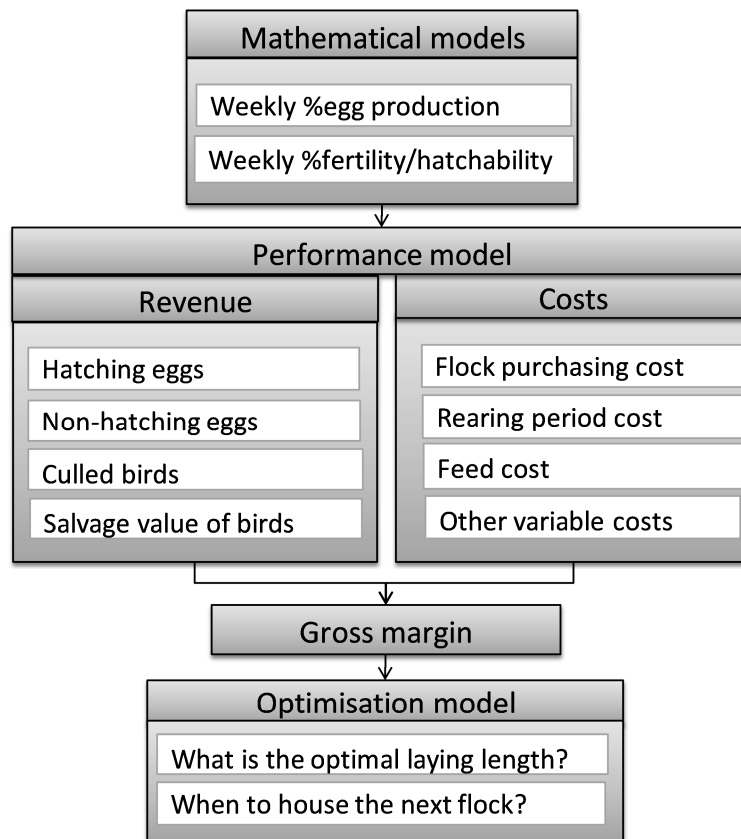
Figure 6.1. Schematic representation of the model elements

It is assumed that 20wks old parent breeders are bought from a rearing farm and that the flock starts laying eggs at the age of 23 up to a maximum of 68wks. Furthermore, it is assumed that the cleaning period at the breeder farm lasts 3wks before the next flock is housed. The replacement decision should be made at the end of 33wks assuming the minimal replacement age is when the hens reach end of 55wks. This is because, it takes at least 25wks to produce a replacement flock as the processing of the order at the rearing organization may take 2wks, the hatching process of day-old chicks takes 3wks (or 21d) and the rearing time takes 20wks (Figure 6.2).
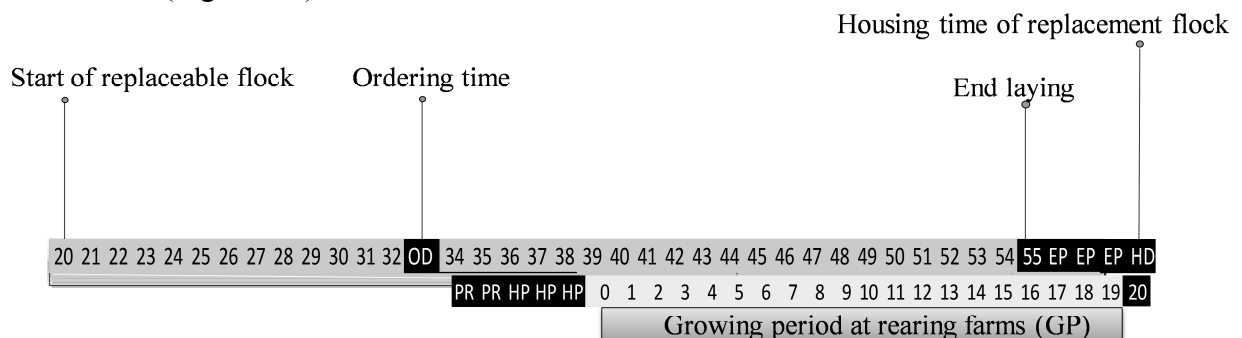
*PR is planing period at rearing farms, HP is hatching period, EP is cleaning period at breeder farms

Figure 6.2. Graphical illustration of the production cycle, where a breeder flock would be replaced at the age of 55wks.

6.2.1   Determination of the optimal length of the laying cycle of a replaceable flock
Because of the declining pattern of the flock's performance with age, the principal question in the replacement process is to find the economic optimal laying age by comparing the gross margin gained from every additional week during the production cycle of a replaceable flock against that of an average flock (Faris, 1960; Renkema and Stelwagen, 1979; Dijkhuizen et al., 1985; Groenendaal et al., 2004). The decision to replace a flock can be made for tactical as well as operational management. For tactical decisions, it is assumed that the replaceable flock performances according to a standard and thus the flock will be replaced according to the standard laying length on this farm. For operational decision making, one should consider the real performance of the replaceable flock and changing market prices.

The replacement decision
The economic decision criteria for replacing a flock is that a flock should be replaced if the marginal gross margin (MGM_i) is lower than the average gross margin of an average flock (AGM_{ri}) (Faris, 1960; Renkema and Stelwagen, 1979; Dijkhuizen et al., 1985; Giesen et al., 1988; Groenendaal et al., 2004). The marginal gross margin is the gross margin from one additional week. The average gross margin is the sum of gross margin in the productive weeks divided by the number of productive weeks.

According to the law of diminishing returns MGM_i is greater than AGM_i during the early stages of production. When the MGM_i is above the AGM_i, AGM_i will continue to increase. When MGM_i is below AGM_i however, the AGM_i will decrease. For breeder flocks, in the beginning of the laying period, the number and quality of eggs produced is small but it increases each week till the peak egg production is reached. After the peak egg production, the weekly production decreases and so does the marginal gross margin. Figure 6.3 gives a graphical illustration of the optimal replacement decision of a breeder flock.
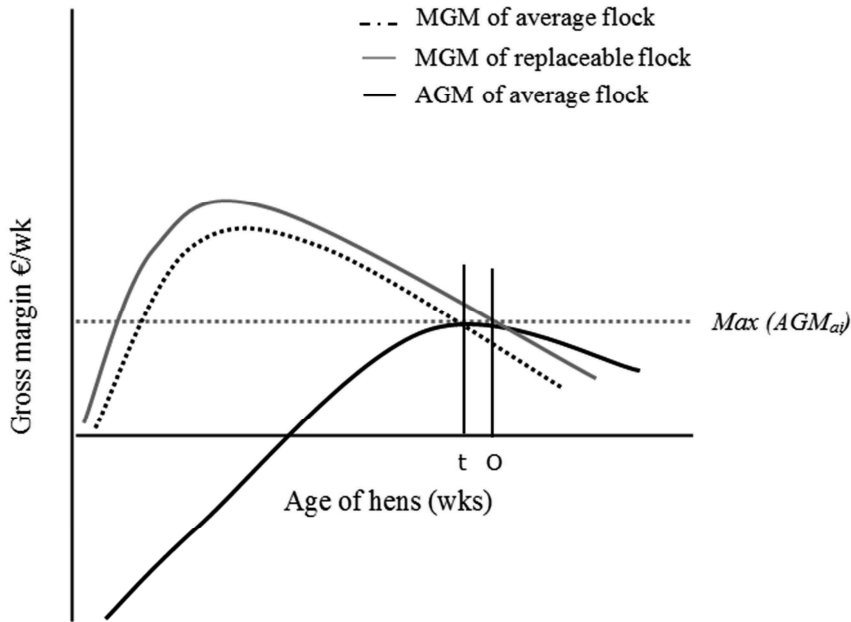
Figure 6.3. Graphical illustration of the economic optimal flock replacement moment at tactical (t) and operational level (o).

The average gross margin (AGM_i) per week equals the cumulative gross margin (TGM_i) earned till a particular production age (i) divided by the length of the production cycle, which includes the periods when there is egg production (FP) and without egg production (NP):

$$AGM_i = TGM_i / (NP + FP) \tag{1}$$

$$NP = (RP) + (EP) \text{ and } FP = i - 22 , \tag{2}$$

Where (RP) is the rearing period at the breeder farm in weeks and (EP) is the cleaning period at the end of the flock's life in weeks, (i) is the age at production and 22wks is the number of weeks before the hens start laying eggs.

For any flock, the cumulative gross margin (TGM_i) at age 'i' is the value from the cumulative weekly egg production (RE_i) and birds ($RCSV_i$) minus the purchase price of the flock (PP_f), the rearing cost of the flock (RC_f), the cumulative weekly feed costs (FC_i) and other variable costs (VC_i):

$$TGM_i = RE_i + RCSV_i - \left(PP_f + RC_f + FC_i + VC_i\right) \tag{3}$$
$$MGM_i = \Delta TGM_i \tag{4}$$

The purchasing price per bird, feed and egg prices are farm specific.

Based on the above mentioned principle, tactical as well as operational decisions can be made. For tactical decisions, when no change is expected in performance of different flocks, the moment of optimal replacement is the age when (AGM_{ai}) of the average flock is highest:

$$RD_i = \max_{i=23}^{N} (AGM_{ai}), \qquad (5)$$

Where RD_i is the replacement age in weeks and $i = 23,...,N$

When the performance of the current flock is expected to be different from the average flock, i.e. the operational decision, the optimal replacement age could be earlier or later than that of a tactical decision. In this case, a flock of a particular age should be replaced when the marginal gross margin of a replaceable flock (MGM_{ri}) is less than the average gross margin of the replacement or average flock (AGM_{ai}). So, as long as $MGM_{ri} \geq AGM_{ai}$ the flock should be kept.

