Economics of young stock rearing decisions on Dutch dairy farms

Norhariani Binti Mohd Nor

ISBN 978-90-393-6297-6

KHL Printing Co Sdn Bhd

Lot 10 & 12, Jalan Modal 23/2, Seksyen 23, Kawasan Miel Phase 8, 40300 Shah Alam, Selangor, Malaysia

Tel: (+603)55413695 / fax: (+603)55413712

Website:www.khlprint.com.sg/ e-mail:dennis@khlprint.com

Cover and book design:
Norhariani
Cover photo:
A dummy dairy cow and a girl at open air museum, Arnhem, The Netherlands
(Photograph by Norhariani)

Economics of young stock rearing decisions on Dutch dairy farms

Economie van jongvee beslissingen op Nederlandse melkveebedrijven
(*met een samenvatting in het Nederlands*)

Ekonomi keputusan dalam penternakan anak lembu di ladang tenusu Belanda
(*dengan ringkasan dalam bahasa Melayu*)

Proefschrift

ter verkrijging van de graad van doctor aan de Universiteit Utrecht op gezag van de rector magnificus, prof.dr. G.J. van der Zwaan ingevolge het besluit van het college voor promoties in het openbaar te verdedigen op donderdag 17 maart 2015 des middags te 2.30 uur

door

Norhariani Binti Mohd Nor

geboren op 20 oktober 1981
te Malakka, Maleisië

Promotoren: Prof. dr. J. A. Stegeman

Prof dr. ir. H. Hogeveen

Copromotor: Dr. ir. W. Steeneveld

The research described in this thesis was financially supported by Universiti Putra Malaysia, Malaysia

Buat cinta hati seumur hidupku,

Abang, Ain & Anas

Contents

List of figures

List of tables

Acknowledgements

"Lucky is opportunity meets hardwork!"

(Prof Dr Sheikh Omar Abd Rahman)

Many have contributed to this thesis, although some may not have realized it at the time. The outcomes of my PhD required much guidance and assistance from many people and I am extremely fortunate to have this, all throughout the process of my thesis.

First and foremost, the opportunity to pursue my study needs to be credited to Prof Dr Zuki, Prof Dr Zamri, Prof Dr Sheikh Omar, Prof Aini, Prof Dr Bashir and Prof Madya Dr Goh Yong Meng. I took the challenge of doing this with your help and motivation and I do hope that I have made all of you proud.

Secondly, I thanked the Ministry of higher Education and Universiti Putra Malaysia for the funding of my study.

I also owe my profound gratitude to my supervisor, Henk and co-supervisor, Wilma.

Henk, with your understanding of my role as a mother and with your encouraging words, helpful modeling/scribbling hands, and brilliant ideas, finally, we made it through. It was also with your patience and trust that made me believe that I can do it (*Gewoon doen*!).

Wilma, you did tremendously well as a co-supervisor, a mentor and a same-age friend. You made things easier and simpler yet you are meticulous when it comes to my work. You always give helpful tips and critics right from the beginning which was from your single-status-PhD years until your current-married-and-soon-to-be motherhood years and it was a pleasure working with you.

My sincere thanks also goes to Monique, who, has been very passionate with the topic and helpful throughout the process. You are extremely kind and generous with your smile, laughter and knowledge. That, have always inspire me.

Living in NL for 5 years took away my time from my family in Malaysia. Despite the difficulty, it is a place I can call home where 'family' consists of people that are initially a complete strangers. I am thankful to these people who have made this journey worth it.

I thanked friends who I encountered while doing my Msc in Utrecht; Che Dah, Andi, Andro, Pudsa, Waldi, Juthatip, Ayu, Scott, Welling, Francisco and Okti. You guys were the most craziest people on earth and you guys rock!.

I have also found a best friend along the way- Christina Milka. Christina, I wish we can go 'smoking' and talk again for hours! Thank you for the time we have spent together. I also thanked my BEC-Leeuwenborch buddies; Farahnaz, Victor, Simone, Eliana, Wudu, Waldi, Frazen, Koenraad and many more. You always have something to talk, to discuss, to share, to laugh and to cry. Just being there made me feel happy all day long. My sincere gratitude and thanks also goes to the staffs and lectures at BEC group, who have been very helpful towards me and my family.

My thought and gratitude goes to my first landlord, Paul Sightermans at Julialaan, Bilthoven. You were the best landlord and like a father to me. My sincere thanks also goes to Kak Syahira & family for helping me going through my first 6 months in NL.

I thanked my Malaysian friends that lit up the spirit of Haarweg 297 and Kolkakkerweg 108 apartments, Wageningen. With all of you (Naim, Fatimah, Najla, Huda K, Huda R, Ajak, Azie, Mimi, Kak Mai, abg Fadzli & sons, Ameen, Izan, Aryan, Ani, Dayah, Ilah, Asyraf, Fizah, Sharul, Su, Ani, Tihah, Nuyu, Termizi, Eti, Amir, Lau and Kak Ra and many more), I find myself always having something to do. The organizing of potlucks, trips, midnight movies, chit chatting, babysitting, girls night out and exchanging meals were all the memories I will cherish for the rest of my life.

My unconditional love and sincere thanks to my humble, wonderful, loving and caring husband. Abang, you stayed with me all the way through. You never fail to cheer me up when I was sad and angry (to myself of course). You never fail to solve my problems (with computer: love-hate relationship!) and made my life easier. You never fail to care for our family that you have made me a one lucky wife! My love to you have grew even more throughout this whole process!

My deepest love and sincere gratitude goes to my family especially my father, Abah and my late mother, Ma.

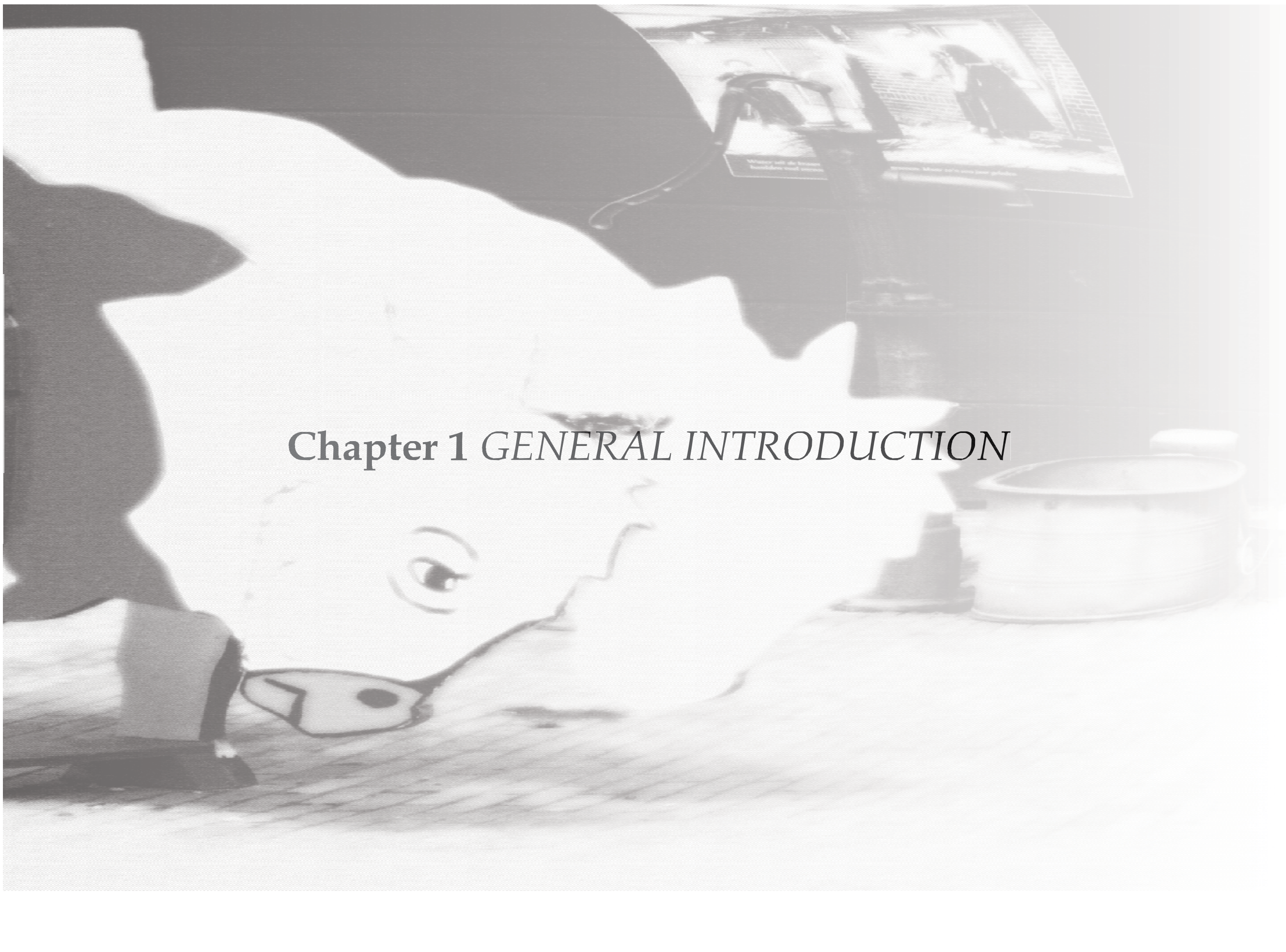
Ma, reciting Alfatihah is all I can give to you when I miss you. Thank you for caring to my daughter during my early study years and for your countless blessings and prayers. I will deeply missed the days when you visited me in NL and the time we spent in Malaysia 3 months before you passed away. Not being able to see you on your burial day did made me questioned my

decision to study oversea. But despite all of this, I believe that Allah has better plans for us and I hope to see you again in heaven, InshaAllah.

My sincere thanks also goes to my mother-in-law, who, despite being away from his son, has been very understanding and thoughtful.

My everlasting love to my beautiful children, 'Ain and Anas. You are my strength and because of you, I have more courage to move forward and achieve anything.

Finally, I would like to ask for forgiveness if I have done any mistakes or hurt any feelings towards anyone in the past. I also praised Allah the Almighty, who rewarded me with this success. May all the knowledge benefited others as well.



Chapter 1 *GENERAL INTRODUCTION*

CHAPTER 1

1. General Introduction

1.1 Young stock rearing on Dutch dairy farms

On Dutch dairy farms, the culled dairy cows need to be replaced by replacement heifers. To produce the replacement heifers, most Dutch dairy farms rear their own young stock. From a management perspective, the Dutch dairy farm is therefore made up of 3 different 'enterprises': the dairy cows, land, and the rearing of young stock. The dairy cow enterprise consists of lactating dairy cows, and the main outputs are milk and culled dairy cows, either alive or dead. The main focus of the land enterprise is on producing roughage and, on some farms, as grazing sites for dairy cows and heifers. To assist in roughage production, farmers might buy fertilizers or lend machinery from other farmers. Nevertheless, to assist in feeding of the animals, farmers might buy feed such as concentrate and milk replacer. The land enterprise also manage wastes from the other 2 enterprises.

The young stock rearing enterprise is linked to the dairy enterprise through the supply of newborn heifer calves. Farmers can decide to sell these newborn heifer calves at an age of 2 weeks. Alternatively, farmers can retain the heifer calves in the rearing enterprise until they calve, at an average age of 26 months (CRV, 2013), and then move them to the dairy enterprise. The farmer can also decide to cull the heifer earlier in some cases, for example if the heifer is not needed, diseased, or infertile (Chiumia et al., 2013).

The dairy cow and land enterprises receive the most attention from the farmer and are also the main focus in research (Mourits et al., 2000). Less attention is usually given to the young stock enterprise, despite its relevance for the rearing of future dairy cows (Mourits et al., 2000). This limits the ability of farmers to make optimal decisions during the rearing of young stock.

1.2 Towards a sustainable dairy farming

Much progress has been achieved in dairy farming through advancements in technologies, genetics, nutrition, and herd management. This has changed the landscape of dairy farms over the past decades, particularly in terms of the number, size, and intensiveness of dairy farms. For instance, in the 1950s, the number of Dutch dairy farms was estimated at 208,000, with a total of 1.4 million dairy cows and an average milk production of 4,110 kg/cow. Now, the number of farms has decreased to 18,682 with a total of 1.5 million dairy cows and with an average milk production of 8,217 kg/cow (CRV, 2013). Similar patterns have also been observed on dairy farms in other north-western European countries (Jongeneel et al., 2010) and in the US (Blayney et al., 2002).

The intensiveness of agriculture has contributed to environmental pollution through a higher production of waste materials. For example, an increasing amount of nitrate and phosphate has leached into the groundwater, worsening the ecological quality of many surface waters in the Netherlands (Oenema et al., 2011). In addition, dairy farming contributes to global warming through emissions of methane, nitrous oxide, and carbon dioxide, (Oenema et al., 2001) and to acidification due to emissions of ammonia (Bussink and Oenema, 1998). From an economic perspective, dairy farms are also under pressure mainly due to decreasing margins per kg of milk (Burrell, 2004). These environmental and economic pressures mean that it is nowadays important that milk is produced in a more sustainable way (von Keyserlingk et al., 2013; Oudshoorn et al., 2012). Sustainable dairy farming can includes economic sustainability, which is defined as the ability of the dairy farmer to continue his farming business (economic viability) and ecological sustainability, which is defined as concerns, threats, or benefits to flora, fauna, soil, water, and climate (Van Calker et al., 2005).

Following the strong demand by society for sustainable food production, Dutch dairy organizations introduced in 2012 their plans for sustainable dairy farming by 2020 with the initiative of the '*duurzame zuivel keten*' (website page is www.duurzamezuivelketen.nl). For instance, the largest Dutch milk processor, FrieslandCampina, supports their farmers to produce milk in a sustainable way. This sustainability covers milk quality, animal health and welfare (e.g. responsible use of antibiotics), production process (e.g. water use), and environment (e.g. more sustainable energy production).

The young stock rearing enterprise also contributes to the sustainability of dairy farming. For example, decisions about the number of young stock to retain on the farm and the length of the rearing period (from birth to first calving age (FCA)) have consequences for the amount of waste produced. By reducing the number of young stock or having a shorter rearing period, waste production can be reduced and a more environmentally sustainable young stock rearing enterprise can be achieved. At the same time, these decisions lower the cost of rearing, which leads to a more economically sustainable young stock rearing enterprise.

A more sustainable young stock rearing enterprise can be achieved if the optimal decisions are taken during the rearing period. However, these decisions are very complex because many different factors are involved. For instance, retaining too few young stock can result in not enough replacement heifers to replace culled dairy cows, and a shorter rearing period might negatively influence the future performance of dairy cows. Therefore, it is necessary to obtain insight into these decisions.

1.3 The decisions during young stock rearing

There are many decisions that have to be made during the rearing of young stock. These include decisions on feeding strategy (e.g. time of weaning and grazing), breeding (e.g. time of insemination and FCA), healthcare (e.g. vaccinations, use of antibiotics, and preventive measures), housing (e.g. type of housing), and the number of heifer calves to retain at 2 weeks of age. For this thesis, we decided to focus on 2 important decisions that are directly related to the number of animals on the farm, and therefore to waste production. These decisions are about the FCA and the number of 2-week-old heifer calves to be retained.

The decision about the FCA. The decision about whether to inseminate a heifer becomes important as soon as the heifer reaches puberty. This decision influences the length of the rearing period, and thus the FCA. Additionally, the decision to reduce the FCA might reduce the cost of rearing, and to some extent reduce the production of wastes. This decision, however, might also lower the milk production in the first lactation, which could affect the milk revenues of the farm. This is because, the main factor that determines milk production in the first lactation is bodyweight at calving. Attaining the required bodyweight at a certain FCA makes growth another important factor. Because bodyweight, growth, and FCA are correlated (Le Cozler et al., 2008), it is difficult to ascertain independently the effect of each variable on milk production in the first lactation (Mourits et al., 1997). Moreover, there is a lack of information from practical studies on bodyweight and growth.

Studies have found that lowering the FCA by a month in a herd with the same rearing strategy reduces the milk production in the first lactation by 56 to 60 kg (Berry and Cromie, 2009; Dobos et al., 2001; Pirlo et al., 2000). To advise farmers on the decision about the FCA, a study is needed that examines the association between the FCA and milk production in the first lactation under practical farm circumstances.

The decision about the number of heifer calves to retain. As soon as a heifer calf is born, the first decision that farmers need to make is either to retain or cull it. Farmers tend to rear almost all of their newborn heifer calves because this strategy gives them flexibility and security in ensuring that enough replacement heifers are timely available. However, it might not be sustainable to retain a higher number of heifer calves as the production of waste is higher and it increases the cost of rearing. A sustainable dairy farm can be achieved by retaining an optimal number of heifer calves.

No study has determined the optimal number of heifer calves that need to be retained, and taken into account the uncertainty of losing heifer calves and variation in the culling rate of dairy cows. In addition, the economic consequences of retaining too few or too many heifer calves have not been investigated.