If the economic optimal replacement moment of a replaceable flock is determined, it is possible to determine the ordering date (OD) and housing date (HD) of the replacement flock (Figure 6.2). For this, the breeder farmer should consider the age of the flock at the economic optimal replacement moment (RD_i), the cleaning period (EP), the time needed for planning at the rearing farm (PR), the time needed for hatching (HP), and the time needed for growing of the new replacement flock (GP).:

$$OD = RD_i + EP - (PR + HP + GP) \qquad (6)$$
$$HD = RD_i + EP \qquad (7)$$

6.3 Prediction models for egg production and fertility/hatchability

Two simple models are developed to predict egg production and egg fertility or hatchability of the replaceable breeder flock for operational decision making 25wks in advance. The predicted egg laying percentage (EL_{pi}), fertility (FF_i) or hatchability (FH_i) of eggs of the replaceable flock at age "i" are used in the performance model to calculate weekly gross margin.

6.3.1 Prediction model for egg production:

This model predicts the weekly egg production of a replaceable flock between the age of 34 and 68wks. The model uses weekly egg production data of the replaceable flock till the age of 33wks (Figure 6.2). To predict weekly egg production, a descending slope is estimated using data of flocks of the previous two years at the same breeder farm. The weekly %egg production is predicted using the following model:

$$Y_i = a + b(x_p - x_i), \qquad (8)$$

Where Y_t is weekly egg production, a the peak egg production of the replaceable flock, b the descending slope after the peak egg production, x_p the age at peak egg production of the replaceable flock and x_i age of the replaceable flock at week i.

6.3.2 Prediction model for fertility/hatchability:

This model predicts the fertility or hatchability of a replaceable flock between 31 and 68wks. In contrast to the prediction of egg production, this prediction is not based on data of the replaceable flock. This is because only six weeks (25-30wks) of fertility/hatchability data are

available at the moment of decision to replace a flock, which should be made at week 33. This number of data is too small to make an accurate prediction. Therefore, fertility/hatchability of a replaceable flock is assumed to be equal to the average fertility/hatchability of the previous two years at the same farm.

6.4 The performance model

The performance model calculates the weekly gross margin and includes costs such as purchasing cost of birds, weekly costs for feed, other variable costs, and revenues, such as the revenues from the weekly egg production, culled birds and the salvage value of birds.

If TR_i is the weekly cumulative revenue at age 'i' and TVC_i is the weekly cumulative variable cost at age 'i', then the net earning function i.e. the cumulative gross margin at age 'i' (TGM_i) is expressed as:

$$TGM_i = TR_i - TVC_i \tag{9}$$

The cumulative revenue at age 'i' TR_i is earned from sale of eggs (RE_i) and birds ($RCSV_i$) at age 'i'. Revenue from eggs (RE_i) is derived from hatching (HE_i) and non-hatching (NHE_i) eggs. Revenue from birds ($RCSV_i$) is derived from culled birds (CB_i) and sale of birds at the end of the laying period (i.e. the salvage value of birds (SV_i) (Figure 6.1). Therefore the weekly cumulative revenue can be expressed as:

$$TR_i = HE_i \cdot P_{ei} + NHE_i \cdot P_{nei} + CB_i \cdot P_{cbi} + NB_i \cdot SP \tag{10}$$

Where P_{ei}, P_{nei} and P_{cbi} and SP are the prices of hatching egg, non-hatching egg, culled birds and salvage price of birds respectively.

Hatching eggs at age 'i' (HE_i) is calculated from total eggs (TE_i) and the percentage of hatching egg at the age 'i' (HE_{pi}).

$$HE_i = TE_i \cdot HE_{pi} \tag{11}$$

Total eggs at age 'i' (TE_i) is calculated from laying percentage (EL_{pi}) and the number of hens at age 'i' (NH_i).

$$TE_i = NH_i \cdot EL_{pi} \tag{12}$$

The number of hens at age 'i' (NH_i) is calculated from the number of hens at the end of previous week NH_{i-1} and percentage hen mortality rate at age 'i' (MH_i).

$$NH_i = NH_{i-1} \cdot MH_i \tag{13}$$

Breeder farms can have five types of pricing systems for hatching eggs depending on the contract signed with the hatcheries. These are a payment based on:

- Hatching eggs delivered without price correction for fertile or hatched eggs (payment system A);
- Hatching eggs delivered with a price correction for the percentage of fertile eggs during the production cycle (payment system B);
- Hatching eggs delivered with a price correction for the percentage of hatched eggs during the production cycle (payment system C);
- The number of fertile eggs during screening (payment system D) and,
- The number of hatched eggs to good quality chicks (payment system E).

Note that here fertile eggs are eggs which are fit for hatching after a screening (i.e. candling) at the 18th date of the incubation process.

To adjust the price of hatching eggs, target percentage fertility (TF) or hatchability (TH) and the price for extra fertile or hatched egg (PCV) are given on the contract (NOP, 2011).

Accordingly the three possibilities of payment for hatching eggs are:

I. $PHE_i = CHE_i \cdot P_{ei}$ when there is no price correction or (14)

$PHE_i = CHE_i \cdot (P_{ei} + PC_i)$ if there is price correction

II. $PFE_i = CFE_i \cdot P_{ei}$; or (15)

III. $PHDE_i = CHDE_i \cdot P_{ei}$ (16)

Where PHE_i is payment based on hatching egg, CHE_i weekly cumulative number of hatching eggs, PFE_i is payment based on fertile eggs, CFE_i weekly cumulative number of fertile eggs, $PHDE_i$ is payment based on hatched eggs, $CHDE_i$ weekly cumulative number hatched eggs, PC_i price correction per extra fertile or hatched egg, and P_{ei} is contract price per hatching egg.

The weekly price correction per extra fertile or hatched egg (PC_i) is calculated as follows:

$PC_i = (FF_i - TF) \cdot PCV$ or (17)

$PC_i = (FH_i - TH) \cdot PCV$

The weekly salvage value of a flock (SV_i) is calculated from the number of hens (NH_{i-1}) and males (NM_{i-1}) at the end of each week, mortality rate of hens (MH_i) and males (MM_i), the average body weight of hens (WTH) and males (WTM) and the salvage price per bird (SP).

$RSV_i = (NH_{i-1} \cdot MH_i \cdot WTH + NM_{i-1} \cdot MM_i \cdot WTM) \cdot SP$ (18)

The weekly cumulative variable cost at age 'i' (TVC_i) is calculated from feed cost (FC_i) and other variable costs (VC_i) at age 'i'. Additionally, the costs made during the rearing period (RC_f) and the purchasing price of the flock (PP_f) are included weekly.

$TVC_i = PP_f + RC_f + FC_i + VC_i$ (19)

6.5 Demonstration of the model

Data from a Dutch broiler breeder farm are used to demonstrate the model described in the previous section. The breeder farmer buys 19,609 female and 1,400 male Ross308 parent breeders. The mortality rate for hens and males till 22wk is 0.03% and 0.4% respectively. Therefore, at the end of 22wk the farm has 19,602 hens and 1,393 male parent breeders. The breeder farmer has a contract with a hatchery with regard to the payment of hatching eggs. The payment for hatching eggs is based on hatching eggs delivered with a price correction for the percentage of fertile eggs (payment system B). To gain insight into the base scenario situation used in the model, important production and price parameters are presented in Table 6.1 and the weekly performance of the average flock in Table 6.2.

Table 6.1. Parameter values used in the base scenario

Variable	Unit	Value
Duration of rearing period	Days	15
Duration of cleaning period	Days	21
Expected hen mortality during LP[*]	%	8%
Expected male mortality during LP	%	35%
Expected average body weight of hens during LP	Kg	4
Expected average body weight of males during LP	Kg	5
Purchasing and rearing cost till wk 22	€/HH*	10.60
Other variable costs	€/HH/wk	0.035
Expected price of feed (23-30wk)	€/100kg	30.75
Expected price of feed (31-68wk)	€/100kg	28.60
Contract price of hatching eggs	€/100eggs	20.62
Contract price of fertile eggs	€/100eggs	23.57
Target fertility	%	83%
Price correction per extra hatched egg	€/egg	0.001
Expected price of non-hatching eggs	€/egg	0.01
Expected price of replacement males	€/male	7.10
Expected price of culled birds	€/HH	0.05
Slaughter price of birds	€/kg	0.42

*HH is the number of hens housed at the beginning of the laying period and LP is laying period

Table 6.2. Weekly performance of the average flock

Age (wks)	%hens	%males	%eggs	#eggs/ hen/wk	%hatching eggs	%fertility Per wk	%fertility Average until wk	Price (€/egg) hatching egg	Price (€/egg) Fertile egg
55*	100.0%	100.0%	100.0%	3.88	95%	72.8%	86.3%	20.62	23.57
56	99.8%	98.9%	96.5%	3.75	95%	71.7%	86.0%	20.62	23.57
57	99.6%	97.8%	92.5%	3.61	95%	71.3%	85.7%	20.62	23.57
58	99.4%	96.7%	91.4%	3.57	95%	70.4%	85.4%	20.62	23.57
59	99.1%	95.6%	89.4%	3.50	95%	70.0%	85.0%	20.62	23.57
60	98.9%	94.5%	84.2%	3.30	95%	68.2%	84.7%	20.62	23.57
61	98.7%	93.4%	79.3%	3.12	94%	67.8%	84.4%	20.62	23.57
62	98.5%	92.4%	76.9%	3.03	94%	66.9%	84.2%	20.62	23.57
63	98.3%	91.3%	74.1%	2.93	94%	66.0%	83.9%	20.62	23.57
64	98.1%	90.2%	71.4%	2.83	94%	65.2%	83.6%	20.62	23.57
65	97.9%	89.1%	68.7%	2.72	93%	64.3%	83.3%	20.62	23.57
66	97.6%	88.0%	66.0%	2.62	93%	63.5%	83.1%	20.62	23.57
67	97.4%	86.9%	63.3%	2.52	93%	62.6%	82.8%	20.62	23.57
68	97.2%	85.8%	60.6%	2.42	93%	61.7%	82.6%	20.62	23.57

* Numbers of hens, males and eggs at wk 55 are 18308, 1020 and 71070 respectively.