1.4 Information needed in the thesis

In the previous section, we described the focus of this thesis, which is on the decisions about the FCA and the number of heifers to be retained. These decisions are dependent on several factors, such as the mortality of young stock, the number of replacement heifers needed, culling rate of dairy cows, and the space/slots available in the barn. The prices of feed, milk, and animals and the cost of rearing also influence these decisions. All this information is needed to achieve our objective of obtaining insight in these 2 decisions. There is a particular lack of information in the Netherlands on the cost of rearing and the culling rate of dairy cows (Figure 1.1).

The total cost of rearing. Dutch farmers underestimated the total cost of rearing in a survey by Mourits et al. (2000). Most Dutch farmers

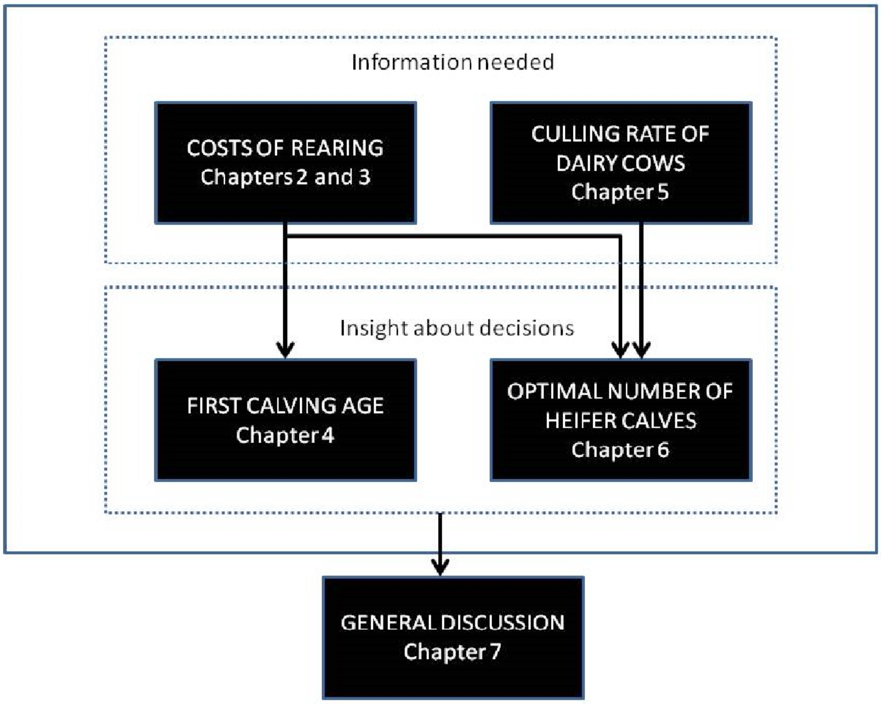


Figure 1.1 Overview of the content of this thesis, with the main objective to provide insight in the economic consequences of decisions during young stock rearing. The decisions are on the FCA (chapter 4) and on the optimal number of heifer calves to be retained (chapter 6). These decisions require information on the costs of rearing (chapters 2 and 3), and the culling rate of dairy cows (chapter 5). The findings are discussed in the general discussion (chapter 7).

thought that the total cost of rearing was less than Dfl 1,500 (€609) per heifer whereas experts estimated it at Dfl 2,500 (€1,800) per heifer (Mourits et al., 2000). Reasons for this underestimation could be that some costs are hidden because young stock share common facilities and feed with dairy cows, and because farmers do not keep records on what they spend on young stock rearing.

If farmers tend to underestimate the cost of rearing and not realize that rearing young stock is a major cost component of a dairy farm, they may not see young stock rearing as a priority. Consequently, they may take decisions that are economically non-optimal. This hinders the economic sustainability of the herd, and therefore it is important that farmers become aware of the true cost of rearing young stock.

The costs of young stock rearing include the costs for healthcare, feed, labor, housing, breeding, mortality, and reproductive failure. A limited number of studies on the costs of rearing young stock have been published (Tozer and Heinrichs, 2001; Gabler et al., 2000; Mourits et al., 1999). Although these studies provide insight in the total cost of rearing young stock, they did not consider the uncertainty related to calf diseases and variations in growth.

The cost of young stock rearing is difficult to calculate due to interrelationships with diseases, growth, and reproduction of the young stock. Therefore, a stochastic model is appropriate because it provides insight in the variation in the costs of young stock rearing. Dairy farmers will become more aware of the cost of rearing young stock if the costs are calculated for their own farm, taking into account its specific characteristics. This requires an economic tool that dairy farmers can use to estimate the total cost of rearing young stock.

Culling rate of dairy cows. A farmer needs to have a replacement heifer available as soon as a dairy cow is culled. Decisions about the number of heifer calves to retain as replacement heifers therefore relate to the number of culled dairy cows. The culling rate of dairy cows in the Netherlands was estimated to be around 30% (Sol et al., 1984). Since this study, almost all studies on culling have focused on risk factors for individual cows within the herd (Bach et al., 2011; Brickell and Wathes, 2011), and were conducted for countries other than the Netherlands. The variation in the culling rate on Dutch dairy farms is therefore unknown. Knowledge about the culling rate is useful to advise dairy farmers on the associated number of replacement heifers that are needed, and thus the number of 2-week-old heifer calves to be retained.

1.5 Objectives of the thesis

The general objective of this thesis is to provide insight in the economic consequences of decisions taken during young stock rearing on Dutch dairy farms, with a view to improving the sustainability of the young stock rearing enterprise. This thesis focuses on 2 important decisions, the FCA and the number of 2-week-old heifer calves to be retained. To reach the general objective, we defined 4 sub-objectives:

- To provide insight in the distribution of the cost of young stock rearing,
- To provide insight in the decision of lowering the FCA on the first lactation milk production (FLP),
- To provide insight in the average culling rate of dairy cows and its variation,
- To provide insight in the optimal number of 2-week-old heifer calves to be retained and reared as replacement heifers.

1.6 Outline of the thesis

In **chapter 2**, the stochastic model developed to calculate the costs of rearing a young stock is described. The model includes uncertainty in young dairy calf diseases, and variation in reproduction and growth. Moreover, the model calculates the different cost components separately (costs for feed, barn, labor, health, insemination, mortality, and revenues foregone).

In **chapter 3**, the costs of rearing young stock are calculated for 75 Dutch dairy farms. The farmers first estimated the cost of young stock rearing and subsequently filled in an economic tool to calculate the costs. The amount of underestimation or overestimation for these specific farms is determined. The model outcome on the calculated total cost of rearing in this chapter is used to validate the outcome of the stochastic model in chapter 2.

In **chapter 4**, the effect from lowering the FCA on the FLP is described using data from 8,454 heifers. The analysis is extended by investigating the association between the FCA and FLP and the following health and management factors: general management, healthcare, incidence of calf diseases, pre-weaned colostrum and milk feeding, housing, hygiene, and breeding.

Chapter 5 describes the average culling rate for slaughter/death of dairy cows in 1,903 Dutch farms during the period from 2007 to 2010, and the variation in culling rate. The analysis is extended by exploring the association between the average culling rate and the characteristics of the herd.

Chapter 6 investigates the decision to retain the optimal number of heifer calves at 2 weeks of age, using a stochastic model at herd level. The model uses information from chapters 2 and 5 (see Figure 1.1). The optimal number is defined as the number of retained heifer calves for which the net cost of rearing is at its minimum. This chapter elaborates on changes in the optimal number of retained heifer calves for different scenarios and circumstances.

Finally, in **chapter 7**, critical points and concerns that have not been mentioned in the earlier chapters are discussed. Chapter 7 finishes with conclusions based on the work presented in this thesis. The relationships between chapters is depicted in Figure 1.1.

References

Bach, A. 2011. Associations between several aspects of heifer development and dairy cow survivability to second lactation. J. Dairy Sci. 94:1052-1057.

Berry, D. P. and A. R. Cromie. 2009. Associations between age at first calving and subsequent performance in Irish spring calving Holstein-Friesian dairy cows. Livest. Sci. 123:44-54.

Blayney, D. P. 2002. The Changing Landscape of U.S. Milk Production. Accessed on Nov. 5, 2014. http://www.ers.usda.gov/media/488847/sb978_1_.pdf..

Bussink, D. W. and O. Oenema. 1998. Ammonia volatilization from dairy farming systems in temperate areas: a review. Nutr. Cycl. Agroecosys. 51:19-33.

Burrell, A. 2004. The 2003 CAP reform Implications for the EU dairy sector. Outlook Agr. 33:15-25.

Brickell, J. S. and D. C. Wathes. 2011. A descriptive study of the survival of Holstein-Friesian heifers through to third calving on English dairy farms. J. Dairy Sci. 94:1831-1838.

Chiumia, D., M. G. G. Chagunda, A. I. Macrae, and D. J. Roberts. 2013. Predisposing factors for involuntary culling in Holstein–Friesian dairy cows. J. Dairy Res. 80:45-50.

CRV, 2013. CRV Jaarstatistieken Nederland (in Dutch). In: Buiting, J. (Ed.) CRV Holding BV, Arnhem. Accessed Oct.15, 2014. https://www.crv4all.nl/over-crv/publicaties/jaarverslagen/crv-jaarstatistieken-2013/.

Dobos, R. C., K. S. Nandra, K. Riley, W. J. Fulkerson, I. J. Lean, and R. C. Kellaway. 2001. Effects of age and liveweight at first calving on first lactation milk, protein and fat yield of Friesian heifers. Aust. J. Exp. Agr. 41:13-19.

Gabler, M. T., P. R. Tozer, and A. J. Heinrichs. 2000. Development of a cost analysis spreadsheet for calculating the costs to raise a replacement dairy heifer. J. Dairy Sci. 83:1104-1109.

Jongeneel, R., S. van Berkum, C. de Bont, C. van Bruchem, J. Helming, and J. Jager. 2010. European dairy policy in the years to come: Quota abolition and competitiveness. Pages 1-56. LEI, The Hague.

Le Cozler, Y., V. Lollivier, P. Lacasse, and C. Disenhaus. 2008. Rearing strategy and optimizing first-calving targets in dairy heifers: a review. Anim. 2:1393-1404.

Mourits, M. C. M., A. A. Dijkhuizen, R. B. M. Huirne, and D. T. Galligan. 1997. Technical and economic models to support heifer management decisions: Basic concepts. J. Dairy Sci. 80:1406-1415.

Mourits, M. C. M., R. B. M. Huirne, A. A. Dijkhuizen, and D. T. Galligan. 1999. Optimal heifer management decisions and the influence of price and production variables. Livest. Prod. Sci. 60:45-58.

Mourits, M. C. M., H. J. Van der Fels-Klerx, R. B. M. Huirne, and M. W. C. Huyben. 2000. Dairy-heifer management in the Netherlands. Prev. Vet. Med. 46:197-208.

Oenema, J., G. J. Koskamp, and P. J. Galama. 2001. Guiding commercial pilot farms to bridge the gap between experimental and commercial dairy farms; the project 'Cows & Opportunities'. Neth. J. Agr. Sci. 49:277-296.

Oenema, J., H. van Keulen, R. L. M. Schils, and H. F. M. Aarts. 2011. Participatory farm management adaptations to reduce environmental impact on commercial pilot dairy farms in the Netherlands. NJAS-Wagen. J. Life Sci. 58:39-48.

Oudshoorn, F. W., T. Kristensen, A. J. van der Zijpp, and I. J. M. de Boer. 2012. Sustainability evaluation of automatic and conventional milking systems on organic dairy farms in Denmark. NJAS-Wagen. J. Life Sci. 59:25-33.

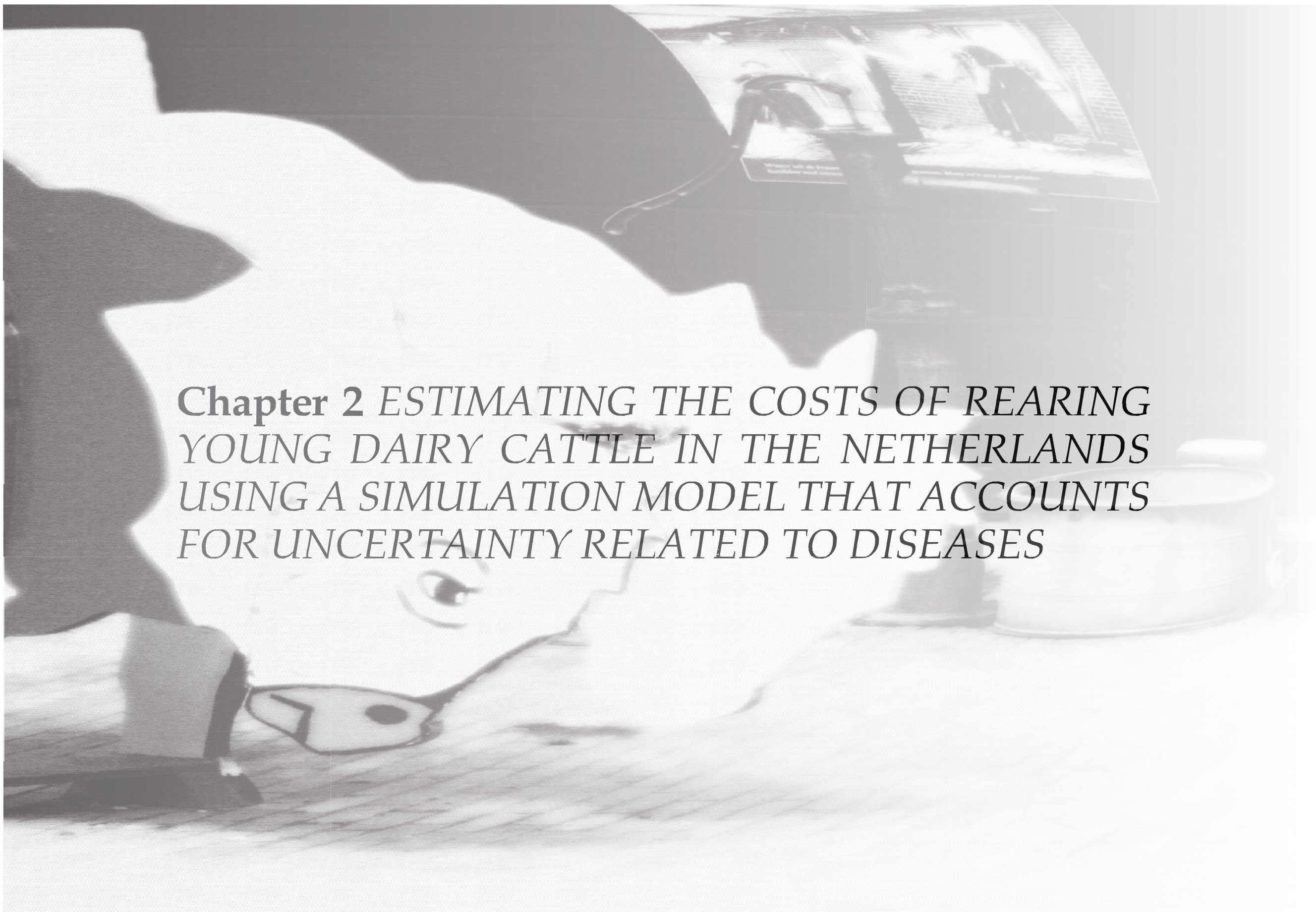
Pirlo, G., F. Miglior, and M. Speroni. 2000. Effect of age at first calving on production traits and on difference between milk yield returns and rearing costs in Italian Holsteins. J. Dairy Sci. 83:603-608.

Tozer, P. R. and A. J. Heinrichs. 2001. What affects the costs of raising replacement dairy heifers: A multiple-component analysis. J. Dairy Sci. 84:1836-1844.

Sol, J., J. Stelwagen, and A. A. Dijkhuizen. 1984. A 3 year herd health and management program on 30 Dutch dairy farms .2. Culling strategy and losses caused by forced replacement of dairy cows. Vet. Q. 6:149-157.

Van Calker, K. J., P. B. M. Berentsen, G. W. J. Giesen, and R. B. M. Huirne. 2005. Identifying and ranking attributes that determine sustainability in Dutch dairy farming. Agr. Hum. Values. 22:53-63.

von Keyserlingk, M. A. G., N. P. Martin, E. Kebreab, K. F. Knowlton, R. J. Grant, M. Stephenson, C. J. Sniffen, J. R. Harner, A. D. Wright, and S. I. Smith. 2013. Invited review: Sustainability of the US dairy industry. J. Dairy Sci. 96:5405-5425.



Chapter 2 *ESTIMATING THE COSTS OF REARING YOUNG DAIRY CATTLE IN THE NETHERLANDS USING A SIMULATION MODEL THAT ACCOUNTS FOR UNCERTAINTY RELATED TO DISEASES*

This chapter has been adapted from published version: Mohd Nor, N., W. Steeneveld, M. C. M. Mourits, and H. Hogeveen. 2012. Estimating the costs of rearing young dairy cattle in The Netherlands using a simulation model that accounts for uncertainty related to diseases. Prev. Vet. Med. 106:214-224.