Table 6.2 shows that as the flock ages, the percentage of hens, eggs and the fertility of the eggs reduce. Table 6.3 shows the economic performance of the flock at tactical and operational level. According to the replacement model, a flock of a particular age should be replaced if the *MGM* is less than the *AGM*. Table 6.3 shows that the flock should be replaced at the end of 60wk if the decision is made at tactical as well as operational level. This is because, at 61wk the *MGM* of the average flock and the replaceable flock are less than the *AGM* of the average flock i.e. 4,053< 4,427 and 3,678<4,427 for tactical and operational decisions respectively (Table 6.3).

Table 6.3. Economic performance of the flock at tactical and operational level

Age wk	TGM Cum. Average flock	TGM Cum. Replaceable flock	MGM €/wk Average flock	AGM €/wk Average flock	MGM €/wk Replaceable flock
55	165998	147056	7137	4241	6244
56	172701	152961	6703	4302	5904
57	178858	158490	6156	4347	5529
58	184906	163680	6049	4388	5190
59	190733	168535	5827	4421	4855
60	195844	173018	5111	4437	4483
61	200216	177061	4372	4435	4043
62	204269	180738	4053	4427	3678
63	207993	184090	3725	4412	3352
64	211390	187115	3397	4391	3025
65	214330	189690	2940	4361	2574
66	216948	191945	2618	4327	2255
67	219212	193847	2264	4286	1903
68	221158	195433	1946	4241	1586

6.5.1 Sensitivity analysis

Before using the model on individual farms, it is helpful to know which parameters have an effect on the replacement decision. To determine this, a number of parameters were varied individually. Table 6.4 shows results of a sensitivity analysis of model results of the tactical and operational decisions. The sensitivity analysis was done with two payment systems for hatching eggs to demonstrate the effect of fertility of the eggs on the replacement decision. Payment system B is based on the total number of hatching eggs delivered to the hatchery with price correction related to extra percentage fertility compared to the target fertility given in table 6.1.. Payment system D is based on the number of fertile eggs that are fit for hatching after screening/candling at the 18th date of the incubation process.

At tactical level, the sensitivity analysis showed that there is no effect of peak egg production and fertility on the replacement decision (Table 6.4). The decrease in weekly fertility after the peak (here called fertility curve), has no effect on the replacement decision with payment system B. This is because there is no big difference between the average fertility of the eggs of the average flock given in Table 6.2 and the target fertility given in Table 6.1. As a result, the price correction is too small to show a visible effect on the revenue. The decrease in weekly fertility after the peak however, has effect on the replacement decision with payment system D, a 10% decrease in weekly fertility shortens the replacement

age with one week (Table 6.2). The decrease in the weekly egg production after the peak (egg production curve) has effect on the replacement decision with both pricing systems. Lower feed price affects the replacement decision with payment system B but not D. This might be because payment system B is more advantageous than D and lower feed price prolonged the replacement age. Furthermore, price of the eggs has effect on the replacement decision. Lower price of hatching eggs prolonged the replacement decision in both payment systems. Low egg price means less revenue from eggs thus lower gross margin. However, the weekly change in gross margin i.e. *MGM* affects the replacement decision which should be less than the *AGM* at the moment of decision.

At operational level, similar to the tactical level, there is no effect of peak egg production and fertility on the replacement decision with both payment systems (Table 6.4). Also decrease in weekly fertility after the peak has no effect on replacement decision with payment system B but with payment system D similar to the tactical decision. The decrease in weekly egg production after the peak affects the replacement decision with both payment systems. Both feed and egg prices also affect the replacement decision.

Parameters which affect the replacement decision has a greater effect on operational decision compared to the tactical decision. For example a 10% decrease in weekly egg production with payment system B shortens the replacement age with one week at tactical level and eight weeks at operational level i.e. 60wk to 59wk and 60wk to 52wk respectively for tactical and operational decisions (Table 6.4). This is because, for tactical decisions, a change in the weekly egg production egg production affects both *MGM* and *AGM* of the average flock. However, for operational decisions, change in the weekly egg production egg production affects only the *MGM* of the replaceable flock because the *AGM* of the average flock is fixed (Figure 6.3).

Table 6.4. Sensitivity analysis

Variables	Change	Tactical level Replacement age (wks)[a] Payment systems		Operational level Replacement age (wks) Payment systems	
		B[b]	D[c]	B	D
Peak fertility[d]	±%[e]	60	56	60	55
Peak egg production[f]	±%	60	56	60	55
Fertility curve[g]					
	+1%	60	56	60	55
	+5%	60	56	60	56
	+10%	60	56	60	58
	-1%	60	56	60	54
	-5%	60	56	60	54
	-10%	60	55	60	51
Egg production curve[h]					
	+1%	61	56	60	55
	+5%	61	56	63	57
	+10%	62	57	67	59
	-1%	60	56	59	54
	-5%	60	56	56	54
	-10%	59	55	52	50
Feed price €/100kg (31-68wk)					
	23.0	61	56	63	57
	33.0	60	56	57	54
Egg price €/100eggs for					
payment system B	16.0	63		52	
	24.0	60		64	
payment system D	19.0		59		50
	27.0		55		58

[a] The flock should be replaced at the end of the week

[b] Payment system B is based on hatching egg with price correction related to extra fertile eggs

[c] Payment system D is based on fertility of the eggs

[d] ±% is increase or decrease in any percentage

[e] Baseline peak fertility for the tactical and operational level is 92%

[f] Baseline peak egg production for the tactical and operational level are 87% and 88% respectively

[g] Fertility curve is the curve will decrease in weekly fertility after the peak

[h] Egg production curve is the curve will decrease in weekly egg production after the peak

6.6 Discussion

The optimal laying length or optimal replacement moment of a flock is related to the profit (gross margin) made during a production cycle. One of the major variables influencing profitability of raising broiler breeder flocks is the total number of good quality eggs produced. Total number of eggs produced during the production cycle of a flock is determined by the egg production curve, which has certain phases in relation to the age of the hens. These are: the starting phase or egg production at the onset of sexual maturity, the increasing phase to a maximum or peak egg production and the decreasing phase (Adams and Bell, 1980;

Lokhorst,1996; Grossman and Koops, 2001). In other words, the total number of eggs produced by a flock depends on the age at sexual maturity, level of egg production at sexual maturity, age at peak production, level and persistency of peak egg production and the declining rate of egg production. Differences in management practices at broiler breeder farms can affect the curve of egg production curve. For example, differences in the lighting and feed restriction programs affect body weight uniformity or flock uniformity (Gous et al., 2000; Leeson et al., 2005). The level of flock uniformity in turn affects the degree of sexual maturity and level of peak egg production. Flocks with high uniformity mature sexually earlier, reach peak egg production earlier, and have higher and persistent peaks than those of low uniformity (North, 1980).

The number of hatching eggs produced during flock's production cycle is the other main output variable of economic importance at broiler breeder farms. Hatchability is the percentage of the total number of hatching eggs set that result in good quality chicks (first grade day-old chicks) to be sold to the broiler farms. Hatchability is related to the fertility of the eggs. Fertility is the percentage of eggs laid that are fertilized and contain an embryo. The number of eggs that are culled by candling "% not fertile" is strongly related to the number of day-old chicks hatched at the end of the incubation. Numerous factors influence fertility and hatchability, but in flocks of similar genotype under standard management practices the major determinant factor is the age of the hens (Krik et al., 1980). Significant differences were found in hatchability among and within breeder flocks in relation to the age of the hens (Tona et al., 2007; Yassin et al., 2008).

In addition, the earned profit from a flock is affected by the costs made during the production period. In this study, only the costs which can be influenced by farmers' management (variable costs) are considered. Of all the production costs, cost of feed resource is the most important one as it accounts for a great part of the costs in commercial poultry farms (LEI, 2011). Furthermore, mortality and weight of the birds are important factors to be taken in to account when a flock is evaluated for replacement.

In this study, models that predict egg production and egg fertility of the replaceable flock are developed. The fact that the replacement decision should be made 25wks in advance, results in too limited data points of the replaceable flock to make predictions. Therefore, the descending slope of egg production is predicted from egg production data of the previous two years at the same breeder farm. Fertility/hatchability of the sample flock is the average fertility/hatchability of eggs of the previous two years at the same breeder farm. Though it is known that flocks differ in peak egg production, peak fertility/hatchability, ascending and descending slopes (North, 1980; Lokhorst,1996; Tona et al., 2007; Yassin et al., 2008), the sensitivity analysis of this study showed that the replacement decision is not sensitive to changes in peak egg production and peak fertility (Table 6.4). However, the replacement decision was sensitive to changes in the weekly egg production and fertility after the peak depending on the payment system (Table 6.4). For the operational level, slope of egg production is predicted from egg production data of the previous years and fertility is the average fertility of data of previous years at the same breeder farm. Hence, the breeder replacement decision can preferably made at tactical level rather than operational level unless flock-specific models are developed to predict the descending slopes of egg production and fertility. For the tactical decision, rather than using other standards such as a norm of the

genetic strain, it is advisable to use the average of performance data of previous years at the same farm as the difference in performance is bigger for flocks kept at different breeder farms than those kept at the same breeder farm (Yassin et al., 2008).

The timing of the replacement decision in the replacement model should be at the end of 33 wk of hens age, which is a disadvantage for the breeder farms and hatcheries. This timing is based on the current Dutch broiler-chain structure where the breeder farmer should order a new flock at the rearing organizations before the parent stock chicks are produced. Flexibility in the system, (e.g. If a breeder farm doesn't have beforehand information on which parent stock chicks he will receive for the following period), might improve the overall chain production. However, for this to happen, chain coordination is needed, which is hard to achieve with a lot of independent businesses in the chain.

6.7 Conclusion

A flock replacement model was developed to determine the optimal laying length of a breeder flock at tactical as well as operational level. The optimal laying length was substantially affected by the weekly decrease of egg production after the and the prices of hatching eggs and feed. The weekly decrease in fertility after the peak affects the replacement decision if the payment of hatching eggs is based on the fertility of the eggs delivered to the hatchery. The optimization model developed is simple and can be modeled in computer programs that are familiar to breeder farmers. Apart from breeder farms, results from the model can be used by the hatcheries and rearing farms to plan production. The model saves unnecessary costs at breeder farms and hatcheries. If the replacement decision is made at the optimal moment in the production cycle, profitability at all levels of the supply chain might be improved due to lower cost, higher production and more efficient planning. For the model to be used at operational level, further research is needed to make accurate predictions of egg production, fertility and prices.

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General Discussion

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7.1 Introduction

The overall objective of this thesis was to develop a management information system (MIS) based on available data in the broiler supply chain to support broiler breeder farm management. Breeder farms deliver hatching eggs which are the origins of the broilers to be delivered at slaughterhouses. Based on this, it is assumed that if the performance at breeder farms is improved, the quality of the hatching eggs is improved and therefore the performance of the businesses at the subsequent levels of the chain will improve. First, the question whether management factors at breeder farms are related to performance indicators at the subsequent levels of the broiler supply chain is answered. For this, field data were analysed to explore management factors that are related to hatchability in chapter 2 and first week chick mortality at the broiler farms in chapter 3. Second, the availability and quality of data in the chain were assessed in chapter 4. Next, a data collection protocol aiming to improve the quality of data in the chain was proposed and validated, also in chapter 4. Third, two models were developed to support the tactical as well as operational management at breeder farms. The first model is a management information system (called IFAS) aiming to support tactical management at the breeder farms (Chapter 5). The second model is a broiler breeder flock replacement model which supports replacement decisions based on an economic optimal performance (Chapter 6).

This thesis shows that management factors at the breeder farms are related to the performance indicators at hatcheries and broiler farms. Hatchability and first week mortality of chicks were used as performance indicators as these are related to the performance of the breeder farms, hatcheries and broiler farms. Hatchability and first week mortality are significantly related with breeder flock age, egg storage length, strain, feed company of the breeder farm, season, year, as well as hatchery (chapter 2 and 3). Consequently, it can be concluded that improving management at the breeder farms improves not only performance at the breeder farms but also at the subsequent level of the supply chain. In this context, exchange of production and technical information and thus collection of relevant data is crucial in the broiler supply chain. Hatcheries play a central role in collecting data from the breeder farms as well as the broiler farms. Data collection practices implemented by a firm, like a hatchery or a breeder farm, determine data quality, how data are interpreted and thus the quality of information used for decision making (Ballou and Tayi, 1999). A data quality analysis of three Dutch hatcheries showed that the data sets had different contents. The data sets were incomplete and were lacking information about the management of the breeders, eggs and chicks. Moreover, there was a difference in data collection systems at hatcheries and farms whereby the information recorded varied (Chapter 4). A uniform data set containing all relevant variables and complete information may provide opportunities to improve the current data collection system. For this reason a protocol was developed to standardise data sets in the broiler supply chain (Chapter 4).

When data are available, they can be analysed and transformed into information to support management decisions. Production and financial data that are collected by breeder farms are used to develop a management information system called IFAS (Chapter 5). IFAS supports tactical decisions at the breeder farms by identifying the strong and weak management practices during a flock's production life. Additionally, production and financial data from breeder farms and hatcheries are used to develop a breeder flock replacement

model. This model enables to replace a breeder flock at an economic optimal moment, from a tactical and from an operational perspective. Furthermore, the model can be used to plan the hatching, rearing and housing of a replacement flock.

The applied methods and results of the abovementioned subjects are discussed in each of the corresponding chapters. In this chapter, implications and strengths and weaknesses of the current study are discussed in detail. Finally, the main conclusions of the research are presented.

7.2 Scientific implications of the current study

This thesis presented one of the first studies on hatchability and first week mortality using field data. In addition, two management tools that support the tactical and operational decisions at breeder farms are presented. Three steps were followed to reach to the final goal of the thesis.

In the first step of this research (Chapter 2 and 3) the aim was to test whether data that are available in the field can be used as input variables in a management information system. Data from three commercial Dutch hatcheries were analyzed to explore the impact of management factors on breeder farms, on hatchability and on first week mortality. Results showed that, flock age is an important management variable that needs continuous attention in management decisions at breeder farms, hatcheries and broiler farms.

In most experimental studies, though eggs are produced by flocks of different ages, they are stored and incubated under uniform conditions (Lapa et al., 1999; Elibol et al., 2002; Tona et al., 2004). However, eggs produced by flocks of different ages have different egg characteristics which is a major determinant factor of incubation conditions and thus hatchability and day-old chick quality (Decuypere et al, 2001; Christensen et al., 2005). First, eggs produced by flocks of different ages differ in egg size. Eggs laid by young hens have smaller eggs than those laid by older hens (Wilson, 1991). Egg size is related to heating and cooling requirements of the hatching eggs during incubation (Deeming, 1996). Second, eggs produced by flocks of different ages differ in eggshell structure, i.e. eggs laid by young hens have thicker eggshell with smaller pore numbers than those laid by older hens (Peebles et al., 2000). Eggshell and membrane structure are proved to affect egg weight loss/moisture loss during incubation (Christensen et al., 2005). Eggs with poor shell quality have a higher percentage of egg weight loss (Reis et al., 1997) and low hatchability (Narushin and Romanov, 2002). Third, eggs produced by flocks of different ages differ in internal content of the egg. Eggs laid by young hens have higher albumen and lower yolk content than those laid by older hens (Vieira and Moran, 1998a). The yolk content, specifically the lipids contained in it, is the main source of energy for embryonic development during incubation and during the first few days post hatch (Noy and Sklan, 1999). Also, a positive correlation has been reported between the nutrient content of the yolk sac and the subsequent performance of broilers (Vieira and Moran, 1999). All the above mentioned facts imply that to achieve optimum hatchability and chick quality, the optimum incubation conditions like temperature, humidity and ventilation should be adjusted in accordance with the characteristics of the hatching eggs. Moreover, chicks from eggs of different age classes of breeders should be reared under different nutritional and environmental conditions to optimize chick post-hatch performances at the broiler farms. Identifying ideal incubation/hatching conditions for eggs of

different age classes of breeders and ideal rearing conditions for chicks from eggs of different age classes of breeders at the broiler farms is a challenge for future research. Moreover, study of economic advantages of screening of eggs from different age classes of breeders during incubation can be of interest in future research as results of such research might give an indications to the ways of production at hatcheries, broiler farms and at the producers of hatchery machineries.

Results in this thesis (Chapter 2) also showed that prolonged storage affects hatchability negatively, in line with the findings of many experimental studies (Reis et al., 1997; Lapa et al., 1999; Elibol et al., 2002; Tona et al., 2004; Samli et al., 2005). The decrease in hatchability due to prolonged storage differed for different age classes, and the effect was bigger among the young breeders. Eggs from younger breeders were more sensitive to prolonged storage than eggs from older breeders which is contrasting with the findings of experimental researches (Reis et al., 1997; Samli et al., 2005). This means that different storage management is required for eggs from different age classes of breeders. Identification of the ideal storage conditions for eggs of different age classes of breeders is therefore an important topic for future research.

Furthermore, in chapter 3 results are presented on first week mortality using field data. In the literature, mortality of broilers is calculated in different ways. In most cases mortality is confounded with culling and hence different criteria for culling influence the levels of mortality. Mortality figures from experimental work are accurate, but the limited number of birds depress the reliability of data. In contrast to the mortality rate given in the literature and/or experimental studies, the (first week) mortality in this thesis is calculated as a ratio of the number of dead birds during the first week and the number of birds delivered at the broiler farm. This mortality rate is an important indicator in the field and used in the EU regulation to determine the stocking density of future flocks at the broiler farms (European Union, 2007).

Finally, results highlighted the inter-dependence between the supply chain partners (Chapter 2 and 3). The interdependence among the chain partners in the broiler chain suggests an opportunity for improving performance by supply chain coordination. Supply chain coordination is a strategic response to the challenges that arise from interdependencies among supply chain members (Xu and Beamon, 2006). As firms in the broiler supply chain should in many cases work together, an integration of firm's management or part of firm's management into that of chain's is important. This can be facilitated through the use of an integrated management information system. An integrated management information system has been proven to enhances supply chain performance through improved chain coordination and thus management (Holland, 1995; Humphreys et al., 2001; Xu and Beamon, 2006; Wang and Wei, 2007). The results presented in this thesis can be used to develop an integrated management information system that coordinates management activities of different level of the chain so that performance at all level of the supply chain can be improved.

In the second step of this research (Chapter 4), the aim was to analyse the suitability of field data for use in a management information system. The quality of field data was analyzed and a protocol was developed to improve and standardize datasets in the broiler supply chain. At any organisation, when information is collected, a thorough understanding of the nature of the information needs and the particular application for which the information will be used is required (Davis and Olson, 1985). In this thesis, the critical success factors (CSFs) approach

was used to identify information requirement in the broiler supply chain. CSFs are those factors which determine the success for an organization. These are the areas of activity that should receive constant attention from management. The idea of the CSFs approach is that in any organization, certain factors are critical to the success of that organization and if objectives associated with the factors are not achieved the organization will fail (Rockart, 1979). The CSFs approach is an appropriate tool for identifying the information intensive areas and thereby information needs of organizations within a supply chain (Huotari and Wilson, 2001). It is also indicated that ensuring the attainment of an organization's goals necessitates good performance in CSFs and it is therefore imperative that management receive constant feedback regarding them (Rockart, 1979). Hence, if goals are to be achieved, decision makers should rely their decisions on information related to the CSFs of an organisation. In addition, to the CSFs, identification of the indices and indicators that are related to the CSF's enables the creation of relevant and complete data set at an organization (Goodger et al.,1984). Indices summarize the management activities or mechanisms which should be fulfilled to reach to the CSF's of an organization. Whereas, indicators are concrete management objectives or management decisions that have to be defined or made daily to reach to the main objective. The steps mentioned in the protocol in chapter 4 can be regarded as a general procedure for data collection in other food supply chains and to prepare questionnaires for collecting data.