CHAPTER 2

2

2.1 ABSTRACT

The costs of rearing young dairy cattle are a part of the cost of the price of milk, as rearing produces the future dairy cows. As most dairy farmers are not aware of the rearing costs, the rearing of dairy replacements often does not get the attention it deserves. Calculating the distribution of the rearing costs throughout the rearing process is difficult as the costs are correlated with biological processes, such as variation in growth rate and disease uncertainty. In this study, a calf level simulation model was built to estimate the rearing costs and their distribution from 2 weeks of age until first calving in the Netherlands. The uncertainties related to calf diseases (calf scours and bovine respiratory disease) were included, in which both the probabilities of disease and the effects of diseases (growth reduction) differ at different ages. In addition, growth was modeled stochastically and in a detailed manner using a two-phase growth function. The total cost of rearing young dairy cattle was estimated as €1,567 per successfully reared heifer and varied between €1,423 and €1,715. Reducing the age of first calving by 1 month reduced the total cost between 2.6% and 5.7%. The difference in the average cost of rearing between heifers that calved at 24 months and those calving at 30 months was €400 per heifer reared. Average rearing costs were especially influenced by labor efficiency and cost of feed. The rearing costs of a heifer that experienced disease at least once (20% of the simulated heifers) were on average €95 higher than those of healthy heifers. Hence, for an individual diseased heifer, disease costs can be rather high, while the relative contribution to the average rearing cost for a standard Dutch dairy farm is low (approximately 3%). Overall, the model developed proved to be a useful tool to investigate the total cost of rearing young dairy cattle, providing insights to dairy farmers with respect to the cost-efficiency of their own rearing management.

Key words: young dairy cattle rearing, simulation model, calf diseases, economics

2.2 INTRODUCTION

In the Netherlands, on average, 30% of the dairy cows are culled each year (CRV, 2009) and have to be replaced. Most Dutch dairy farms rear their own young dairy cattle to provide replacement heifers. To produce a good quality replacement heifer, well-managed young dairy cattle rearing is important. It consists, among other things, of keeping a close check on the weight and age at first calving (Tozer and Heinrichs, 2001; Mourits et al., 2000a). Nevertheless, as a component of the farm management system, the rearing of dairy replacements often does not get the attention it requires to be successful (Gulliksen et al., 2009b; Bach and Ahedo, 2008). This is probably because dairy farmers are not aware of the total cost of rearing young dairy cattle. In the Netherlands, the average rearing period is 26 months (CRV, 2009). Such a marked time lag between input and output makes it difficult for dairy farmers to recognize the economic impact of rearing decisions made on the farm. If farmers were to become aware of the variation in the cost components related to rearing of dairy replacements, it would be easier for them to apply cost-effective changes on their farms.

The total cost of rearing young dairy cattle comprises several cost components, such as healthcare costs, feed costs, barn costs, labor costs, costs of breeding, mortality costs, reproduction failure costs and carcass removal costs. These cost components are difficult to calculate because they are correlated with variation in growth (Bach and Ahedo, 2008; Mourits et al., 1997) and the uncertainty of the occurrence of diseases (Van Der Fels-Klerx et al., 2001), mortality (Tozer and Heinrichs, 2001), and estrus and conception (Gabler et al., 2000). Growth, in particular, is the most important factor in rearing young dairy cattle as it determines the feed costs, first calving age and weight (Gabler et al., 2000; Mourits et al., 1999) and is correlated with milk production in the first lactation (Heinrichs and Heinrichs, 2011; Svensson and Hultgren, 2008; Zanton and Heinrichs, 2005).

Various studies on the cost of rearing young dairy cattle have been published (Tozer and Heinrichs, 2001; Gabler et al., 2000; Mourits et al., 1999). Although these studies give good insights into the total cost of rearing, they did not consider the uncertainty related to calf diseases. Therefore, in this study, a stochastic model is developed to account for the uncertainty related to calf diseases and variations in growth.

The objective of this study is to develop a stochastic model to estimate the distribution of costs during young dairy cattle rearing in the Netherlands. On the basis of the results of this study, farmers can become more aware of the distribution of costs during young stock rearing, and thus start to prioritize and change the management of rearing young stock to improve the profitability of the dairy farm.

2.3 MATERIALS AND METHODS

2.3.1 Model Development

To estimate the costs of rearing young dairy cattle in the Netherlands, a Monte Carlo simulation model at the calf level was developed in Microsoft Excel (Microsoft Corporation, Redmond, WA, USA) using @Risk add-in software (Palisade Corporation, Ithaca, NY, USA). The settings of the model were chosen to represent the Dutch dairy production system. According to Dutch legislation, new born heifer calves are not allowed to leave the farm before 2 weeks of age. Accordingly, selection of heifer calves takes place at the age of 2 weeks. Thus, the rearing period in this study is defined as the period between 2 weeks of age and first calving. In this model, 54 stages were defined to reflect time steps in the development for a heifer calf from 2 weeks of age to a fully grown heifer. At each stage, a young dairy animal is characterized by a combination of observations including body weight (BW), health status (healthy, diseased or dead), and reproduction status (pre-pubertal, cyclic, pregnant) that we have called 'states' in this study. Transition between these states within stages is determined stochastically using various probability distributions (Table 2.1). At each stage, healthcare costs, feed costs, barn costs, labor costs and breeding costs were calculated and accumulated from 2 weeks of age until first calving, death or age at culling. Considering the variations in the combination of states occurring per stage, 20,000 replications were carried out to obtain insight into the possible range of outcomes. The results of these replications were stored and were analyzed using SAS version 9.1 (SAS Institute Inc., Cary, NC).

Table 2.1. Probability distributions employed with the specific commands used in @Risk to model the uncertainty and variation in young dairy cattle rearing

Input variable	Command
Month of birth	RiskIntUniform (1; 12)
Disease	
State	RiskDiscrete (states[1]; states probability)
Veterinary call	RiskDiscrete (0: 1; 1-call probability: call probability)
Growth	
2 phase growth function	
a_1 [2]	RiskNormal (309; 41.9; RiskTruncate (308; 340)) [3]
a_2 [2]	RiskNormal (237; 48.2; RiskTruncate (236; 270)) [3]
b_1 [2]	RiskNormal (161; 29.5; RiskTruncate (150; 175)) [3]
b_2 [2]	RiskNormal (550; 81.1; RiskTruncate (520; 570)) [3]
km [2]	RiskNormal (0.01128; 0.00157; RiskTruncate (0.01122; 0.01129)) [3]
Reproduction	
Estrus detection	RiskDiscrete (0: 1; 1-estrus detection rate: estrus detection rate)

[1]States have to be translated to: 1 = healthy, 2 = calf scours, 3 = bovine respiratory disease, 4 = dead
[2]a_1 = asymptotic BW during the first phase (kg), a_2 = asymptotic BW during the second phase (kg), b_1 = age at the first inflection point (d), b_2 = age at the second inflection point (d), km = maturation rate
[3]RiskNormal (Mean; Standard deviation; RiskTruncate (Minimum; Maximum))

Heifer calves were simulated assuming the application of a management approach ensuring good herd health. Inputs were based on information obtained from scientific articles, handbooks and webpages (Table 2.2). If no information was available, veterinary expertise (veterinarians from Faculty of Veterinary Medicine, Utrecht University, and from a practice in the north of the Netherlands) and the authors' expertise were used.

Table 2.2. Input prices for estimating the total cost of young dairy cattle rearing

Input variable	Price (€)	Source
Prevention		
Dehorning at 10 weeks old	11.20/ heifer calf	Veterinary expertise
Anthelmintic during a grazing season	7.80/ heifer	Veterinary expertise
Farmer's treatment		
Calf scours	36/ treatment	Authors expertise
Bovine respiratory disease	5.60/ treatment	Authors expertise
Veterinary treatment		
Calf scours	186/ treatment	Veterinary expertise
Bovine respiratory disease	62.10/ treatment	Veterinary expertise
Farmer's labor	18/hour	Huijps et al. (2008)
Veterinarian labor	100/hour	Veterinary expertise
Breeding	27/ insemination	CRV (2009)
Feed ration	0.17/1000 VEM[1]	KWIN-V (2007)
Milk replacer	1.63/kg	KWIN-V (2007)
Barn	92/calf/year	van Zessen (2009)
Heifer calf at 2 weeks old	55/ calf	LEI (2010)
Heifer at 20 months old	475/ heifer	KWIN-V (2007)
Carcass removal		
less than one year old	28/ carcass	Rendac (2010)
more than one year old	55/ carcass	Rendac (2010)

[1] VEM unit is used in Dutch net energy system. 1 VEM unit contains 1.650 kcal net energy

2.3.2 Model Description

Stages. The model consists of 54 stages. The first 16 stages correspond to intervals of one week to reflect the time span from 2 weeks until 4 months of age. The remaining stages (19 to 54) comprise intervals of 3 weeks. The need for different intervals was due to the concentration of the incidence of diseases in the first 4 months of a calf's life (Gulliksen et al., 2009b) requiring time intervals of one week, and, after 4 months of age, 3 week intervals to match the length of the estrus cycle.

States. Within the model, BW is the main state variable as it determines the development of the heifer calf and therefore the onset of puberty and subsequently the moment of first calving. BW is described in this model as a continuous state variable with the use of a stochastic and continuous growth curve (see next section), ranging from a minimum of 43 kg at birth to a maximum of 594 kg at calving. The BW variable represents the actual live weight of the heifer, corrected for the weight of any fetal tissue.

Only calf diseases that occur in the Netherlands and cause weight loss and death were included in the simulation model (Table 2.3). Four states were defined (healthy, calf scours (CS), bovine respiratory disease (BRD) and dead) to reflect the health condition of the simulated heifer. The healthy state was defined as a heifer that does not exhibit any clinical symptoms of disease. The CS state was applied to heifers that exhibit clinical symptoms of scours, diarrhea, enteritis, navel ill, omphalophlebitis and umbilical infection from 2 weeks until 3 months of age. The BRD state was applied to the heifers with symptoms of calf pneumonia from 2 weeks to 3 months of age, and as BRD after 3 months of age: parasitic infections were excluded. BRD was considered only to occur during the winter season

Table 2.3. Transition matrix applied with respect to the health status comprising 4 states (healthy, calf scours (CS), bovine respiratory disease (BRD) and dead). H1 = probability that the young dairy animal remains healthy in the next stage (one minus total incidence risk). S1 and B1 = probabilities that the healthy heifer will become diseased in the next stage (using incidence risk). H2 and H3 = Probability of cure from a previous diseased state. S2 and B3 = assumed 10% repeated cases. M1 was set equal to zero assuming only a diseased has the probability of death. M2 and M3 = Case fatality risk, proportion of heifers that die within a specified age period)

		Stage = x+1			
	States [1]	Healthy	CS	BRD	Dead
Stage = x	Healthy	H1[2]	S1[3]	B1[3]	M1[4]
	CS	H2[2]	S2	0	M2[4]
	BRD	H3[2]	0	B3	M3[4]
	Dead	0	0	0	1

[1] The probability is dependent on previous state at stage = x, calf age and season.
[2] Estimates based on Constable (2004); Bateman et al. (1990); Fodor et al. (2000)
[3] Estimates based on Gulliksen et al. (2009b); Hultgren et al. (2008); Svensson et al. (2006a); Svensson et al. (2003); Busato et al. (1997); Menzies et al. (1996); Perez et al. (1990)
[4] Estimates based on Gulliksen et al. (2009a); Svensson et al. (2006b); Perez et al. (1990)

(Van Der Fels-Klerx et al., 2001). In this model, 'death' only occurred as a result of CS and BRD. Culling, which is the result of a voluntary decision, can be the consequence of reproductive failure. (See next section.)

2

To reflect the reproduction condition of the simulated heifer, 3 states were defined (pre-pubertal, cyclic and pregnant). In order to determine these states, the estrus detection rate and the conception rate were used (see next section). Heifers that reached first calving were defined as successfully reared heifers. Unsuccessfully reared heifers were the ones that did not reach first calving age through death or reproductive failure.

2.3.3 Transition between States within a Stage.

To calculate the young dairy cattle BW at each stage, the model used the 2 phase growth function based on the Dutch study of Koenen and Groen (1996). This growth function (Equation 1) is based on the summation of 2 sigmoidal curves that partly overlap.

$$Y_t = \frac{a_1}{1+e^{-km(t-b_1)}} + \frac{a_2}{1+e^{-km(t-b_2)}} \quad (1)$$

where
Y_t= BW (kg) at age t (day)
a_1 = asymptotic BW during the first phase (kg)
b_1 = age at the first inflection point (day)
km= maturation rate
a_2 = asymptotic BW during the second phase (kg)
b_2 = age at the second inflection point (d)
t= age (day)

To determine BW development for healthy young dairy cattle reared under Dutch general management conditions, the values for variables a, b and km were based on the same study (Koenen and Groen, 1996) and were modeled using a normal distribution (Table 2.1). Since the variables were stochastic, each simulated heifer (replication) had different input values for the variables a, b and km to produce a different BW. For example, age at the first inflection point (b_1) could occur between 150 days to 175 days and second inflection point (b_2) could be between 520 days to 570 days (Table 2.1). For an individual heifer, a, b and km values were similar at each stage. These values were independent of each other, and were truncated at the minimum and maximum values around the mean (Table 2.1). These truncations gave a realistic BW and also ensured that the modeled growth rate was restricted to a maximum of 1.2kg/day to meet the Dutch feeding recommendation and standards of 2008 (CVB, 2008).

The growth rate (kg/day) of a healthy heifer was determined directly from the growth function, by subtracting the previous BW (stage x) from the current BW (stage x+1). By multiplying the potential growth rate (kg/day) of a healthy heifer with % disease-induced reduction in growth rate, growth loss (kg/day) was obtained. When the simulated heifer was diseased (state CS or BRD) at stage x+1 and then cured, the BW at stage x + 1 was calculated as the sum of BW at stage x plus growth rate that was reduced owing to the impact of the disease. As a consequence, for a diseased heifer, the growth curve was lower than and parallel to the growth curve of a similar but healthy heifer. The level of reduction in growth rate was dependent on the type of disease and age (Van Der Fels-Klerx et al., 2001; Virtala et al., 1996). CS caused 10% reduction in growth rate (Virtala et al., 1996). For calf pneumonia, growth rate was reduced by 23% in the first month of age to 11% and 2% in the second and third months of age, respectively (Virtala et al., 1996). After 4 months of age, BRD caused a 30% reduction in growth rate (Van Der Fels-Klerx et al., 2002b). Only a short term effect of reduction in growth rate was assumed to occur, ranging from 7 days for the diseases occurring before 3 months of age to 21 days for diseases occurring after 4 months of age. Compensatory weight mechanisms were not taken into account after the heifer became healthy again.

At every stage, a transition matrix combining the incidence risk (IR) of diseases, probability of cure (PC), case fatality risk (CFR) and repeated cases (RC) was built in order to adapt for the uncertainty of disease from 2 weeks until the age at first calving. An example of a transition matrix is given in Table 2.3. H1 represents the probability that the heifer remains healthy in the next stage, and is calculated as one minus total IR. S1 and B1 describe the probabilities that the healthy heifer will become diseased in the next stage, using IR (Dohoo et al., 2007). The PC from a previous diseased state is represented by H2 and H3. It was assumed that there is 10% RC which is represented by S2 and B3. Once healthy, the heifer could be diseased again in the next stage. As it was assumed that only a diseased heifer has a probability of dying, M1 was set equal to zero. M2 and M3 reflected the CFR which describes the proportion of heifers with a specific disease that die from it within a specified age period (Dohoo et al., 2007). The complete overview of IR, PC, CFR and RC for all stages and states are presented in Table 2.3 and also in Table A1 of the appendix.

Seasonality was modeled to determine the time for anthelmintic treatment and IR of diseases. To simulate seasonal impact, month of birth was determined by a uniform probability distribution (Table 2.1).

By using discrete probability distributions for estrus detection (75%) and conception rate, the model determined whether a heifer had successfully bred. The conception rate for the first AI was 64% followed by 60%, 61%, 41%, 36% and 19% for 2nd, 3rd, 4th, 5th and 6th AI, respectively (Brickell et al., 2009; Båge, 2003). First calving age was 9 months after a successful breeding because it was assumed that abortion did not occur. Since estrus detection started at 15 months (at minimum BW of 360kg) and ended at 22 months of age, first calving age could vary between 24 to 31 months of age. If a heifer was not pregnant at 22 months of age, or when AI was unsuccessful 6 times, the heifer was culled because of reproductive failure.

2.3.4 Economic Components.

A Dutch dairy farmer may decide to sell the heifer calf at 2 weeks of age or to keep the heifer calf for future replacement. By keeping the heifer calf, the farmer has reduced revenues equal to the price of a heifer calf at 2 weeks of age (€55) (Table 2.2). Total healthcare costs include disease prevention costs, farmer's treatment costs and veterinary treatment costs. The prevention costs are based on the costs of dehorning and anthelmintic treatment (including labor costs from the veterinarian and the dairy farmer). All heifers infected with CS and BRD were treated by the farmer for 2 days. The costs included the costs for treatment and labor. Labor costs are based on the amount of time spent on treating the heifer which was for CS, 10 minutes per treatment and for BRD, 2 minutes per treatment. For 25% of the CS cases and 10% of the BRD cases, it was assumed that the veterinarian was called and performed treatment. These probabilities included the farmers' willingness to call a veterinarian (Table 2.1) considering the labor costs of the veterinarian and the severity of the disease. Subsequently, the farmer continued the treatment for the next 2 days. The amount of time spent by the veterinarian for treating CS was 45 minutes per treatment and for BRD 5 minutes per treatment. In the following 2 days, treatment time was reduced to 10 minutes per treatment for CS and one minute per treatment for BRD. CS treatment requires more time compared to BRD treatment because, when treating for CS the heifer might need electrolyte treatment and intravenous drip, while for BRD only a parenteral treatment with antibiotics is required.

A heifer calf with a BW less than 42 kg was fed with 4 liters of milk replacer per day. A heifer calf with a BW of more than 42 kg is fed 5 liters milk replacer per day until its BW reached 73 kg. After 73 kg, the heifer calf was fed 2 liters of milk replacer per day, reduced to 1 liter after 78 kg, which continued until weaning (Melkveehouderij, 2006). The price for 1 kg milk powder was €1.62 (Table 2.2). Weaning is after 10 weeks of age for a heifer calf with BW of more than 82 kg (Mourits et al., 2000b). After weaning, the BW and average weight gain at each stage determined the feed energy units (VEM) required, covering the energy requirements for maintenance and growth (CVB, 2008). [VEM is the unit used in Dutch net energy systems for ruminants. One VEM unit contains 1.650 kcal net energy (Van Es, 1978)]. Besides growth and maintenance requirements, there was an additional energy requirement during the grazing season, varying with BW from 250 to 950 VEM per day. Further, heifers at the 6^{th}, 7^{th}, 8^{th} and 9^{th} month of pregnancy had an additional energy requirement of 250,700, 1,150 and 1,950 VEM per day, respectively (CVB, 2008). The model assumed feed rations to be balanced and took into account substitutions of hay, silage, grass and concentrate in the ration. VEM unit price was based on the concentrate (940 VEM/kg) price (Table 2.2). The VEM unit price was assumed to be reduced by 20% during the grazing season because there was substitution of concentrate and silage with fresh grass, which is cheaper.

Farmer's labor costs were based on the time needed to feed and inspect the calves. This was estimated as 5 minutes per calf per day before weaning, and 2 minutes per heifer per day after weaning. During the grazing season it was assumed that labor was 1 minute per calf per day. All input prices used are in Table 2.2.

The total costs of a successfully reared heifer were corrected for the number of heifers that did not successfully reach first calving age and were calculated as per Equation 2:

$$TC_{Success} + \frac{(TC_{Dead} * n_{Dead}) + (TC_{Culled} * n_{Culled})}{n_{Success}} \quad (2)$$

where,

$TC_{Success}$ = Average total costs of successfully reared heifer
TC_{Dead} = Average total costs of dead heifer
TC_{Culled} = Average total costs of culled heifer
n_{Dead} = Number of dead heifers
n_{Culled} = Number of culled heifers
$n_{Success}$ = Number of successfully reared heifers

2.3.5 Validation and Sensitivity Analysis.

Since no data were available for external validation, an internal validation was performed. Inputs were compared to output to check for consistency and reliability of the model output. Sensitivity analyses were performed to evaluate the varying effect of input parameters towards economic and non-economic output in young dairy cattle rearing. Sensitivity analyses were performed for economic and non-economic input values (Table 2.4). The non-economic input values analyzed concerned the impact of disease probabilities, growth rate reduction due to impact of diseases, growth rate, estrus detection rate, conception rate, number of AI allowed, labor efficiency and treatment time (Table 2.4). The variation in growth rate was defined as a ±10% increase of the growth function variables, a_1 and a_2, resulting in a reduced growth (RG) analysis and an increased growth (IG) analysis, respectively. A sensitivity analysis was also performed for a non-grazing farm by disregarding the impact of grazing season on feed requirements and feed price (Table 2.2).

2.4 RESULTS

In total, 90.9% of the simulated young dairy cattle successfully reached first calving. An additional 6.1% died prematurely (between 2 weeks

Table 2.4. Inputs changed for sensitivity analysis in the model

Input variable	Input change	Source
Disease incidence risk		
Calf scours	-8% and +8%	Veterinary expertise
Bovine respiratory disease	0.5% and +0.5%	Svensson et al. (2003); Svensson et al. (2006a); Veterinary expertise
Case fatality risk		
Calf scours	-20% and +20%	Perez et al. (1990); Svensson et al. (2006a); Gulliksen et al. (2009a)
Bovine respiratory disease	-15% and +15%	Perez et al. (1990); Svensson et al. (2006a); Gulliksen et al. (2009a)
Repeated cases		
Bovine respiratory disease	-10% and +10%	Bateman et al. (1990)
Calf scours	-10% and +10%	Veterinary expertise
Growth rate slow and fast		
a_1 and a_2	-10% and +10%	Authors expertise
Reproduction		
Estrus detection rate	-20% and +20%	CRV (2009)
AI maximum number	-2 and +2	Authors expertise
Conception rate	-10% and +10%	Inchaisri et al. (2010)
Prices		
Concentrate	-€0.04 and +€0.04	Authors expertise
Heifer calf	-€29 and +€27	LEI (2010)
Heifer	-€100 and +€100	Authors expertise
Labor	-€18, -€2 and +€2	Authors expertise
Others		
Non grazing farm	Excluding pasturing	Authors expertise
Labor efficiency (minutes/day)	-0.5 and +0.5	Authors expertise
Farmer's treatment time (minutes/treatment)		
Calf scours	-5 and +5	Authors expertise
Bovine respiratory disease	-1 and +10	Authors expertise
Veterinarian treatment time (minutes/treatment)		
Calf scours	-15 and +15	Veterinary expertise
Bovine respiratory disease	-5 and 15	Veterinary expertise

until first calving) and 3% was culled because of reproductive failure. On average, birth weight was 46 kg, and first calving occurred at 25 months of age with an average BW of 542 kg (Table 2.5).

The total cost of young dairy cattle rearing was €1,567 per successfully reared heifer and varied between €1,427 and €1,715 (Table 2.6). Feed costs contributed the most, 44.5% (€698), to the total cost of rearing (Table

Table 2.5. Average non-economic output values (5% to 95% percentiles given in parentheses)

Variable	Output
Birth weight (kg)	46 (44; 49)
Weaning weight (kg)	82 (79; 86)
Age at first estrus (months)	15 (15; 16)
Weight at first estrus (kg)	373 (361; 394)
Artificial insemination	2 (1; 3)
Pregnancy age (months)	16 (15; 18)
Pregnancy weight (kg)	382 (361; 424)
First calving age (months)	25 (24; 27)
First calving weight (kg)	542 (521; 565)
Culling age (months)	20[1] (18; 21)
Death age (days)	57[2] (28; 210)

[1] Result is from culled heifer due to reproductive failure analysis

[2] Result is from dead calf analysis

2.6). This was followed by labor costs (31.8%), barn costs (11.5%), heifer calf costs (3.5%), healthcare costs (3.1%) and breeding costs (2.5%). Culling costs (€28 on average per successfully reared heifer) and death costs (€19 on average per successfully reared heifer) also contributed to the total cost. The difference in the average rearing cost between heifers that calved at 24 months and 30 months was almost €400 per successfully reared heifer.

The sensitivity analysis results of the non-economic values are presented in Table 2.7. Increasing and decreasing the IR of CS and BRD influenced the number of dead young dairy cattle. Reducing estrus detection by 20% caused an increase in the proportion of culled heifers to 3.6% and also resulted in a higher age at first calving (25.2 months) and higher first calving weight (545 kg). Increasing growth by 10% resulted in heifers that calved earlier (24.4 months old) at a higher first calving weight (additional 53 kg). Reducing the growth by 10% increased the average first calving age (27 months old) and lowered the average first calving weight (501 kg).

Table 2.6. Average economic output values, categorized as successfully and unsuccessfully reared heifers (5% and 95% percentiles given in parentheses)

Variable	Average costs (€)		
	Successfully reared heifer (90.9%)	**Dead young dairy cattle (6.1%)**	**Culled heifer (3%)**
Heifer calf price	55	55	55
Prevention	27	2 (0; 11)	24 (19; 27)
Farmer's treatment	9 (0; 36)	32 (6; 72)	10 (0; 36)
Veterinary treatment	12 (0; 186)	45 (0; 186)	14 (0; 186)
Carcass removal	-	29 (28; 28)[1]	-
Feed	698 (659; 778)	34 (8; 145)	493 (440; 543)
Labor	499 (475; 533)	68 (21; 237)	419 (382; 449)
Breeding	40 (27; 81)	0.3 (0; 0)[2]	161 (162; 162)[3]
Sales	-	-	-475
Barn	180 (176; 198)	9 (2; 44)	140 (129; 150)
Subtotal	1,520 (1,427; 1,715)	274 (151; 583)	842 (736; 1,006)
Average loss per successfully reared heifer	47[4]	-	-
Average total rearing cost	1,567[5]	-	-

[1] The 1% to 99% percentiles are €28 to €55
[2] The range is €0 to €27
[3] The 1% to 99% percentiles are €135 to €162
[4] The average loss per successfully reared heifer was calculated as the sum of average loss of dead young dairy cattle (€19/successfully reared heifer) and culled heifer (€28/ successfully reared heifer). For the calculation of losses refer to Equation 2.
[5] The average total cost of successfully reared heifer's 5% to 95% percentiles could not be determined because they were summed up with the average loss per successfully reared heifer. The 5% to 95% percentiles of average subtotal costs per successfully reared heifer varied from €1,427 to €1,715

The results of the sensitivity analysis on the non-economic input values are presented in Figure 2.1. The total cost of rearing was especially sensitive to labor efficiency, followed by IR of CS, excluding pasture, conception rates, growth rates, estrus detection rates and IR of BRD.

Reducing the labor time by ½ minute per heifer per day resulted in the reduction of total cost by more than €100 per successfully reared heifer. Increase in IR of CS by 8% increased the total cost by €110 per successfully reared heifer.

Table 2.7. Sensitivity of the non-economic output for different changes in input values

Variable	Input change	% Dead young dairy cattle	% Culled heifer	Average first calving age (month)	Average first calving weight (kg)
Default situation		6.1	3.0	24.7	542
Disease					
Calf scours incidence risk	-8%	1.9	3.1	24.7	542
Calf scours incidence risk	+8%	14.8	2.8	24.7	542
Bovine respiratory disease incidence risk	-0.5%	4.9	3.2	24.7	542
Bovine respiratory disease incidence risk	+0.5%	8.4	2.9	24.7	542
Calf scours case fatality risk	-20%	2.4	3.3	24.6	542
Calf scours case fatality risk	+20%	11.4	3.1	24.7	542
Bovine respiratory disease case fatality risk	-15%	4.7	3.1	24.7	542
Bovine respiratory disease case fatality risk	+15%	7.1	3.0	24.6	542
Calf scours repeated cases	-10%	5.5	3.1	24.7	542
Calf scours repeated cases	+10%	6.3	2.9	24.6	542
Bovine respiratory disease repeated cases	-10%	5.9	3.0	24.7	543
Bovine respiratory disease repeated cases	+10%	6.2	3.1	24.7	542
Growing					
Increased growth	+10%	5.9	3.0	24.4	595
Reduced growth	-10%	6.1	3.2	26.7	501
Reproduction					
Estrus detection	-20%	6.1	3.2	25.2	546
Estrus detection	+20%	6.3	3.1	24.3	540
Conception rate	-10%	6.2	7.1	24.8	543
Conception rate	+10%	5.9	1.1	24.5	541

Excluding pasturing (non-grazing farms) gave an additional total cost of €92 per successfully reared heifer. Better reproductive performance, such as increasing the estrus detection rate (20%), saved €17 per successfully reared heifer while increasing conception rate by 10% saved €30 per successfully reared heifer. The results also showed that reducing and increasing the growth by 10% resulted in additional costs of €41 and €43 per successfully reared heifer, respectively. Increase in the IR of BRD by 0.5% increased the total cost by €19 per successfully reared heifer.

The sensitivity of the total cost per successfully reared heifer to the economic input values is presented in Figure 2.2. The reduction in the labor cost

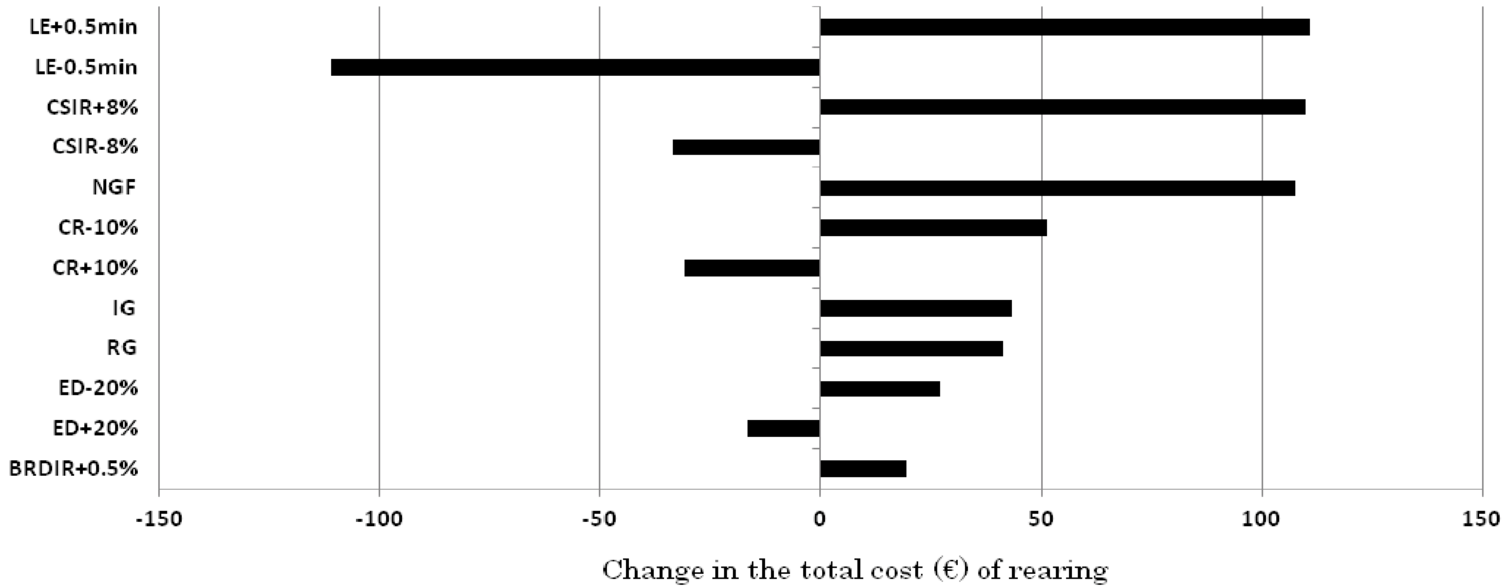


Figure 2.1 Sensitivity of the total cost of rearing per successfully reared heifer for different non-economic input. LE+0.5min = Labor efficiency increased ½ minute per day; LE-0.5min = Labor efficiency reduced ½ minute per day; CSIR+8% = Calf scours incidence risk increased 8%; CSIR-8% = Calf scours incidence risk reduced 8%; NGF = Non-grazing farm; CR-10% = Conception rate reduced 10%; CR+10% = Conception rate increased 10%; IG = Growth increased by 10%; RG = Growth reduced by 10%; ED+20% = Estrus detection increased 20%; ED-20% = Estrus detection reduced 20%; BRDIR+0.5% = Bovine respiratory disease incidence risk increased by 0.5%

2

by €2 reduced the total cost by €61 per successfully reared heifer. Considering no opportunity costs for the farmer's own labor (i.e. labor costs are €0) reduced the total cost by €520 per successfully reared heifer.

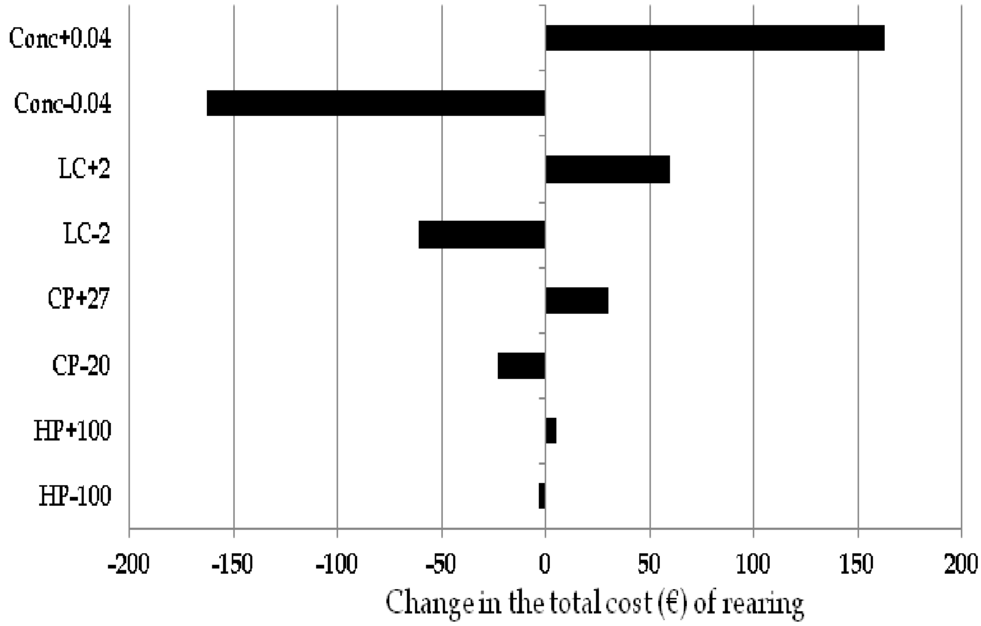


Figure 2.2 Sensitivity of the total cost of rearing per successfully reared heifer for different input prices. Conc+0.04 = Concentrate price increased €0.04; Conc-0.04 = Concentrate price reduced €0.04; LC+2 = Labor costs increased €2; LC-2 = Labor costs reduced €2; CP+27 = Heifer calf price increased €27; CP-20 = Heifer calf price reduced €20; HP-100 = Heifer price reduced €100; HP+100 = Heifer price increased €100.