In the third step of this research (Chapters 5 and 6), two management tools were developed for breeder farms, using data available in the field. In the first management tool called IFAS, the gross margin earned from a flock at a breeder farm is compared with the gross margin earned from an average flock which is raised during the same time period. Next, a simulation model is used to identify the factors that are responsible for the deviation in gross margin. The simulation model distinguishes deviation that can be explained by available information on farm-specific factors from deviation that cannot be explained. The factors that are responsible for the deviation are ranked according to their statistical and economic importance enabling the farmer to identify the strong and weak management practices during the flocks life time (Huirne et al., 1992). The approach used in IFAS can be applied to broiler farms and can also be applied to farms in other food supply chains. Moreover, expanding the simulation model developed in IFAS by incorporating extended information required to analyse the performance of a flock could be of interest for future research. The second management tool is an economic optimal flock replacement model that uses the gross margin earned from a flock to make an economic optimal replacement decision. The Marginal Net Revenue approach is known for its simplicity so that it can be modelled in a software that is familiar to farmers (Groenendaal et al., 2004). The replacement model developed in this thesis can be easily extended to economic optimal broiler flock replacement decisions. In addition, future research is recommended to develop flock-specific performance prediction models so that decision at the operational level will be more accurate.

7.3 Business implications of the current study

As results of this thesis are based on field data, they are more reliable to be used at firms in the broiler supply chain compared to results from experimental studies.

Results in chapter 2 and 3 have demonstrated that young breeder flocks produce eggs with low hatching potential and low chicks quality, as judged by first weak mortality. Hatching time of eggs of young breeders is reported to be long compared to eggs of older breeders (Suarez et al., 1997). The combination of the effect of small egg size (Wilson, 1991, Suarez et al., 1997), lower proportion of yolk content (Vieira and Moran, 1998a), and longer hatching time results in weak chicks from young breeders than old breeders. In addition, prolonged storage of eggs from young breeders decreases hatchability while increasing first week mortality at the broiler farms compared to eggs from old breeders. Besides, the effect of egg storage length is significantly different at different hatcheries. Egg storage length, incubation protocols (including incubation climate parameters), storage conditions at the hatcheries and pre-storage egg handling at the breeder farms and during transportation can contribute to the differences in hatchability between farms. Moreover, hatchability and first week mortality are significantly different among the strains of the breeders. All above mentioned results suggest that for an optimum output, at the breeder farms, hatcheries as well as broiler farms, the hatcheries should store and hatch eggs from different age classes and strains of breeders separately. The problem of mixing eggs of extreme age classes and strains during storage, hatching and rearing at the broiler farms can be minimized by effective planning at hatcheries and good chain coordination. Although there is no evidence yet as to its practicality and economic advantage, the hatcheries should try to plan in a manner that they hatch eggs from more similar age categories of breeders at the same time. Using smaller storage rooms, hatchers and incubators can also minimize the problem of mixing eggs of extreme age classes.

Nowadays, modern broiler production is under increasing pressure from global competition and from retailers who expect to offer their customers a safe and welfare-friendly product at low prices. This means that the best broiler performance should be achieved, meeting profit expectations and animal welfare friendly and socially responsible production conditions. Therefore, to be profitable and to stay competitive, firms in the supply chain must broaden their area of analysis and decision making to encompass not only single business units but also whole supply chains (Lee and Whang, 2000). This can be achieved by coordination in the supply chain (Dyer and Singh, 1998). One way of coordination in a supply chain is through information sharing (Lee et al., 1997). Results in chapter 2 and 3 showed that management decisions at the breeder farm affect the performance at the hatchery and broiler farms. This means that, decision makers should not only be concerned with optimizing their own objectives but also that of other partners in the chains. Therefore, for decision making, the hatchery and the broiler farms need relevant information about the flock and the eggs from which the chicks originated. At the same time, the breeder farms need feedback from the hatchery and broiler farms about the performance of their eggs and thus their breeder flocks.

Although results in chapters 2 and 3 have emphasised the importance of sharing of technical and production information in the broiler supply chain, it has to be noted that information sharing meets barriers. One of the most important barriers to sharing information in a supply chain is farmers' attitudes (Cress et al., 2006). Some firms are unwilling to share

sensitive information because of lack of trust. Confidentiality, timeliness and accuracy of the provided information, differing technologies between the supply chain partners or a mismatch in the alignment of incentives are other obstacles for sharing information in a supply chain (Lee and Whang, 2000). Managers in the supply chain must be aware of the barriers to information sharing and thus need to collaborate to overcome the barriers.

In the current structure of the Dutch broiler supply chain, every firm acts independently and little information is shared among the firms in the supply chain. For inter-organisational information sharing to be effective, every firm in the chain should collect relevant and good quality data. Donnelly et al.(2009) suggested that universal standards for name and content of data elements would improve information exchange between buyers, sellers, authorities, consumers and other interested parties. Using the protocol developed in chapter 4 of this thesis, a standardized data set can be developed for the broiler supply chain.

The management tools developed in chapter 5 and 6 also have business implications. First, IFAS (Chapter 5) enables identification of the strong and weak management practices at the breeder farm. A breeder farmer can learn from past experience and adjust his management for the next flock which, as a result can improve not only the performance at the breeder farm, but also at the hatchery and broiler farms. Second, the economic optimal flock replacement model (Chapter 6) enables the breeder farms make a timely decision as to when to replace a flock and when to house the next flock. As a result, a breeder farmer avoids keeping a less productive flock longer on his farm. Consequently, the breeder farmer avoids unnecessary costs and the hatcheries and broiler farms avoid hatching and raising poor quality chicks respectively. As the decision to replace a flock is made ahead of time while a flock is still in production, the model enables effective planning at the rearing farm, hatcheries and breeder farms.

In summary, this thesis demonstrated the importance of collecting and analysing relevant data to support decision making in the broiler supply chain. Collecting and analysing data is important because the development of the broiler supply chain in the future is determined by the increasing consumer demands for more food safety, lower environmental impact, and better animal welfare conditions. In this context, traceability of broiler products is essential. This involves the careful selection of broiler suppliers, with the focus on quality rather than on price. Monitoring flock health status, welfare and environmental impacts related to poultry production can be the key for the safe expansion of future poultry industry. Thus, collecting data and its interpretation to information can enable decisions makers in the broiler chain to identify and solve the problems that need attention, identify appropriate interventions to solve those problems, or know how progress is made towards achieving their goals.

7.4 Strengths and weaknesses of the current study

Management information systems can improve decision making of farmers by integrating information into a more useable form. Despite the potential benefits of management information systems, evidence from the literature indicates that the adoption in the field has been limited (Cox, 1996, Lynch et al., 2000, McCown, 2002). Some of the reasons for limited adoption in the field are: limited computer ownership among producers, lack of field testing, no end user input preceding and during development, model complexity and possibly the need for considerable data input, distrust for the outputs because the end users do not understand the underlying theories of the models, mismatch of the outputs with the decision-making style of the end users (Cox, 1996, Lynch et al., 2000, McCown, 2002). Four options are suggested if decision support systems and related information systems are to be adopted in the field: i)the system should be a 'small' tool for aiding farmers' tactical decisions; ii)the system should be a versatile simulator as a consultant's tool; iii) the system should be a versatile simulator as the core of a facilitated 'learning laboratory', and iv) the system should be a formal framework that supports regulatory objectives in constraining and documenting farming practice (McCown , 2002).

The strength of this thesis is that its objective was motivated from the field and that representatives from the field (hatcheries, breeder farms, broiler farms, feed companies and other experts) were involved throughout the research. Results were presented to end users and discussed in workshops. Feedbacks and suggestions from the workshops were incorporated in the research. IFAS and the flock replacement model are small management tools that can aid breeder farmers for tactical as well as operational decision making. These management tools can easily be adapted at farm level. This is because, both models are developed using simple mathematical methods and are programmed in Excel to avoid complexity related to programming languages. Both management tools are developed using technical end economic inputs that are already in use at breeder farms, consultancy offices and hatcheries. IFAS is developed in combination with an existing farm accounting system, which is already familiar to most of the breeder farmers. Moreover, results derived from both models are easily interpretable by farmers and/or their advisors. IFAS was presented to farmers and advisors during a workshop where they had the opportunity to practice the system and interpret outputs from the system themselves. Results of the workshop showed that IFAS is an easy tool to work with by poultry advisors and that it produces results that are comprehensible. And maybe most importantly, IFAS is already adopted by the collective organization of breeder farms called BRAVO .

However, since this thesis used available field data in the broiler supply chain, particularly of the breeder-hatchery-broiler farms, there are limitations to the results. For example, the hatchery data set used to assess breeder farm management factors related to performance indicators at hatchery and broiler farms that were not collected for scientific research purposes (Chapters 2 and 3). As a result, the data were not complete and it was difficult to test the causality of the relations. For example, chapters 2 and 3 showed that in addition to the age and strain of the breeder flocks, the variable breeder farm'' has a significant effect on hatchability and first week mortality. However 'breeder farm' can represent different factors like management skills of the breeder farmer, egg storage management at the breeder farm,

feeding and health management and others. Therefore, the causality of the relation is not defined.

Although using farm accountancy data has the advantage that farmers are already familiar with these data, there is also an important limitation. That is, IFAS (Chapter 5) uses only input variables that are available in a farm accounting system. Consequently, the simulation model developed in IFAS encompasses not all required relationships to analyse the performance of a flock. For example, in the farm accounting system, all performance variables are given in totals like total egg production and body weight during the laying period instead of weekly performance. Based on this information it was not possible to build the relationship between weekly body weight and egg production in the simulation model. Hence, increased body weight can have positive economic importance as it is positively related to the salvage value of hens but it has also negative economic importance as it is negatively related to egg production.

7.5 Main conclusions

With the research described in this thesis, the interest to collect and analyse data for management decision has increased in the Dutch broiler supply chain, in particular at the hatcheries and broiler breeder farms. This research shows the technical and economic interdependence among the farms and firms in the chain. In addition, the need for information exchange within the chain is demonstrated. The following conclusions are drawn from this thesis:

- Hatchability is affected not only by management factors at the broiler breeder farms but also by management factors at hatcheries. Difference in hatchability among breeder farms and hatcheries reveals a scope for improvement in breeder farm and hatchery management.

- First weak mortality at the broiler farms is affected by management factors at the broiler breeder farms and at hatcheries. This reveals that broiler farmers need information from the broiler breeder farms as well as the hatcheries to support their decisions.

- Production data collected by the hatcheries can be analysed and used to support management decisions at hatcheries, breeder and broiler farms. However, data quality has to improve to be more useful in management information systems.

- The implementation of the protocol for data collection can standardise and improve the quality of datasets in the chain. Particular attention should be paid to pre-defining the time, frequency and method of measurements while standardising the data set.

- IFAS can help broiler breeder farmers to identify the weak and strong elements of their management practices to improve future decisions. However, in order to implement IFAS a complete and good quality data set is needed. To compare data of broiler breeder farms, standardization of all names, codes, contents, definitions and formats of the input variables is a prerequisite.

- The economic optimal flock replacement decision model for the broiler breeder farms can be used at operational as well as tactical level. However, flock-specific prediction models are required to predict performance of the flock and improve operational decisions.

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Summary

Global poultry meat consumption and production have increased quickly during the last decades. In order to meet the increasing demand, the genetic potential of broilers and breeders has changed dramatically. This resulted in a more productive but fragile chickens and consequently the management of these highly productive modern broilers and breeders became complicated and demanding. Hence, to secure the continuity and profitability of the broiler supply chain, improving farm management is important. This can be achieved by using management information systems (MIS) that support farmers' decision making.

Poultry meat is the output of a supply chain that involves several interdependent farms and firms such as; the breeding and feed companies, the rearing (grandparent) farms, parent stock (breeder) farms, broiler hatcheries and broiler farms. This means that, not only the performance of the whole supply chain but also the performance of each farm or firm within the chain depends on the management decisions made at upstream farms or firms in the chain. Therefore, exchange of information is important to support management decisions at each level in the chain. In the broiler supply chain, data are collected as a routine practice. However, the data collection systems are not uniform and each farm or firm in the supply chain collects data according to its own specific format. Data generated at different firms or farms in the chain are not often processed to information to support management decisions.

The objective of this research was to develop management information systems based on available data in the broiler supply chain to support breeder farm management.
The research included three parts that are summarized in the following sections:

- Exploration of management factors at breeder farms that are related to performance indicators at subsequent levels of the broiler supply chain;
- Assessment of the quality of available field data in the broiler supply chain and designing a data collection protocol in the chain;
- Development of management information systems that support management decisions at breeder farms.

In the first part of the thesis, management factors at the breeder farms related to the performance indicator at the subsequent levels of the broiler supply chain are explored. Breeder farms deliver eggs to hatcheries. These eggs are hatched to day-old broilers after 21 days of incubation. Among other factors, the profitability at breeder farms is determined by the number of eggs and the quality of the eggs produced. The number of eggs produced is related to the number of eggs delivered to the hatcheries. The quality of the eggs delivered to hatcheries determines the number and quality of chicks hatched. For this reason, hatchability (an indicator of egg quality) and first week mortality (an indicator of day-old chick quality), are taken as performance indicators at the breeder farms.

Hatchability is the percentage of the total number of eggs set (i.e. hatch of eggs set) that results in good quality chicks which can be sold to broiler farms. Factors related to hatchability are well documented in the literature. However, most of those studies are based on experimental data. To explore factors that relate to hatchability in the field, a data set from three Dutch hatcheries for the years 2004, 2005 and 2006 were analyzed (chapter 2). In total information about 24,234 batches of 724,750,444 eggs originating from 511 breeder flocks

was included. This covers 37% of the total annual eggs set in the Netherlands. Results showed that hatchability differs significantly among breeder flocks. In agreement with the results of many experimental studies, hatchability is significantly related with flock age, egg storage length, strain, feed company, season, year, as well as hatchery. Results indicated that breeder flocks vary in persistency and level of hatchability. Flocks with eggs of high initial hatchability at the intercept have a lower ascending rate and a relatively lower descending rate in contrast to those with lower initial hatchability. Additionally, the variation in hatchability among flocks increases with flock age. In conclusion results indicated that there is a difference in management of flocks among breeder farms and the difference increased as flocks aged. Results also showed that hatchability is affected not only by the management at the breeder farms but also at hatcheries.

The potential of chicks to survive the first week is directly related to the quality of day-old chicks. Therefore, factors that are related to first week chick mortality (FWM) at broiler farms were explored using three years field data of 16,365 flocks of day-old broiler chicks from two Dutch hatcheries (chapter 3). FWM is related to breeder flock age, egg storage length at the hatchery, season, strain, feed company of the breeder farm, year and hatchery. There is a significant difference in FWM among flocks originating from different breeder farms kept at a broiler farm. Moreover, there is significant difference in FWM among flocks originating from a single breeder farm and kept at different broiler farms. This indicates that there is a difference in flock and egg management at breeder farms. In addition, there is difference in flock management at the broiler farms. Furthermore, the need for information exchange among broiler farms, hatcheries and breeder farms is indicated.

In the second part of the thesis, the quality of field data was assed. Good quality data enables to generate good quality information that can be used to support management decisions. In the literature, data quality is defined very broadly, but the most common definition is "fit for use by data consumers". This means that data quality depends on the actual use of data by the data consumer. In the Dutch broiler supply chain, the hatcheries play a key role as they hatch eggs from the breeder farms and deliver the day-old chicks to the broiler farms. They collect data routinely from breeder and broiler farms and can thus facilitate data communication. Data quality in the field was assessed using three years data collected by three Dutch hatcheries (chapter 4). In addition, a protocol was proposed and validated aiming to standardize the content of the data set in the broiler supply chain. Data quality was analysed according to the intuitive approach, whereby quality attributes are selected by the researcher. Results of data quality analysis showed that data sets have some fields with inaccurate, incorrect, inconsistent, non-uniform, incomprehensible, and/or incomplete data. Results indicated that there is a great variability in the quality and content of the data sets collected by the three hatcheries. The developed protocol was validated at 30 breeder farms, three hatcheries, and seven broiler farms. Of all questions, on average 88% were answered at breeder farms, 57%, 65% and 82% at each of the three hatcheries, respectively, and 79% at broiler farms. Data collected by the protocol at two hatcheries are more consistent than those collected at the third hatchery. Results also showed that data at hatcheries, breeder farms and broiler farms are not always uniform, possibly due to differences in management strategies.

In the third part of the thesis, MIS are developed to support decision making at the breeder farms. If data set are standardised and quality of data is improved, management information system can be developed to support farmers' decisions. A management information system called IFAS was developed for breeder farms to evaluate the tactical management of a breeder flock by combining individual farm analysis and deterministic simulation model (chapter 5). Individual farm analysis is a method that evaluates the performance of individual farms by comparing them with standards, like the average of similar farms. IFAS uses flock performance, technical and financial data from a farm accounting system. The system compares the performance of an individual breeder flock with the averages of a group of similar flocks within the same time period. The first step in the evaluation process is comparing various flock performance parameters with average flock performance parameters. The second step is to explain the differences using a simulation model. The simulation model uses input variables from the evaluated farm and replaces these variables one-by-one with the variable of the standard to determine the deviation in performance value due to the replacement. Deviations between performance values can be caused by differences in input variables. To identify the most important input variables that caused deviations, the economic and statistical importance of the deviations are calculated. A relevant deviation can be positive or negative and indicates strong or weak elements in farmers' management practices respectively. Not all deviations are explained using the simulation model; some are unexplainable and some cannot be explained due to lack of information.

Furthermore, a deterministic model is developed to support flock replacement decision at the breeder farms (chapter 6). The optimal replacement decision is known as one of the most important factor affecting farm profitability. Two of the major performance indicators of measuring profitability of raising breeder flocks are the total number of good quality eggs produced and the fertility (or hatchability) of the eggs. These performance indicators decline as the flock ages. The deterministic model uses the marginal net revenue (MNR) approach to determine the optimal replacement moment which may vary between the hens age of 55 and 68 wks. The model deals with a forecast in production parameters of 25 weeks to enable the planning, hatching and rearing period of a new flock. The MNR approach determines the optimal replacement time based on comparison of marginal net revenue of a replaceable flock with the average net revenue of the average flock. The objective function maximizes the annual gross margin per flock's production life. The economic decision criteria for replacing a flock is that, a flock should be replaced if the marginal gross margin (MGM) is lower than the average gross margin (AGM) of an average flock. The decision to replace a flock can be made at tactical as well as operational level. For tactical decisions, when no change is expected in performance of different flocks, the moment of optimal replacement is the age when AGM of the average flock is highest. For the operational decision, i.e. when the performance of the current flock is expected to be different from the average flock, the flock is replaced when the MGM of the replaceable flock is less than the AGM of the replacement or average flock. In addition to the determination of an optimal laying length of an existing flock, the result of the model enables breeder farmers to determine the purchasing and housing date of a new flock. Furthermore, the result from the model can be used for planning purposes at the hatcheries and rearing farms.

Summary

Main conclusions

With the research described in this thesis, the interest to collect and analyse data for management decision has increased in the Dutch poultry meat supply chain, in particular at the hatcheries and broiler breeder farms. This research confirms the technical and economic interdependence among the farms and firms in the chain. In addition, the need for information exchange within the chain is approved. The following conclusions are drawn based on the main findings:

- Hatchability is affected not only by management factors at the broiler breeder farms but also by management factors at hatcheries. Difference in hatchability among breeder farms and hatcheries reveals a scope for improvement in breeder farm and hatchery management.

- First weak mortality at the broiler farms is affected by management factors at the broiler breeder farms and at hatcheries. This reveals that broiler farmers need information from the broiler breeder farms as well as the hatcheries to support their decisions.

- Production data collected by the hatcheries can be analysed and used to support management decisions at hatcheries, breeder and broiler farms. However, data quality has to improve to be more useful in management information systems.

- The implementation of the protocol for data collection can standardise and improve the quality of datasets in the chain. Particular attention should be paid to pre-defining the time, frequency and method of measurements while standardising the data set.