2.5 DISCUSSION

The average total cost of rearing young dairy cattle was estimated as €1,567 per successfully reared heifer (Table 2.6). Previously, the total costs were estimated between €907 and €1,134 for Dutch circumstances (Mourits et al., 2000b), not taking inflation rate into account. Within these costs, labor costs were excluded. In our study, when labor costs were excluded, the average total cost of rearing was €1,047 per successfully reared heifer. The estimated total cost of rearing in the US (Gabler et al., 2000) was lower, and was estimated as €714 and €788 (including labor costs) for custom operations and milking operations, respectively, stressing the difference in production circumstances in comparison to the Dutch situation.

Based on the simulation results, calving occurred on average at the age of 25 months (Table 2.5). The simulated average age of 25 months is lower than what has been observed in practise (average Dutch heifer first calving age is 26 months (CRV, 2009)). This is due to the limited calving age range (24 months to 27 months), while in practise this range is larger and more skewed (Mourits et al., 2000b). Furthermore, our model simulated heifer calves under good rearing conditions, and extreme values were not taken into account. For instance, breeding was started not earlier than at 15 months of age and AI was allowed up to 6 times. In contrast, dairy farmers in practise breed their heifers before 15 months of age and breed more than 6 times when necessary, resulting in first calving ages varying from 22 months to 36 months (Mourits et al., 2000b).

The growth curve used in the model we developed has successfully determined the age for weaning and breeding, feed costs, first calving age and weight. In addition, our use of a stochastic and continuous growth curve has several advantages. Firstly, the growth curve is based on actual data in the Netherlands. Secondly, variations have also been included in the data. Consequently, these gave an accurate estimation of the total cost of rearing. Because the growth curve settings were flexible, it was possible to evaluate the costs at different growth rates (Figure 2.1). In this study, when growth was increased by 10%, the heifer reached the minimal breeding weight (which was 360 kg in our model) on average at 13 months of age (data not shown), and therefore could have been bred at that age. However, to reflect practise, it was assumed within the model that breeding did not occur before the age of 15 months. Consequently, a 10% increase in growth resulted in additional feed costs as breeding was unnecessarily postponed until the age of 15 months. So, with 10% increase in growth, lower rearing costs could be expected if the heifers are bred earlier.

There are no studies known by the authors that measured the actual growth curve of diseased heifers from birth until first calving. In most studies, BW in diseased heifers was measured at a certain age or at first calving, which was not detailed enough for this model. Therefore, it was decided that the diseased growth curve should run below and parallel to the potential healthy growth curve, as reduction in growth after being diseased can persist until first calving (Smith, 1998). [The inputs on growth rate reduction were from Van der Fels-Klerx et al. (2002a), and Virtala et al. (1996)]. In addition, a field veterinarian confirmed that these inputs are applicable for the Dutch situation.

The effect of growth rate, first calving age, and first calving weight on first lactation milk production was not included in this model. However, for a complete economic picture these effects need to be taken into account, especially as farmers are aiming at optimizing milk production. Many studies have shown that growth rate, first calving age and first calving weight can have a significant impact on milk production in the first lactation (Heinrichs and Heinrichs, 2011; Svensson and Hultgren, 2008; Zanton and Heinrichs, 2005). Furthermore, calves with improved nutritional status in the first 2-3 weeks of age have a higher growth rate and are better able to withstand infectious challenges and produce more milk in the first lactation (Drackley, 2005)2005. The simulated calves in our model show values for BW, growth rates and first calving age that fall within established values (Le Cozler et al., 2008; Zanton and Heinrichs, 2005), which would imply that no negative impacts can be expected for milk production capacity.

Labor costs were estimated to be €18 per hour (Huijps et al., 2008). Dutch farms are mainly family businesses, and therefore the level of opportunity costs due to additional labor differs among farms. Most Dutch farmers who work on their own farm perceived the opportunity costs of labor as zero. Thus they will estimate the total cost of rearing lower than our estimation of €1,567 per successfully reared heifer.

The mortality risk from 2 weeks until first calving was 6%, with mortality occurring on average at 57 days of age. The mortality is lower than in the US (9.4%) (Losinger and Heinrichs, 1997), Denmark (8.6%) (Nielsen et al., 2010), and Norway (7.8%) (Gulliksen et al., 2009a). But this is a result of excluding the mortality in the first 2 weeks of life. For Dutch circumstances, the calf mortality within 24 hours of birth and at the first week of age are 6.9% (Harbers et al., 2000) and 2.3% (Perez et al., 1990), respectively. Also, the model did not include disease outbreaks, and death did not occur because of other diseases or conditions (e.g., accidents and dystocia). There was an increase in the total rearing costs by more than €100 per successfully reared heifer when IR of CS was increased (Figure 2.2). This showed that calf health is important and reducing the incidence of disease can lower the total cost of rearing. However, although an increase in the IR of diseases increased the total cost of young stock rearing, the results of the sensitivity analysis showed that a change in disease inputs did not affect first calving age and first calving weight (Table 2.7). These results can be explained by the inputs used and the assumptions made. Firstly, good herd health management was assumed, which includes, for instance, disinfecting the navel appropriately after birth, feeding colostrum at an appropriate time in enough quantity and providing a conducive environment for the young stock to grow (Beam et al., 2009; Bach and Ahedo, 2008). Secondly, it is assumed that only one disease occurs in one stage, although in reality these diseases can occur together (Van Der Fels-Klerx et al., 2002a). Thirdly, the duration of the diseases is confined to a single stage, which is only 7 days before 3 months of age. Fourthly, the reductions in growth rate for CS and BRD before 3 months of age are extremely low (Virtala et al., 1996) and the maximum growth that occurs between 3 months and 7 months could 'compensate' for the loss before the age of 3 months. In reality this is not conclusive because no study has been made of a compensatory weight mechanism after young dairy cattle have been diseased (Van Der Fels-Klerx et al., 2002a). In addition, treatment before 4 months of age for both CS and BRD showed a positive effect on height of withers (Heinrichs et al., 2005). According to previous studies, the effect of the diseases on later stages of rearing period on age at first calving were ambiguous and the short term effects of growth on later breeding were not clear (Van Der Fels-Klerx et al., 2002a; Virtala et al., 1996; Waltner-Toews et al., 1986).

The total cost of rearing a heifer that experienced disease at least once (20% of simulated heifers) was on average €95 higher than that of heifers that are not infected at all (data not shown). Hence, for an individual diseased heifer, disease costs can be rather high while their contribution to the average total cost is minor (Table 2.6). However, this contribution will, to some extent, be underestimated as a consequence of the assumptions made. Therefore, it will be necessary to explore the consequences of transmission of diseases between young dairy cattle. Such consequences can be modeled in a herd-level model, which will be the topic of future work.

Combining the results on total cost (€1,567 per successfully reared heifer) and first calving age (25 months) with the general characteristics of a standardized Dutch dairy farm (100-cow herd, 29% dairy cow replacement, cost price of milk of €0.466/kg and a production of 795,300 kg milk per herd per year (LEI, 2010)), demonstrates that the total cost of rearing contributes approximately 13% to the cost price of milk. This value indicates the necessities for farmers to be more aware of the economic consequences of rearing young dairy cattle in their dairy enterprise.

2.6 CONCLUSIONS

A stochastic model was developed to estimate the total cost and distribution of costs during the rearing of young dairy cattle. The total cost of rearing was €1,567 per successfully reared heifer and varied between €1,423 and €1,715. The cost of rearing a heifer that experienced disease at least once (20% of simulated heifers) was on average €95 higher than that of uninfected heifers. Hence, for an individual diseased heifer, disease costs can be rather high, while the relative contribution to the average rearing cost for a standard Dutch dairy farm is low (approximately 3%). The total cost of rearing contributed approximately 13% to the cost price of milk. In our opinion, this value is high enough for dairy farmers to become more aware of the economic importance of replacement rearing. Overall, the model developed is a detailed, useful tool in calculating the total cost of rearing young dairy cattle. Farmers can benefit from the awareness it provides to start prioritizing and changing rearing management accordingly to improve the profitability of their farm.

ACKNOWLEDGEMENTS

The authors would like to acknowledge Malaysian Higher Ministry of Education (MOHE) and Universiti Putra Malaysia (UPM), Malaysia for the funding of this project. Also, many thanks to Dr Mirjam Nielen, Dr IJmert de Vries, Ing Paul Dobbelaar and Dr Harm Ploeger, from the Faculty of Veterinary Medicine, Utrecht University for their expertise.

References

Bach, A., and J. Ahedo. 2008. Record keeping and economics of dairy heifers. Vet. Clin. N. Am-Food A. 24: 117-138.

Båge, R. 2003. Conception rates after AI in Swedish red and white dairy heifers: Relationship with progesterone concentrations at AI. Reprod. Domestic Anim. 38: 199-203.

Bateman, K. G., S. W. Martin, P. E. Shewen and P. I. Menzies. 1990. An evaluation of antimicrobial therapy for undifferentiated Bovine Respiratory Disease. Can. Vet. J. 31: 689-696.

Beam, A. L., J. E. Lombard, C. A. Kopral, L. P. Garber, A. L. Winter, J. A. Hicks and J. L. Schlater. 2009. Prevalence of failure of passive transfer of immunity in newborn heifer calves and associated management practices on US dairy operations. J. Dairy Sci. 92: 3973-3980.

Brickell, J. S., N. Bourne, M. M. McGowan and D. C. Wathes. 2009. Effect of growth and development during the rearing period on the subsequent fertility of nulliparous Holstein-Friesian heifers. Theriogenology 72: 408-416.

Busato, A., L. Steiner, S. W. Martin, M. M. Shoukri and C. Gaillard. 1997. Calf health in cow-calf herds in Switzerland. Prev. Vet. Med. 30: 9-22.

Constable, P. D. 2004. Antimicrobial use in the treatment of calf diarrhea. J. Vet. Intern. Med. 18: 8-17.

CRV, 2009. CRV Jaarstatistieken Nederland (in Dutch). In: Buiting, J. (Ed.) CRV Holding BV, Arnhem. Accessed Feb. 2, 2010. https://www.crv4all.nl/downloads/jaarverslagen/crv-jaarstatistieken-2009.pdf.

CVB, 2008. Table Booklet Feeding of Ruminants. Feeding standards, feeding advices and nutritional values of feed ingredients. CVB, Product Board Animal Feed, The Netherlands, pp. 12-17.

Dohoo, I., W. Martin, and H. Stryhn. 2007. Measures of disease frequency. Veterinary Epidemiologic Research. AVC Inc, Prince Edward Island, Canada, pp. 68-75.

Drackley, J. K. 2005. Early growth effects on subsequent health and performance of dairy heifers. In: Garnsworthy, P.C. (Ed.), Calf and heifer rearing. Nottingham University Press, Nottingham, pp. 213-235.

Fodor, L., L. Reeve-Johnson, A., Hodge, and J. Varga. 2000. Efficacy evaluations of the use of oral tilmicosin in pneumonic calves. Vet. J. 159: 194-200.

Gabler, M. T., P. R. Tozer, and A. J. Heinrichs. 2000. Development of a cost analysis spreadsheet for calculating the costs to raise a replacement dairy heifer. J. Dairy Sci. 83: 1104-1109.

Gulliksen, S. M., K. I. Lie, T. Løken, O. Østerås. 2009a. Calf mortality in Norwegian dairy herds. J. Dairy Sci. 92: 2782-2795.

Gulliksen, S. M., K. I. Lie, and O. Østerås. 2009b. Calf health monitoring in Norwegian dairy herds. J. Dairy Sci. 92: 1660-1669.

Harbers, A., L. Segeren, and G. de Jong. 2000. Genetic parameters for stillbirth in the Netherlands. Interbull Bulletin No. 25, pp. 117–122.

Heinrichs, A. J. and B. S. Heinrichs. 2011. A prospective study of calf factors affecting first-lactation and lifetime milk production and age of cows when removed from the herd. J. Dairy Sci. 94: 336-341.

Heinrichs, A. J., B. S. Heinrichs, O. Harel, G. W. Rogers and N. T. Place. 2005. A prospective study of calf factors affecting age, body size, and body condition score at first calving of Holstein dairy heifers. J. Dairy Sci. 88: 2828-2835.

Huijps, K., T. Lam and H. Hogeveen. 2008. Costs of mastitis: facts and perception. J. Dairy Res. 75: 113-120.

Hultgren, J., C. Svensson, D. O. Maizon, and P. A. Oltenacu. 2008. Rearing conditions, morbidity and breeding performance in dairy heifers in southwest Sweden. Prev. Vet. Med. 87: 244-260.

Inchaisri, C., H. Hogeveen, P. Vos, G. C. van der Weijden, and R. Jorritsma. 2010. Effect of milk yield characteristics, breed, and parity on success of the first insemination in Dutch dairy cows. J. Dairy Sci. 93: 5179-5187.

Koenen, E. P. C. and A. F. Groen. 1996. Genetic analysis of growth patterns of black and white dairy heifers. J. Dairy Sci. 79: 495-501.

KWIN-V, 2007. Melkvee. In: Vermeij, I., B. Bosma, A. Evers, H. Hemmer, I. Vink (Eds.), Kwantitatieve informatie veehouderij (in Dutch) Wageningen UR, Lelystad, pp. 141-154.

Le Cozler, Y., V. Lollivier, P. Lacasse, and C. Disenhaus. 2008. Rearing strategy and optimizing first-calving targets in dairy heifers: a review. Anim. 2: 1393-1404.

LEI, 2010. Agriculture prices (in Dutch, keywords in english) Wageningen UR, Accessed Jan. 15, 2010 http://www3.lei.wur.nl/BIN_ASP/show.exe?aktie=vindtoonandbj=2008andej=2011andlanguage=USandValuta=2002andpublicatieID=2001andkiestabel=2008.2001andDatabase=Prijzen.

Losinger, W. C. and A. J. Heinrichs. 1997. Management practices associated with high mortality among preweaned dairy heifers. J. Dairy Res. 64: 1-11.

Melkveehouderij, 2006. Handboek Melkveehouderij (in Dutch). In: De Jong, O., M. van Oostende, and T. van Schie. (Eds.) Roodbont Publishers B.V, The Netherlands. , p. 179.

Menzies, F. D., D. G. Bryson, T. McCallion and D. I. Matthews. 1996. Mortality in cattle up to two years old in Northern Ireland during 1992. Vet. Rec. 138: 618-622.

Mourits, M. C. M., A. A. Dijkhuizen, R. B. M. Huirne and D. T. Galligan. 1997. Technical and economic models to support heifer management decisions: Basic concepts. J. Dairy Sci. 80: 1406-1415.

Mourits, M. C. M., D. T. Galligan, A. A. Dijkhuizen, and R. B. M. Huirne. 2000a. Optimization of dairy heifer management decisions based on production conditions of Pennsylvania. J. Dairy Sci. 83: 1989-1997.

Mourits, M. C. M., R. B. M. Huirne, A. A. Dijkhuizen, and D. T. Galligan. 1999. Optimal heifer management decisions and the influence of price and production variables. Livest. Prod. Sci. 60: 45-58.

Mourits, M. C. M., H. J. Van Der Fels-Klerx, R. B. M. Huirne and M. W. C. Huyben. 2000b. Dairy-heifer management in the Netherlands. Prev. Vet. Med. 46: 197-208.

Nielsen, T. D., L. R., Nielsen, N. Toft and H. Houe. 2010. Association between bulk-tank milk Salmonella antibody level and high calf mortality in Danish dairy herds. J. Dairy Sci. 93: 304-310.

Perez, E., J. Noordhuizen, L. A. Vanwuijkhuise and E. N. Stassen. 1990. Management factors related to calf morbidity and mortality rates. Livest. Prod. Sci. 25: 79-93.

Rendac, 2010. Tarievenlijst (in Dutch). Accessed Jan. 10, 2010. www.rendac.nl/pdf/tarieven/2010.pdf.

Smith, R.A. 1998. Impact of disease on feedlot performance: A review. J. Anim. Sci. 76: 272-274.

Svensson, C. and J. Hultgren. 2008. Associations between housing, management, and morbidity during rearing and subsequent first-lactation milk production of dairy cows in southwest Sweden. J. Dairy Sci. 91: 1510-1518.