- IFAS can help broiler breeder farmers to identify the weak and strong elements of their management practices to improve future decisions. However, in order to implement IFAS a complete and good quality data set is needed. To compare data of broiler breeder farms, standardization of all names, codes, contents, definitions and formats of the input variables is a prerequisite.

- The economic optimal flock replacement decision model for the broiler breeder farms can be used at operational as well as tactical level. However, flock-specific prediction models are required to predict performance of the flock and improve operational decisions.

Samenvatting

De wereldwijde consumptie van pluimveevlees is in de laatste decennia sterk gestegen, en daarmee ook de wereldwijde productie. Om aan deze toenemende vraag te voldoen, is het genetisch potentieel van vleeskuikens en vleeskuikenouderdieren drastisch veranderd. Het resultaat hiervan is dat de dieren hoog productief zijn, maar ook kwetsbaar. Het managen van deze productieve vleeskuikens en vleeskuikenouderdieren is dan ook een moeilijke en veeleisende taak.

In de pluimveevleesketen spelen verschillende bedrijven een rol. De houders van vleeskuikenouderdieren, ofwel vermeerderaars, produceren broedeieren die geleverd worden aan broederijen, die deze uitbroeden tot eendagskuikens. Deze eendagskuikens gaan vervolgens naar vleeskuikenhouders, die ernaar streven om een eindproduct te produceren, dat tegemoet komt aan de ethische, morele en financiële wensen van de consument. Daarom hangt het economische resultaat van de gehele pluimveevleesketen af van de prestaties van de individuele bedrijven en schakels in de keten, en van de (bedrijfsmatige) interacties tussen deze bedrijven. Bijvoorbeeld, het opfokbedrijf voor vleeskuikenouderdieren is afhankelijk van de kwaliteit van de geleverde kuikens door de ouderdierbroederij. Het resultaat van het vermeerderingsbedrijf is vervolgens afhankelijk van de kwaliteit en uniformiteit van de koppel vleeskuikenouderdieren aangeleverd door het opfokbedrijf. Uiteindelijk is het resultaat van een vleeskuikenbroederij afhankelijk van de kwaliteit van de geleverde broedeieren door het vleeskuikenvermeerderingsbedrijf en is het resultaat van de vleeskuikenbedrijven afhankelijk van de kwaliteit van de door de broederij geleverde eendagskuikens. Samenvattend kan gesteld worden dat de performance van de verschillende partners in de pluimveevleesketen onderling afhankelijk zijn en dat het management van deze bedrijven steeds bepalender wordt voor een hoge ketenprestatie. Daarom is het verzamelen, bewerken en uitwisselen van informatie in de pluimveevleesketen belangrijk voor de optimalisatie van individuele bedrijven en van de keten als geheel. Dit alles kan worden bereikt door gebruik te maken van managementinformatiesystemen (MIS-sen).

Voor de ontwikkeling van een MIS is de beschikbaarheid van complete, consistente en accurate praktijkdata van essentieel belang. In de pluimveevleesketen, worden praktijkdata routinematig verzameld. Echter, de systemen voor dataverzameling zijn niet uniform en op elk bedrijf in de keten worden data verzameld op basis van eigen specifieke definities. Helaas, worden deze praktijkdata meestal niet verwerkt tot informatie om strategische beslissingen van het management te ondersteunen.

Het doel van dit onderzoek was om, op basis van beschikbare praktijkdata in de pluimveevleesketen, managementinformatiesystemen voor vermeerderingsbedrijven te ontwikkelen.

Het onderzoek bestond uit drie delen die zijn samengevat in de volgende secties:

• De verkenning van managementfactoren op vermeerderingsbedrijven die gerelateerd zijn aan prestatie-indicatoren verderop in de pluimveevleesketen;

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• De beoordeling van de kwaliteit van de beschikbare praktijkdata in de pluimveevleesketen en het ontwerpen van een protocol om de data in de pluimveevleesketen te standaardiseren;

• De ontwikkeling van managementinformatiesystemen om beslissingen op vermeerderingsbedrijven te ondersteunen.

De verkenning van managementfactoren op vermeerderingsbedrijven die gerelateerd zijn aan prestatie-indicatoren verderop in de pluimveevleesketen is beschreven in hoofdstuk 2 en 3. De gedefinieerde prestatie-indicatoren zijn het uitkomstpercentage (een indicator van de kwaliteit van de eieren) en de uitval eerste week (een indicator van de kwaliteit van eendagskuiken). Het uitkomstpercentage is het percentage van het totale aantal ingelegde eieren dat resulteert in een goede kwaliteit kuikens die verkocht worden aan vleeskuikenbedrijven; de uitval eerste week is het percentage kuikens dat in de eerste week sterft. Beide indicatoren zijn uitleesparameters voor het aantal en de kwaliteit van de geleverde broedeieren, welke de winstgevendheid van een vermeerderingsbedrijf en de broederij bepalen.

Factoren die geassocieerd zijn met het uitkomstpercentage worden beschreven in de literatuur. Echter, de meeste studies zijn gebaseerd op experimentele data. Om factoren die gerelateerd zijn met uitkomstpercentage in het veld te verkennen, is een dataset van drie Nederlandse broederijen geanalyseerd (hoofdstuk 2). De dataset bevatte informatie over 24.234 ingelegde partijen broedeieren (ofwel 724.750.444 eieren) afkomstig van 511 vermeerderingskoppels in de periode van 2004 tot en met 2006. Dit betrof 37% van het totale aantal jaarlijkse ingelegde broedeieren in Nederland. De resultaten lieten zien dat het uitkomstpercentage aanzienlijk verschilt tussen de koppels. Bovendien is het verschil in uitkomstpercentage groter tussen vermeerderingsbedrijven dan tussen koppels van eenzelfde vermeerderingsbedrijf. Ook bleek dat koppels verschilden in persistentie en het niveau van het uitkomstpercentage. Koppels die met een hoog uitkomstpercentage beginnen te produceren, hebben over het algemeen een persistenter uitkomstpercentage dan koppels die met een laag uitkomstpercentage beginnen. Daarnaast neemt de variatie in het uitkomstpercentage tussen koppels toe met de leeftijd van de hennen. In overeenstemming met de experimentele studies uit de literatuur is het uitkomstpercentage significant gerelateerd aan de leeftijd van de hennen, de bewaarduur van de eieren op de broederij, het merk of ras, de voerleverancier van de vermeerderaar, het seizoen, het jaar en de broederij. Tot slot kan geconcludeerd worden dat het management op vermeerderingsbedrijven verschilt en dat dit verschil groter wordt naarmate de hennen ouder worden. Daarnaast wordt het uitkomstpercentage ook beïnvloed door het management op de broederijen.

Het percentage kuikens dat de eerste week overleeft is direct gerelateerd aan de kwaliteit van de eendagskuikens die geleverd worden aan de vleeskuikenbedrijven. Daarom werden factoren die gerelateerd zijn aan uitval eerste week op vleeskuikenbedrijven onderzocht met behulp van drie jaar praktijkdata van 16.365 koppels eendagskuikens geleverd door twee Nederlandse broederijen (hoofdstuk 3). De uitval in de eerste week is gerelateerd aan de leeftijd van de hennen, de bewaartijd van de eieren bij de broederij, het seizoen, het merk of ras, de voerleverancier van het vermeerderingsbedrijf, het jaar en de broederij. Er is een significant verschil in uitval eerste week onder eendagskuikens die afkomstig zijn van

verschillende vermeerderingsbedrijven en geleverd zijn aan één vleeskuikenbedrijf. Bovendien is er een significant verschil in uitval eerste week onder eendagskuikens die afkomstig zijn van één vermeerderingsbedrijf en die geleverd zijn aan verschillende vleeskuikenbedrijven. Dit geeft aan dat het management van de vermeerderingskoppel en het management van de vleeskuikenkoppel beiden van invloed zijn op de overleving van de kuikens in de eerste week. Uitwisseling van informatie tussen vleeskuikenbedrijven, broederijen en veermeerderingsbedrijven over uitval in de eerste week is dan ook belangrijk voor een verdere bewustwording en een beter ketenmanagement.

In het tweede deel van het proefschrift werd de kwaliteit van de praktijkdata beoordeeld. Dit omdat alleen data van hoge kwaliteit, informatie van hoge kwaliteit kan genereren met als doel om beslissingen op een bedrijf te ondersteunen. In de literatuur wordt de kwaliteit van data zeer breed gedefinieerd, maar de meest gangbare definitie is 'geschikt voor gebruik door de data-gebruikers'. Dit betekent dat de kwaliteit van de data afhangt van het feitelijke gebruik van de data en informatie door de gebruiker. In de Nederlandse pluimveevleesketen spelen de broederijen een belangrijke rol in de dataverzameling, omdat ze eieren die geleverd zijn door vermeerderingsbedrijven uitbroeden, en de eendagskuikens leveren aan vleeskuikenbedrijven. De broederijen verzamelen data al routinematig van vermeerderings- en vleeskuikenbedrijven en kunnen dus makkelijk de uitwisseling van informatie in dit deel van de keten faciliteren. De kwaliteit van de praktijkdata werd gemeten met behulp van een dataset verzameld door drie Nederlandse broederijen in een periode van drie jaar (hoofdstuk 4). De kwaliteit werd geanalyseerd met behulp van de intuïtieve benadering waarbij kwaliteitsattributen zijn geselecteerd door de onderzoeker. De resultaten van deze analyse toonden aan dat de kwaliteit van data op een redelijk niveau was maar dat sommige datavelden onnauwkeurige, onjuiste, inconsistente, niet-uniforme, onbegrijpelijke en/of onvolledige data bevatten. Ook waren er grote verschillen in de kwaliteit en de inhoud van de datasets tussen de drie broederijen.