Svensson, C., J. Hultgren and P. A. Oltenacu. 2006a. Morbidity in 3-7-month-old dairy calves in south-western Sweden, and risk factors for diarrhoea and respiratory disease. Prev. Vet. Med. 74: 162-179.

Svensson, C., A. Linder and S. -O. Olsson, 2006b. Mortality in Swedish dairy calves and replacement heifers. J. Dairy Sci. 89: 4769-4777.

Svensson, C., K. Lundborg, U. Emanuelson, S. -O. Olsson. 2003. Morbidity in Swedish dairy calves from birth to 90 days of age and individual calf-level risk factors for infectious diseases. Prev. Vet. Med. 58: 179-197.

Tozer, P. R. and A. J. Heinrichs. 2001. What affects the costs of raising replacement dairy heifers: A multiple-component analysis. J. Dairy Sci. 84: 1836-1844.

Van Der Fels-Klerx, H. J., S. W. Martin, M. Nielen, and R. B. M. Huirne. 2002a. Effects on productivity and risk factors of Bovine Respiratory Disease in dairy heifers; a review for the Netherlands. Neth. J. Agric. Sci. 50: 27-45.

Van Der Fels-Klerx, H. J., H. W. Saatkamp, J. Verhoeff, and A. A. Dijkhuizen. 2002b. Effects of bovine respiratory disease on the productivity of dairy heifers quantified by experts. Livest. Prod. Sci. 75: 157-166.

Van Der Fels-Klerx, H. J., J. T. Sørensen, A. W. Jalvingh and R. B. M. Huirne. 2001. An economic model to calculate farm-specific losses due to bovine respiratory disease in dairy heifers. Prev. Vet. Med. 51: 75-94.

Van Es, A. J. H. 1978. Feed evaluation for ruminants. I. The system in use from May 1977 onwards in The Netherlands. Livest. Prod. Sci. 5: 331-345.

van Zessen, T. 2005. Special jongveeopfok: Nieuwe generatie buitenshuis (in Dutch). Veeteelt, 19th Ed. Wageningen UR, pp. 44 - 45

Virtala, A. M. K., G. D. Mechor, Y. T. Gröhn and H. N. Erb. 1996. The effect of calfhood diseases on growth of female dairy calves during the first 3 months of life in New York state. J. Dairy Sci. 79: 1040-1049.

Waltner-Toews, D., S.W. Martin, A. H. Meek. 1986. The effect of early calfhood health-status on survivorship and age at 1st calving. Can. J. Vet. Res. 50: 314-317.

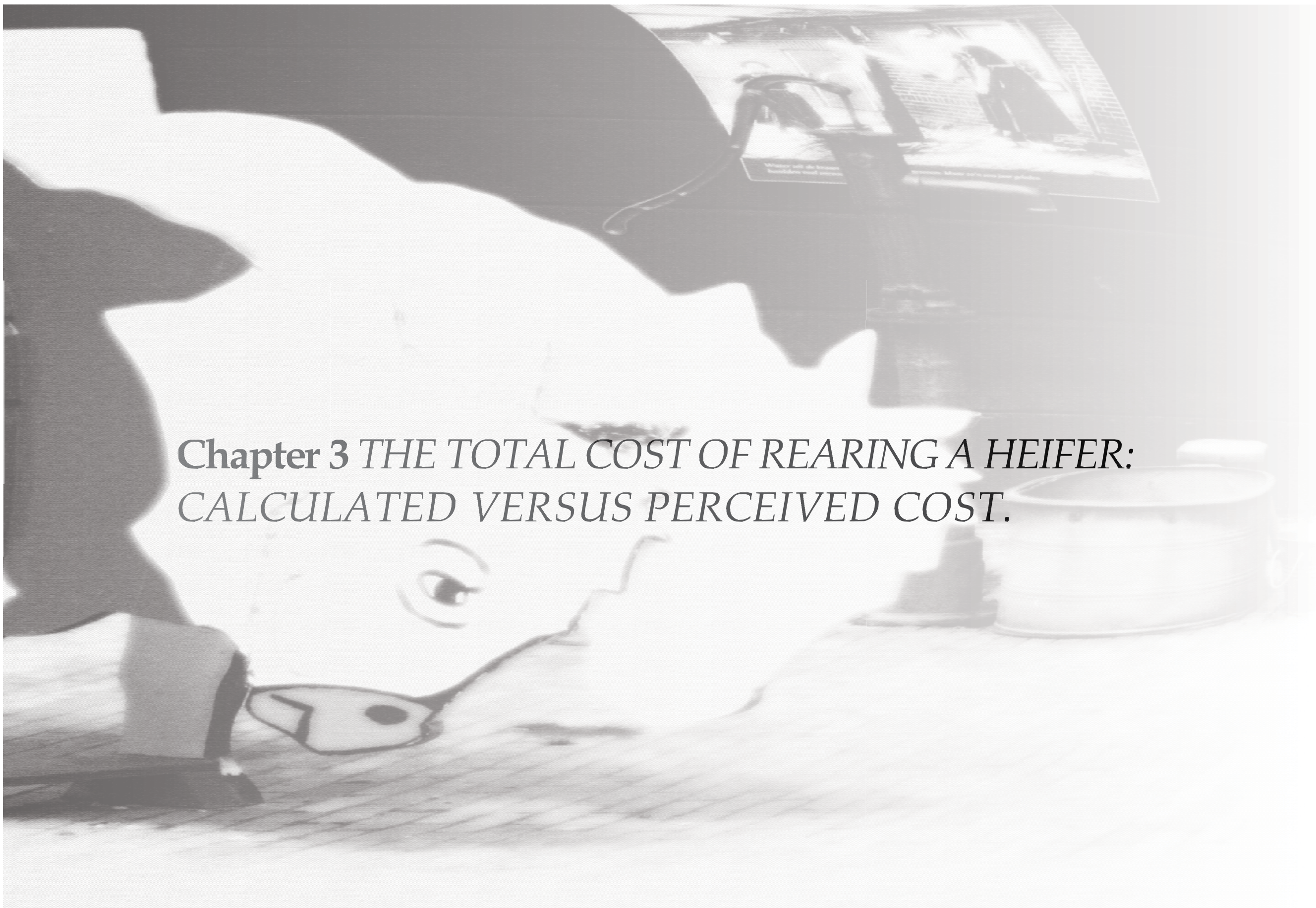
Zanton, G.I., A. J. Heinrichs. 2005. Meta-analysis to assess effect of prepubertal average daily gain of Holstein heifers on first-lactation production. J. Dairy Sci. 88: 3860-3867.

Table A1. Transition matrix combining probabilities and risks

Probability of remaining healthy (H1) in healthy young dairy cattle, incidence risk for calf scours (S1) in healthy young dairy cattle, incidence risk for bovine respiratory disease (B1) in healthy young dairy cattle, case fatality risk for calf scours (M2), case fatality risk for bovine respiratory disease (M3), the probability of cure when infected with calf scours (H2) and the probability of cure when infected with bovine respiratory disease (H3) adapted in the presented model for the winter season (indoor feeding regime).

Age (days)	H1	S1	B1[1]	H2	M2	H3	M3
21	0.9103	0.086	0.0037	0.61	0.29	0.78	0.12
28	0.9102	0.082	0.0078	0.60	0.30	0.78	0.12
35	0.9107	0.080	0.0093	0.60	0.30	0.71	0.19
42	0.9886	0.004	0.0074	0.60	0.30	0.71	0.19
49	0.9929	0.003	0.0041	0.80	0.10	0.71	0.19
56	0.9934	0.003	0.0036	0.80	0.10	0.71	0.19
63	0.9956	0.001	0.0034	0.80	0.10	0.71	0.19
70	0.9942	0.002	0.0038	0.80	0.10	0.71	0.19
77	0.9935	0.002	0.0045	0.80	0.10	0.71	0.19
84	0.9957	0.002	0.0023	0.80	0.10	0.71	0.19
91	0.9956	0.001	0.0034	0.80	0.10	0.71	0.19
98	0.9945	0	0.0055	1	0	0.71	0.19
105	0.9963	0	0.0037	1	0	0.73	0.17
112	0.9942	0	0.0058	1	0	0.73	0.17
119	0.9949	0	0.0051	1	0	0.73	0.17
126	0.9967	0	0.0033	1	0	0.73	0.17
147	0.9965	0	0.0035	1	0	0.71	0.19
168	0.9966	0	0.0034	1	0	0.72	0.18
189	0.9910	0	0.0090	1	0	0.74	0.16
210	0.9938	0	0.0062	1	0	0.74	0.16
231	0.9930	0	0.0070	1	0	0.74	0.16
252	0.9952	0	0.0048	1	0	0.74	0.16
273	0.9961	0	0.0039	1	0	0.74	0.16
294	0.9961	0	0.0039	1	0	0.74	0.16
315	0.9961	0	0.0039	1	0	0.74	0.16
336	0.9961	0	0.0039	1	0	0.74	0.16
357	0.9961	0	0.0039	1	0	0.74	0.16
378	0.9961	0	0.0039	1	0	0.67	0.23
399	0.9961	0	0.0039	1	0	0.67	0.23
420	0.9985	0	0.0015	1	0	0.67	0.23
441	0.9997	0	0.0003	1	0	0.67	0.23
462	0.9997	0	0.0003	1	0	0.67	0.23
483	0.9997	0	0.0003	1	0	0.64	0.26
504	0.9997	0	0.0003	1	0	0.64	0.26
525	0.9997	0	0.0003	1	0	0.64	0.26
546	0.9997	0	0.0003	1	0	0.64	0.26
567	0.9997	0	0.0003	1	0	0.64	0.26
588	0.9997	0	0.0003	1	0	0.64	0.26
609	0.9997	0	0.0003	1	0	0.64	0.26
630	0.9997	0	0.0003	1	0	0.64	0.26
651	0.9997	0	0.0003	1	0	0.64	0.26
672	0.9997	0	0.0003	1	0	0.64	0.26
693	0.9997	0	0.0003	1	0	0.64	0.26
714	0.9997	0	0.0003	1	0	0.64	0.26
735	0.9997	0	0.0003	1	0	0.64	0.26
756	0.9998	0	0.0002	1	0	0.64	0.26

[1] The incidence after 91 days during other seasons is zero



Chapter 3 *THE TOTAL COST OF REARING A HEIFER: CALCULATED VERSUS PERCEIVED COST.*

CHAPTER 3

3

3.1 ABSTRACT

As farmers do not often keep a record of the expenditures for rearing, an economic tool that provides insight into the cost of rearing is useful. In the Netherlands, an economic tool (Jonkos) has been developed that can be used by farmers to obtain insight into the cost of rearing on their farm. The first objective of this study is to calculate the total cost of rearing young stock in Dutch dairy herds using Jonkos. The second objective is to compare the calculated total cost of rearing with the farmers' own estimation of the cost of rearing (the perceived cost). Combining data from two separate studies, information was available for 75 herds that reared their own young stock and who had used the Jonkos tool. The perceived cost of rearing young stock was only available for herds that participated in the first study (36 herds). In these 75 herds, the average herd size was 100 dairy cows and the average milk production of the herd was 811,463 kg/year. The average calculated total cost of rearing a heifer was €1,790 (include labor and barn costs). The average perceived total cost of rearing a heifer (include labor and barn costs) was €1,030 (range from €750 to €1,600) for the 20 herds in the first study. Results show that most Dutch farmers in the study underestimated the total cost of rearing. The Jonkos economic tool has the advantage that herd-specific information can be entered as input values. The output of the tool can improve the awareness of farmers about the total cost of rearing, and this can help farmers to make better-informed decisions about the rearing of young stock.

Key words: costs, dairy, young stock, economics

3.2 INTRODUCTION

Most Dutch dairy herds rear their own young stock to replace culled dairy cows. The total cost of rearing includes several cost factors, such as the costs of feed, the barn, labor, breeding, healthcare, carcass disposal and the cost of buying heifers when not enough replacement heifers are available. Mourits et al. (2000) estimated the total cost of rearing a heifer in a Dutch dairy herd (excluding labor costs) using a dynamic model. The estimates ranged between €907 and €1,134 per heifer. The cost of rearing depends on biological factors, which make it difficult to estimate. Therefore, simulation models are often used to estimate the costs (Gabler et al., 2000; Mohd Nor et al., 2012; Tozer and Heinrichs, 2001). Mohd Nor et al. (2012) used a stochastic model that included uncertainty in diseases and variation in fertility and growth to estimate the total cost of rearing a heifer in a Dutch dairy herd. They estimated that the total cost of rearing a heifer was €1,567 per successfully reared heifer, with costs for feed and labor contributing the most to the total cost (Mohd Nor et al., 2012). In the US, the average total cost of rearing a heifer (including labor costs) was estimated at $1,124 (€788) (Gabler et al., 2000) and $1,808 (€1,320) (Heinrichs et al., 2013).

In practice, farmers do not keep a record of the expenditures made for rearing their young stock. Moreover, it is hard to separate the cost of rearing young stock from the costs for the entire dairy herd enterprise. For instance, because heifers are fed the same type of feed as dairy cows, it is difficult to estimate the proportion of feed costs attributable to young stock. Because of the difficulty of knowing the costs of rearing young stock, it is important for farmers to become more aware of the true cost of rearing. Improved awareness about the cost of rearing allows farmers to make better-informed decisions about the rearing of young stock.

An economic tool that dairy farmers can use to estimate the total cost of rearing a heifer, which is specific for their own herd, has not been developed yet. Furthermore, it is not clear whether farmers are able to accurately estimate the total cost of rearing. The first objective of this study is to estimate the total cost of rearing young stock in individual Dutch dairy herds using a newly developed economic tool. The second objective is to compare the estimated total cost of rearing with the farmers' own estimation of the cost (perceived cost of rearing). The results of this study can help farmers to become more aware of the total cost of rearing a heifer.

3.3 MATERIALS AND METHODS

3.3.1 Jonkos

Jonkos is an economic tool, which has been developed to calculate the cost of rearing young stock. Jonkos was developed to raise farmer awareness about the cost of rearing young stock. The estimation can be made as farm-specific or as general as the farmer wishes, by entering either general information or detailed farm information. The tool calculates both the total cost for the dairy farm and the cost per heifer. Jonkos is developed in Microsoft Excel and was developed as a joint collaboration between WUR Livestock research, Wageningen University Business Economics group, Faculty of Veterinary Medicine of Utrecht University and DLV (*Dienst Landbouw Voorlichting*). The tool Jonkos is available (in Dutch) on the internet (http://www.verantwoordeveehouderij.nl/show/JONKOS-1.htm).

Jonkos consists of a main input-output worksheet, containing the most important input information grouped into eight topics (see Figure 3.1). The eight topics are: general information and numbers of animals, ration, roughage, livestock costs, land and buildings, manure, labor and installations, and water and energy. This sheet has an additional column, where Dutch averages are provided for each parameter,

	A	B	C	D
1	**INPUT**			
2	General and numbers of animals		Suggestion	
3	Delivered milk	800000		kg
4	Number of dairy cows	100		number
5	Number of needed heifer calves	30		number
6	Age at first calving	24		months
7	Number of present youngstock	66.3	58.7	number
8				
9	Replacement rate	30%	30	%
10	Interest on loans	5	5	%
11				
12	Ration			
13	Number of days grazing 0-1 year	90	90	days
14	Number of days grazing >1 year	180	180	days
15	% mais in roughage 0-1 year	10	10	%
16	% mais roughage > 1 year	10	10	%
17	Kg concentrates 0-1 year in barn	1.02	1.02	kg/animal/day in barn
18	Kg concentrates > 1 year in barn	0.93	0.93	kg/animal/day in barn
19	Kg concentrates 0-1 year with grazing	0	0	kg/animal/day grazing
20	Kg concentrates > 1 year with grazing	0	0	kg/animal/day grazing
21				
22	Roughage			
23	Purchase of roughage or own production	purchase		
24	Price of purchased gras silage (45% DM)	50	50	euro/1000 kg incl harvesting + transport
25	Price of purchased maissilage (33% DM)	40	40	euro/1000 kg incl harvesting + transport
26				
27	Livestock costs			
28	Health costs 0-1 year	36	36	euro/animal
29	Health costs > 1 year	15	15	euro/animal
30	Litter costs		876	euro per year
31				
32	Land and buildings			
33	Replacement value barn per animal 0-1 year	1800	1800 - 2000	euro/animal
34	Replacement value barn per animal >1 year	2000	2000 - 2100	euro/animal
35	Lease price land	600	600	euro/ha
36				
37	Manure			
38	Price manure removal	12	12	euro/1000 kg
39				
40	Labor and installations			
41	Price of worked hour	22	22	euro/hour
42				
43	Water and energy			
44	Price of water	1.07	1.07	euro/m^3

Figure 3.1. Input worksheet of the economic tool Jonkos, which calculates the total cost of rearing a heifer.

to assist farmers who do not know their individual farm-specific value. An additional worksheet is available for each topic, where more detailed information on the topic can be entered. These worksheets contain the average Dutch values as the default value, but farmers who think that they deviate from these numbers have the opportunity to enter farm-specific values. The average Dutch values are based on literature (Blanken et al., 2006; Vermeij et al., 2010; Mohd Nor et al., 2012) and the expertise of the developers.

All the costs that can be attributed to the rearing of young stock are taken into account in the Jonkos tool. For instance, the ration of young stock determines the total feed requirements for all young stock present at the farm. If roughage is grown at the farm, then the total feed requirements determine the number of hectares needed for grass and maize, and the subsequent cost of leasing land and cost of labor for fertilizing and harvesting. If roughage is not grown at the farm, then the Jonkos tool calculates the cost of purchasing roughage.

The main input-output worksheet also shows the output, including the cost of rearing young stock expressed per heifer and per herd (Figure 3.2). Details of the different cost components are also presented. To calculate the net cost of rearing for a farm, the revenue foregone from not selling a two-week-old heifer calf is taken into account. Jonkos also accounts for the cost of purchasing heifers if insufficient heifers are available to replace culled dairy cows, as well as the revenue from the sale of excess heifers.

3.3.2 Available data

Using the Jonkos economic tool, the data on the cost of rearing young stock were collected from two separate studies. The first study was conducted in September 2011. In this study, 432 herds associated with

	A	B	C	D	E
1	**OUTPUT**				
2		Per raised heifer		Per 100 kg milk	Per animal/day
3	**Total rearing costs (€)**	1974		7.40	2.50
4	Excluding labor	1481		5.55	1.87
5					
6	**Costs components (€/raised heifer)**				
7	Feed costs	165			
8	Concentrates and milk powder	165			
9	Roughage	0			
10	Livestock costs	211			
11	Health	55			
12	Insemination	47			
13	Interest costs	66			
14	Miscelleneous costs	44			
15	Crop costs	134			
16	Contract work	283			
17	Machines and installations	0			
18	Buildings	316			
19	Lease	313			
20	Water and energy	33			
21	Manure removal	0			
22	Labor	493			
23	Carcass disposal	26			
24					
25	**Results on farm level (€)**				
26	Rearing costs	59298	(+)		
27	Revenue foregone from not selling heifer calves	2049	(+)		
28	Purchase of new heifers	0	(+)		
29	Total	61347			
30	Selling excess heifers	0	(-)		
31	Net costs of rearing	61347			

Figure 3.2. Output worksheet of the economic tool Jonkos, which calculates the total cost of rearing a heifer.

the Utrecht University Large Animal practice (ULP Harmelen) were approached by email. In addition, Veterinary Health Centre '*De Peuvers Esch*' contacted 10 of their clients by telephone to ask them if they were willing to participate in this study. In the first study, 43 herds agreed to participate (34 from the ULP Harmelen and 9 from the De Peuvers Esch). The second study was conducted in June 2013. In this study, 177 herds associated with the Veterinary Centre *Zuid-Oost Drenth*e were approached by email, of which 44 herds agreed to participate.

Each study was conducted by a student from the Faculty of Veterinary

Medicine (Utrecht, the Netherlands). All herds in each study were visited by 1 student in the last phase of his or her study. In the first study, the farmers were first asked orally about the perceived total cost of rearing. Subsequently, it was asked whether the estimate of the farmer included labor and barn costs. In the second study, these questions were not asked. Then, together with the student, the farmers filled in their inputs in Jonkos and obtained an estimation of the total cost of rearing. This took about 20 minutes for each farmer. For four herds in the second study, the data was not useable as the calculations failed to save properly, leaving a total of 83 dairy herds for both studies.

The data editing was performed using Statistical Analysis System (SAS) version 9.2 (SAS Institute Inc., Cary, NC). Of the 83 herds, 7 herds only reared young stock and 1 herd sold all heifer calves at 2 weeks of age. These eight herds were excluded from the analysis, leaving 75 dairy herds. The descriptive results for inputs and outputs were averaged across these herds. In the first study, the farmers were asked whether their perceived total cost for rearing young stock included both labor and barn costs, included labor costs only, included barn costs only, or excluded both labor and barn costs. The difference between the perceived costs and the calculated costs was calculated as the perceived cost minus the calculated cost of rearing a heifer as calculated by Jonkos, where the calculated cost was adjusted for the appropriate inclusion of labor and barn costs.

3.4 RESULTS AND DISCUSSION

The 75 Dutch herds used in the analyses had an average herd size of 100 dairy cows. The milk production of the average herd was 811,463 kg/year. The average number of young stock present in the herds was 69 per year. On average, the first calving age of the heifers was 25.5 months. These results show that the participating herds in our study were bigger than the average herds in the Netherlands (CRV, 2012). The average first calving age for herds in our study was similar to the average first calving age in the Netherlands (CRV, 2012).

The average total cost of rearing a heifer estimated using Jonkos was €1,790. Compared to the previous Dutch study by Mohd Nor et al. (2012), the total cost of rearing in our study is higher. Our estimate includes additional costs, which were not taken into account in the study of Mohd Nor et al. (2012). The additional costs include costs of land ownership, crops, machinery, and contract work. These costs are made to produce feed and were not included in the estimate of Mohd Nor et al. (2012), as they assumed that feed was bought. The total feed cost in our study was €849 per heifer, whereas Mohd Nor et al. (2012) estimated €698 per heifer. The higher cost of feed in our study may suggest that it is expensive for farmers to produce their own feed, nevertheless, this feed could be of a much higher quality.

Previous estimates of the cost of rearing a heifer in US dairy herds varied between $1,124 and $1,808 (Gabler et al., 2000; Groenendaal et al., 2004; Heinrichs et al., 2013). It is difficult to compare these estimates with our study due to different herd systems and circumstances. The largest cost component contributing to the total cost of rearing in our study was the cost of labor, which was an average of €470 (26% of the total cost). This was followed by land ownership (16%), feed costs (15%), barn costs (13%), contract work costs (8%), machine costs (5%), crop costs (4%), carcass disposal costs (3%), interest costs (3%), health costs (2%), insemination costs (2%), miscellaneous costs (2%), water and energy costs (0.9%) and manure costs (0.1%) (see Table 3.1).

Previous studies indicated that feed costs accounted for 50% to 73% of the total cost of rearing (Heinrichs et al., 2013; Mohd Nor et al., 2012). In contrast, feed costs accounted for only 15% of the total cost in our

Table 3.1. Descriptive statistics of the cost components of rearing a heifer (€), estimated using the Jonkos tool for 75 dairy herds.

Cost components	Average	Minimum	Maximum
Labor	470	129	1,661
Barn	236	29	499
Feed	260	74	543
Land ownership	292	0	609
Crops	67	18	173
Contract work	146	0	520
Machines	84	0	516
Health	36	10	84
Insemination	34	0	76
Miscellaneous	31	2	192
Interest	57	23	107
Carcass disposal due to death or culling	58	0	322
Water and energy	17	0	94
Manure	2	0	45
Total	1,790	919	3,307

study. This difference arises because of a different way of classifying costs. Our feed costs only included the cost of milk replacer and concentrates for heifer calves. Other feed costs (production of roughage for heifers) were included in land ownership, contract work costs, and crops costs. If the same cost classification is used as the previous studies, then the actual feed costs during rearing accounted for 43% of the total cost of rearing. This percentage is still slightly lower than previous studies (Heinrichs et al., 2013; Mohd Nor et al., 2012).

The average net cost of rearing, estimated using Jonkos, was €54,034 per year. The total cost of rearing in a 100-cow herd was previously estimated at $32,344 (€23,928) per year (Tozer and Heinrichs, 2001). A comparison is difficult because of different herd systems. In our study, the total cost of rearing (an average of €53,958 per year) had the largest contribution to the net cost of rearing. Other contributing costs were the revenue foregone from not selling heifer calves at two weeks of age (an average of €6,312 per year) and the cost of buying new heifers when insufficient replacement heifers are available (an average of

€1,316 per year). The average revenue from selling excess heifers was €7,553 per year (Table 3.2).

Table 3.2. Costs, revenues, and net cost of rearing a heifer per herd (€), estimated using the Jonkos tool for 75 dairy herds.

Variables	Average	Minimum	Maximum
Costs			
Rearing	53,958	14,802	129,707
Revenue foregone from not selling heifer calves	6,312	665	36,537
Buying new replacement heifers when not enough	1,316	0	35,138
Revenues			
Selling excess heifers	7,553	0	47,614
Net cost of rearing	54,034	8,852	137,724

The perceived total cost of rearing a heifer in 36 herds ranged from €400 to €1,800, with an average of €1,015. The range was large because of the different treatment of labor and barn costs in these estimations. Twenty herds included labor and barn costs, 5 herds excluded labor and barn costs, 9 herds included barn costs only, and 2 herds included labor costs only. For herds that included both labor and barn costs, the average perceived total cost was €1,030 (range from €750 to €1,600). For herds that excluded both labor and barn costs, the average perceived total cost was €925 (range from €400 to €1,300). For herds that included barn costs only, the average perceived total cost of rearing was €1,022 (range from €500 to €1,800) and for herds that only included labor costs, the average perceived total cost was €1,100 (range from €1000 to €1,200). The results show that most farmers (n=30) underestimated the total cost of rearing a heifer (Figure 3.3). The average deviation of the perceived cost from the calculated cost of rearing for herds that included labor and barn costs was -€562 (range from -€1,862 to €134). The average deviation of the cost of rearing for herds that excluded both labor and barn costs was €188 (range from -€89 to €585). The average deviation of the cost of rearing was -€141 (range from -€764 to €866) for herds that only included barn costs and -€391 (range from -€424 to -€359) for herds that only included labor costs. Mou-

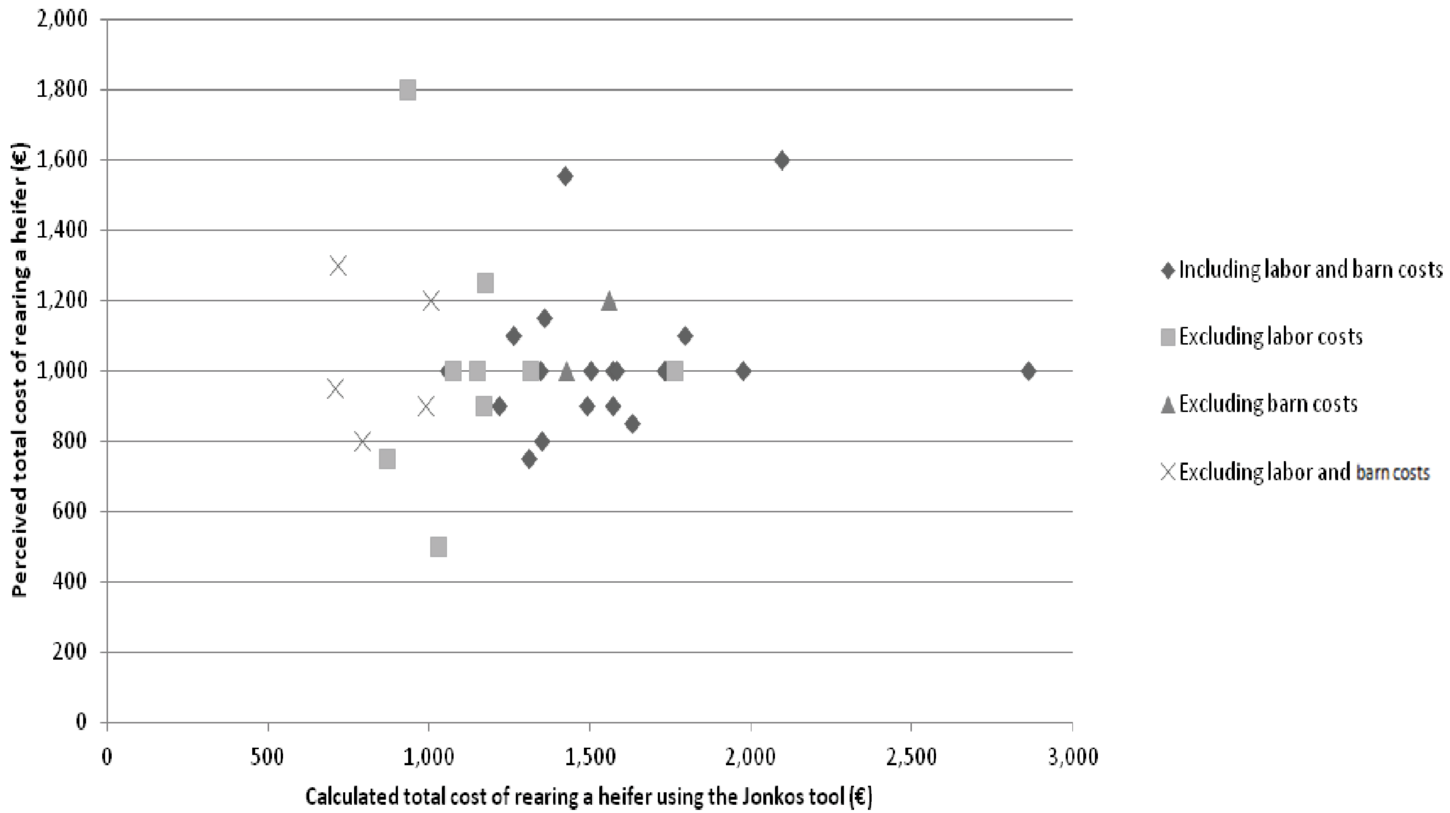


Figure 3.3 The perceived total cost versus the calculated total cost of rearing a heifer using Jonkos (€), for 36 Dutch dairy herds that rear their own young stock, classified according to the treatment of labor and barn costs.

3

rits et al. (2000) found that Dutch farmers perceived the total cost of rearing to be less than Dfl 1,500 (€609) per heifer. No other study has reported the underestimation of the total cost of rearing, therefore comparison with other studies is not possible. It is important to address the underestimation of the total cost of rearing young stock, as the accuracy of the information available to farmers affects the quality of the decisions made about the rearing of young stock. Jonkos is an appropriate tool to improve the awareness of farmers about the total cost of rearing a heifer.

In conclusion, the average total cost of rearing a heifer was €1,790 (include labor and barn costs), estimated using the economic tool Jonkos. The Jonkos tool allows a farmer to use herd-specific information to estimate the total cost of rearing young stock and the tool is easy for farmers to use. The average perceived total cost of rearing a heifer was €1,030 (include labor and barn costs) (range from €750 to €1,600), showing that Dutch farmers underestimated the true cost of rearing. If farmers underestimate the true cost of rearing young stock, then the decisions made about the rearing of young stock may not be well-informed. Jonkos is an appropriate tool to address this underestimation and thereby assist farmers to make better decisions about the rearing of young stock.

Acknowledgements

The authors thank the participating farmers.

References

Blanken, K., A. Evers, R. Ferwerda, C. J. Hollander, G. Kasper, K. de Koning, J. van Middelkoop, W.Ouweltjes, B. Slaghuis, J. Verstappen, J. Visscher and H. Wemmenhove - Animal Sciences Group, Wageningen UR. 2006. Handboek Melkveehouderij. Uitgeverij Roodbont, Zutphen, the Netherlands.

CRV, 2012 (in Dutch, vocabulary in English) https://www.crv4all.nl/over-crv/publicaties/jaarverslagen/327327/

Gabler, M. T., P. R. Tozer, and A. J. Heinrichs. 2000. Development of a cost analysis spreadsheet for calculating the costs to raise a replacement dairy heifer. J. Dairy Sci. 83, 1104-1109.

Groenendaal, H., D. T. Galligan, and H. A. Mulder. 2004. An economic spreadsheet model to determine optimal breeding and replacement decisions for dairy cattle. J. Dairy Sci. 87, 2146-2157.