Als tweede stap in dit (sub)onderzoek is een dataprotocol ontwikkeld en gevalideerd met als doel de data in de pluimveevleesketen te standaardiseren. Het protocol is gevalideerd bij 30 vermeerderingsbedrijven, drie broederijen, en zeven vleeskuikenbedrijven. Van alle vragen (of datavelden) zijn gemiddeld genomen 88% beantwoord op vermeerderingsbedrijven, 57%, 65% en 82% op de drie broederijen, respectievelijk, en 79% op vleeskuikenbedrijven. De data die verzameld zijn op twee broederijen zijn consistenter dan data die verzameld zijn op de derde broederij. De resultaten toonden aan dat de data op broederijen, vermeerderings- en vleeskuikenbedrijven niet altijd uniform zijn. Mogelijk is dit een gevolg van verschillen in de managementstrategieën. Indien data gestandaardiseerd en van hoge kwaliteit zijn, kunnen de ontwikkelde MIS-sen beter worden toegepast om beslissingen van het management te ondersteunen.

In het derde deel van het proefschrift, zijn twee MIS-sen ontwikkeld met als doel het management van vermeerderingsbedrijven te ondersteunen. Het eerste MIS heet IFAS en is ontwikkeld om het tactisch management van vermeerderaars te ondersteunen. Het systeem gebruikt een deterministisch simulatie model voor de individuele bedrijfsanalyse.(hoofdstuk 5). Individuele bedrijfsanalyse is een methode die de prestaties van een individueel bedrijf

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inzichtelijk maakt door deze te vergelijken met een norm zoals het gemiddelde van vergelijkbare bedrijven. IFAS gebruikt technische gegevens van de koppel en financiële gegevens uit het bedrijfsboekhoudsysteem en het vergelijkt de resultaten van een individuele koppel met de gemiddelde resultaten van een groep soortgelijke koppels die in eenzelfde periode hebben geproduceerd. De eerste stap in de bedrijfsanalyse is het vergelijken van de resultaten van een koppel met die van een gemiddelde koppel. De tweede stap is het evalueren van de verschillen in resultaat met behulp van een simulatiemodel. Het simulatiemodel vervangt telkens een input van het koppel dat geëvalueerd wordt door een input van een standaard of een gemiddeld bedrijf om de invloed van de afwijking op het resultaat te bepalen. Het belang van de afwijking wordt uitgedrukt in een economisch en statistisch belang. De invloed van een relevante afwijking op het resultaat kan positief of negatief zijn en geeft daarom ook de sterke of zwakke elementen in het management van deze koppel aan.

De tweede MIS is een deterministisch model dat de beslissing voor het vervangingsmoment van een vermeerderingskoppel op tactisch maar ook op operationeel niveau ondersteunt (hoofdstuk 6). Een optimale vervangingsbeslissing is een bepalende factor voor de winstgevendheid van een bedrijf. Omdat de productiviteit van de hennen (aantal broedeieren en het broedresultaat) afneemt naarmate ze ouder worden, komt er een moment waarop het voordeliger is om de koppel te vervangen door een nieuwe koppel. Het vervangingsmodel kwantificeert de wekelijkse saldi van de koppel om het optimale vervanging moment vast te stellen. Dit moment varieert tussen een leeftijd van 55 en 68 weken. Het model bepaalt het optimale vervangingsmoment door het marginale saldo per week met het gemiddelde saldo per week te vergelijken. Het economische beslissingscriterium voor het vervangen van een koppel is dat een koppel moet worden vervangen wanneer het marginale saldo (MGM) lager wordt dan het gemiddelde saldo (AGM) van een gemiddelde koppel. Het model maximaliseert hiermee het jaarlijks saldo per jaar.

De vervangingsbeslissing moet 25 weken voor het minimale vervangingsmoment (55 weken) worden genomen omdat deze tijd nodig is om een vervangende koppel te plannen, uit te broeden en op te fokken. Daarom extrapoleert het model de technische resultaten (legpercentage en het broedresultaat) van de zittende koppel minimaal 25 weken vooruit. Hierbij wordt gebruik gemaakt van de resultaten van voorgaande koppels op het zelfde bedrijf voor het legpercentage of het gemiddelde van voorgaande koppels voor het broedresultaat.

De beslissing om een koppel te vervangen kan worden genomen zowel op tactisch als operationeel niveau. Voor de tactische beslissing is het vervangingsmoment de leeftijd waarop het AGM van de gemiddelde koppel maximaal is. Voor de operationele beslissing is het vervangingsmoment de leeftijd waarop het MGM van de zittende koppel kleiner wordt dan de AGM van de vervangende of de gemiddelde koppel. Dit levert een ander vervangingsmoment op dan het vervangingsmoment op tactisch niveau wanneer het resultaat van de zittende koppel naar verwachting afwijkt van een gemiddelde koppel. In aanvulling op het bepalen van het vervangingsmoment van een zittende koppel kan het model gebruikt worden voor het bepalen van de aankoop- en opzetdatum van de volgende vermeerderingskoppel. Ook kan het vervangingsmodel gebruikt worden voor het maken van de planning van de nieuwe koppels op broederijen en opfokbedrijven.

Belangrijkste conclusies:

Met het onderzoek beschreven in dit proefschrift, is de belangstelling voor het verzamelen en analyseren van gegevens voor de beslissing van het management toegenomen in de Nederlandse pluimveevleesketen, en vooral op de vermeerderingsbedrijven en broederijen. Dit onderzoek bevestigt de technische en economische onderlinge afhankelijkheid tussen de bedrijven in de keten. Bovendien wordt de noodzaak voor informatie-uitwisseling in de keten helder. De volgende conclusies kunnen worden getrokken op basis van de belangrijkste bevindingen:

- Het uitkomstpercentage wordt niet alleen beïnvloed door managementfactoren op vermeerderingsbedrijven maar ook door managementfactoren op broederijen. De grote verschillen in uitkomstpercentage tussen vermeerderingsbedrijven en bij de verschillende broederijen laat zien dat er ruimte is voor verbetering van het broederijmanagement.

- De uitval van vleeskuikens in de eerste week op de vleeskuikenbedrijven wordt beïnvloed door managementfactoren op vermeerderingsbedrijven en broederijen. Hieruit blijkt dat vleeskuikenhouders informatie van de vermeerderingsbedrijven en broederijen nodig hebben om hun beslissingen te ondersteunen.

- Data die verzameld zijn door broederijen kunnen worden geanalyseerd en gebruikt om beslissingen van het management op broederijen, vermeerderingsbedrijven en vleeskuikenbedrijven te ondersteunen. Hiervoor moet echter de kwaliteit van de data verbeteren zodanig dat ze volledig, uniform, relevant en toegankelijk zijn voor andere ketenpartners.

- Het toepassen van een dataprotocol kan de kwaliteit van data in de keten standaardiseren en verbeteren. Echter, moet er aandacht worden besteed aan het bepalen van het moment, de frequentie en de wijze van metingen in de praktijk zodat de praktijkdata gestandaardiseerd worden.

- IFAS geeft inzicht in de oorzaken van de afwijkende prestaties van een vermeerderingskoppel. Hierdoor kan IFAS helpen om de zwakke en sterke punten van een vermeerderingskoppel te evalueren om toekomstige beslissingen te verbeteren. Echter, om IFAS toe te kunnen passen zijn gegevens van goede kwaliteit nodig.

- Het economisch optimale vervangingsmodel voor de vermeerderingsbedrijven kan gebruikt worden op operationeel en tactisch niveau. Echter, voor het operationele niveau zijn koppel-specifieke voorspellingsmodellen nodig om de prestaties van de koppel goed te kunnen voorspellen

Curriculum Vitae

Hurria Yassin Negash was born on October 11,1973 in Asmara Eritrea. In 1994, she received her BSc degree in Animal Science from Alemaya Agricultural University in Ethiopia. From mid-1994 till 1999 she worked as production expert, project manager and assistant lecturer at dairy farm enterprise, Farm Africa (NGO) and Asmara university respectively. In 1999, she joined the Master of Science program at Wageningen University to study Animal Science. Her specialization was in Animal Nutrition. In 2001, she graduated with the degree of Master of Science (cum laude) from Wageningen University. From 2006 till 2007 she worked as a researcher at the Business Economics Group of Wageningen University. In 2007, she started her doctoral studies at the Business Economics Group of Wageningen University. Hurria is married to Salih and they live in Utrecht (the Netherlands) with their three sons Rakin, Rami and Elim.

Training and Supervision Plan

Description	Institution	Year	ECTS
General part			
Techniques for writing and presenting a scientific paper	WGS	2009	1.2
Interdisciplinary and Tran-disciplinary Research: Inter-vision and Communication Skills	WGS	2009	1.1
Career Perspective	WGS	2010	1.8
Project and time management	WGS	2010	1.5
Mansholt-specific part			
Mansholt Introduction course	Mansholt	2006	1.5
Mansholt Multidisciplinary Seminar	Mansholt	2011	1
'Epidemiological field study on Dutch hatchery data' and 'Hatchability of broiler eggs and hatchery management in the field'	Incubation and fertility research group conference, Edinburgh	2007	2
'A field study on first week chick mortality: which factors are related?' and 'A field study on broiler hatchability: which factors are related to hatchability'	XXIII World's poultry congress 2008, Brisbane	2008	2
'Management information system for the Dutch broiler breeder farms'	Int. Workshop Farm Animal Health Economics, Nantes	2010	1
'Standardized data in the Dutch broiler chain: a protocol'	9th Int. Conference on Chain and Network Management. Wageningen	2010	1
'Management information system for the Dutch broiler breeder farms: Individual farm analysis' and 'Protocol for data collection in the Dutch broiler chain'	Tours/,France	2010	2
Discipline-specific part			
Applied Statistics	Wageningen Business School	2007	6
Hatchery Management Training	Pas Reform BV	2006	1
Information Systems (INF-31306)	WUR	2009	6
PhD meetings (Business Economics Group)		2007 -2012	4
Advanced Agricultural Business Economics (BEC-30306)	WUR	2010	6
Teaching and supervising activities			
Food Safety Economics (assisting in computer lab)		2010	1
Writing research proposal 2007		2007	2
Total (min. 30 ECTS)			**42.1**

Colophon