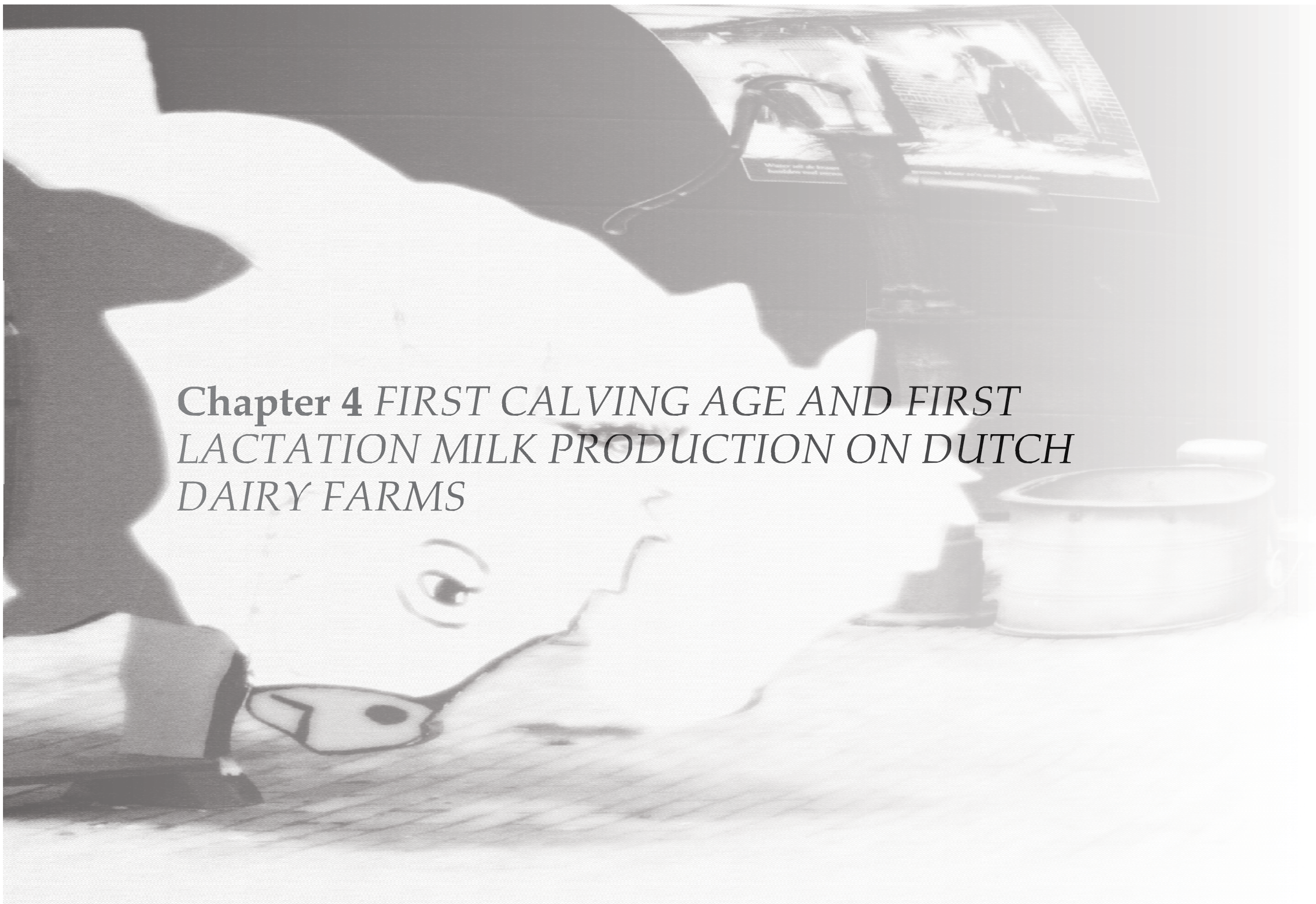
Heinrichs, A. J., C. M. Jones, S. M. Gray, P. A. Heinrichs, S. A. Cornelisse, and R. C. Goodling. 2013. Identifying efficient dairy heifer producers using production costs and data envelopment analysis. J. Dairy Sci. 96, 7355-7362.

Mohd Nor, N., W. Steeneveld, M. C. M. Mourits, and H. Hogeveen. 2012. Estimating the costs of rearing young dairy cattle in the Netherlands using a simulation model that accounts for uncertainty related to diseases. Prev. Vet. Med. 106, 214-224.

Mourits, M. C. M., H. J. Van der Fels-Klerx, R. B. M. Huirne, and M. W. C. Huyben. 2000. Dairy-heifer management in the Netherlands. Prev. Vet.Med. 46, 197-208.

Tozer, P. R. and A. J. Heinrichs. 2001. What affects the costs of raising replacement dairy heifers: A multiple-component analysis. J. Dairy Sci. 84, 1836-1844.

Vermeij, I., B. Bosma, A. Evers, W. Harlaar and I. Vink. 2010. KWIN 2010-2011 (Kwantitatieve Informatie Veehouderij 2010-2011). Handboek 13. Livestock Research, Wageningen UR, Lelystad, the Netherlands.



Chapter 4 *FIRST CALVING AGE AND FIRST LACTATION MILK PRODUCTION ON DUTCH DAIRY FARMS*

This chapter has been adapted from published version: Mohd Nor, N., W. Steeneveld, T. van Werven, M. C. M. Mourits, and H. Hogeveen. 2013. First calving age and first lactation milk production on Dutch dairy farms. J. Dairy Sci. 96:981-992.

CHAPTER 4

4.1 ABSTRACT

Farmers attempting to reduce first-calving age (FCA) need to understand which rearing management factors influence FCA and first-lactation milk production (FLP). Reduced FCA might be associated with lower FLP. This study describes the association between herd FCA, FLP, and several herd-level health and rearing management variables and describes the association between FCA and FLP at the cow level. It uses data from a 2010 survey of 100 Dutch dairy farms about general management, colostrum and milk feeding, housing, cleanliness, healthcare, disease, and breeding. It also used available data on FCA and 305 days FLP at both cow and herd level. The associations between median FCA and median FLP of the herd and herd-level health and rearing management variables were determined using multivariate regression analysis. The median FCA was associated with minimum age of first insemination, feeding of waste milk, and the amount of milk given preweaning. The median FLP was associated with median FCA and vaccination status for bovine respiratory syncytial virus. The association between FCA and FLP (based on 8,454 heifers) was analyzed with a single-effect linear mixed model, where the dependent variable was either FCA or relative FCA (defined as the difference between FCA of the heifer and median FCA of the herd to which they belonged). Heifers having an FCA of 24 months produced, on average, 7,164 kg of milk per 305 days, and calving 1 month earlier gave 143 kg less milk per 305 days. When FCA did not deviate from the median herd FCA, heifers produced, on average, 7,272 kg of milk per 305 days. From the median FCA of the herd, heifers calving 1 month earlier produced 90 kg of milk per 305 days less, and heifers calving 1 month later produced 86 kg per 305 days more. This is the first study that explained

FLP using relative FCA. It assumes that heifers raised within the same farm have similar development because they are similarly managed. Similar management is reflected by the median FCA of the herd, with a deviation of the heifer's FCA from median FCA reflecting the heifer's development relative to the herd's average. The advantage of using relative FCA was that it accounts for between-farm differences in rearing management. It showed that earlier insemination without adjusting management to ensure sufficient development lowers FLP. An economic optimum exists between rearing costs, FCA, and FLP and, as a consequence, decisions with regard to young stock management should be made with care.

Key words: first calving age, milk production at first lactation, dairy heifer, rearing management

4.2 INTRODUCTION

Young stock rearing requires a large economic investment from dairy farmers (Tozer and Heinrichs, 2001; Gabler et al., 2000), with, for example, on Dutch farms, the total costs of rearing varying between \$1,800 and \$2,200 per heifer (Mohd Nor et al., 2012). Per heifer, reducing first-calving age (FCA) by a month reduces the costs of rearing by \$51 to \$116 (Mohd Nor et al., 2012; Gabler et al., 2000). However, a reduced FCA might be associated with lower first-lactation milk production (FLP). This possible negative effect must be considered when making decisions on reducing FCA.

First-calving age, growth rate, and BW at first calving are generally correlated (Le Cozler et al., 2008), making it difficult to ascertain independently the effects of each variable on FLP (Mourits et al., 1997). In rearing experiments, 2 experimental variations will always exist, as growth rate will affect BW at first calving unless the FCA is changed accordingly (Mourits et al., 1997). The advantage of rearing experiments is the possibility of having detailed insights into growth and the time of insemination and time of calving. For instance, lowering the FCA with an accelerated daily gain during the prepubertal period is known to have a negative effect on FLP (Le Cozler et al., 2008; Sejrsen et al., 2000). According to a study by Dobos et al. (2001), this lowering can be offset by increasing the BW at calving. The disadvantage of such experimental studies is the relatively low numbers of animals farms that were studied, which make generalization more difficult.

In contrast, analyses of field data generally involve heifers with the same growth strategies but with different ages and BW at first calving (Mourits et al., 1997). Such studies have high numbers of animals and farms, but lack information about growth and BW at calving (e.g Berry and Cromie, 2009; Haworth et al., 2008; Ettema and Santos, 2004). As previous field studies have shown, lowering FCA by a month can reduce FLP by 56 to 60 kg (Berry and Cromie, 2009; Dobos et al., 2001; Pirlo et al., 2000), lowering FCA under 700 days with an equal daily gain among heifers can create total yield losses of more than 310 kg (Ettema and Santos, 2004) and lowering FCA below 2 years of age can lower FLP by up to 0.6 L per day (Haworth et al., 2008). Under practical farm circumstances, however, the correlation with BW at calving makes studying the association between FCA and FLP difficult.

As findings from previous studies have indicated, specific management factors have an influence on both FCA and FLP. For example, FCA increases with a higher number of days of antibiotic treatment in the first 16 weeks of life, maximum milk intake, maximum humidity, and daily temperature and with increased ammonia levels in calf housing areas (Hultgren et al., 2008; Heinrichs et al., 2005). First-calving age decreases with a high-energy and protein diet during rearing (Davis Rincker et al., 2011). First-lactation milk production has been shown to increase with number of days of antibiotic treatment before 4 months of age, increases in DMI during weaning, and increases in the amount of concentrate fed around calving (Heinrichs and Heinrichs, 2011; Svensson and Hultgren, 2008). First-lactation milk production decreases with morbidity due to calf diarrhea (Svensson and Hultgren, 2008) and with a higher number of days of illness before 4 months of age (Heinrichs and Heinrichs, 2011).

Farmers attempting to make decisions that will reduce rearing costs need to understand which rearing management factors influence FCA and FLP. Yet, studies to support such decisions within intensive dairy farming are scarce (Mourits et al., 1999). Particularly useful in this regard are studies that evaluate the association between FCA and FLP with management factors during rearing such as calf diseases, healthcare, preweaning feeding, housing, and breeding, as well as those that examine the association between FCA and FLP under practical farm circumstances.

The first objective of this study was to describe the association between FCA and FLP with health and management rearing factors derived from a questionnaire that queried Dutch dairy farmers on general management, healthcare, calf diseases incidence, preweaned colostrum and milk feeding, housing, cleanliness, and breeding. The second objective of this study was to describe the association between FCA and FLP at the cow level.

4.3 MATERIALS AND METHODS

4.3.1 Data Collection

Data were collected at 100 farms in the western part of the Netherlands. These farms were chosen to participate because they were regular clients of the University Large Animal Veterinary Practice (Utrecht University, Utrecht, the Netherlands). Each farm was visited once by a trained veterinary student in September or October 2010 for a survey including both the student's observations (e.g., on factors such as the cleanliness of the barns) and a questionnaire about young stock rearing management. The questionnaire included 98 questions related to young stock rearing management, with open-ended (n = 33), closed (n = 44), and semi-closed (n= 20) types of questions. They covered general information about the farm, colostrum, and milk feeding, breeding, diseases, healthcare, and housing. The questions about feeding, diseases, healthcare, housing, and cleanliness were carried out for 3 different age groups: from birth to weaning, from weaning to 1 year of age, and from 1 to 2 years of age. Some questions (e.g., on the cleanliness of the barn during inspection) used a 5-point scale. An outline of the questionnaire design is given in Appendix Table A1. The full questionnaire (in Dutch) is available upon request from the authors. For this study, the University Large Animal Veterinary Practice also provided the average number of animals on the farms in 2010 and the average age of first insemination (months). The average number of animals on the farm was provided for different age groups: less than 1 year of age young stock, between 1 and 2 years of age, and more than 2 years of age. For all heifers on these 100 farms from July 2003 to June 2010, the cooperative cattle improvement organization CRV BV (Arnhem, the Netherlands) provided milk production records and calving dates.

4.3.2 Data Preparation

Herd Level Dataset. For analysis of the association between FCA and FLP with health and management rearing, 13 farms were excluded because they did not rear their own young stock (n = 11) or they had no young stock below 1 year of age (n = 2). The final data set thus covered 87 farms.

For these 87 farms, the median FCA and median 305 days FLP were determined using data of individual heifers. The median was used instead of the average to exclude extreme heifers that may have unduly influenced the results. To determine the median FCA and median 305 days FLP, only heifers calved after January 2008 were used. This guaranteed that the heifers experienced the rearing conditions that were reported in the survey (autumn 2010). For 2 farms that indicated their rearing management changed dramatically since 2008, only heifers calved after January 1, 2010, were included. In one of the farms, data on FCA of the heifer was unavailable and further, in those 2 farms, data on FLP of the heifer was unavailable. Consequently, median FCA was determined for 86 farms and median FLP for 85 farms. The median FCA of the herd was categorized into 3 groups: ≤24 mo of age, >24 to <27 mo of age, and ≥27 mo of age.

From the survey, a total of 115 herd-level rearing management variables were available, representing general management, colostrum and milk feeding, housing, cleanliness, healthcare, disease, and breeding during rearing. Certain variables were excluded (e.g., treatment variables) because more than 50% of values were missing, combined with each other (e.g., hygiene score and barn cleaning frequency), categorized (e.g., housing variables), or newly produced (e.g., estimated number of sick animals) during data editing. In this way, meaningful variables were defined and the power of the statistical analysis was improved. Examples of variables produced from the raw data included disease incidence due to calf scours and bovine respiratory disease (BRD). These were based on the farmer's own estimation of the number of sick animals and not from records, divided by the average number of young stock (age <1 year) on the farm, to yield the disease incidence of these diseases in calves younger than 1 year of age. The waste milk variable used in this study was defined as milk taken from dairy cows treated with antibiotics, which cannot be sold for human consumption. A complete overview of the edited variables appears in Appendix Table A2.

Cow Level Dataset. For the analysis of the association between FCA and 305 days FLP, information on 8,454 individual heifers was available from the 100 herds. These heifers had an FCA >18 months of age, a first-lactation duration >250 days, and had calved between July 3, 2003, and June 10, 2010. Subtracting the heifer's birth dates from their first-calving dates produced the absolute FCA. To account for differences in rearing management among herds, the relative FCA was calculated. This was done by first determining the median FCA for every herd and then calculating relative FCA by subtracting the absolute FCA of every individual heifer from the median FCA of the herd to which they belonged. Data preparation was performed using SAS (version 9.2, SAS Institute, Cary, NC).

4.3.3 Data Analysis

Herd Level Analysis. For the analysis of the association between median FCA of the herd and rearing management, the data were analyzed with a multinomial logistic regression model with a logit link using PROC LOGISTIC in SAS (version 9.2). As a first step, univariate chi-squared analyses were performed, testing (one at a time) the independent variable possibly associated with median FCA of the herd and selecting those independent variables with a type 3 $P \leq 0.25$ based on the F-test. Thereafter, the selected independent variables were used in the multivariate model, which was built using a backward selection procedure. In each step, the least statistically significant independent variable was excluded until all independent variables in the final multivariate model had a type 3 $P \leq 0.05$.

For the analysis of the association between median FLP of the herd and rearing management, analysis of the data was performed with a linear regression model using PROC GLM in SAS (version 9.2), assuming normality of residuals. Univariate analyses were performed to select independent variables possibly associated with median FLP of the herd with a type 3 $P \leq 0.25$ based on the F-test. The selected independent variables and an interaction term [amount of first colostrum (Liters) after birth with the time after birth to give the first colostrum (minutes)] were included in the multivariate model. The final multivariate

4

model was built using a backward selection procedure. In each step, the least statistically significant independent variable was excluded until all independent variables in the final multivariate model had a type 3 $P \leq 0.05$. The overall model fit was assessed by graphical examination of residuals, the Shapiro-Wilk test, looking for outliers, and by checking for homoscedasticity.

Cow Level Analysis. or the analysis on the association between FCA and 305 days FLP, the data of 8,454 heifers were analyzed with a single-effect linear mixed model using PROC MIXED in SAS (version 9.2). The dependent variable was the heifer's 305 days FLP, and the independent variable was absolute FCA. The variables season, herd (random variable), and year (random variable) were forced in the model. The absolute FCA was categorized by monthly age groups and the model was analyzed with an absolute FCA of 24 as the reference category. In addition, a similar model using relative FCA as independent variable was analyzed. The relative FCA was categorized by monthly age groups and the model was analyzed with the category 0 (not deviating from the median FCA of the herd) as the reference category. The overall model fit was assessed by graphical examination of the residuals and by the Kolmogorov-Smirnov test, looking for outliers and checking for homoscedasticity.

4.4 RESULTS

4.4.1 General Herd Characteristics

The average number of dairy cows on the 87 Dutch farms ranged between 26 and 170 cows, with an average of 73 (SD ± 26) cows. The average number of dairy heifers (1 to 2 years of age) and the average number of heifer calves (<1 year of age) present on these farms were 20 (SD ± 8; range 1 to 43) heifers and 24 (SD ± 10; range 7 to 56) heifer calves. The predominant breed was Holstein-Friesian (91%).

The median FCA of the herd on the 86 farms was 25.4 months (SD ± 1.45, range 23 to 30 months). The median 305 days FLP of the herd on the 85 farms was 7,518 kg per 305 days (SD ± 835, range 5,803 to 10,364 kg per 305 days).

4.4.2 Young Stock Rearing Management Characteristics

The average time in providing the first colostrum to heifer calves was 93 minutes (SD ± 77; range 1 to 480 minutes), with an average first amount of 2 Liters (SD ± 0.74; range 0.75 to 4 Liters). Within the first 24 hour, the total amount of colostrum given was, on average, 5.4 Liters/day and decreased to 4.3 Liters/d on the second day. During the first day, the average frequency of feeding the colostrum was 3 times per day (SD ± 0.78, with a range of 1 to 5 times per day). On about 44% of the farms, the heifer calves were given the waste milk. The weaning age was, on average, 74 days (SD ± 24.81; range 24 to 200 days).

The minimum heifer age farmers were willing to start the first insemination was, on average, 14.9 months (SD ± 1.02; range 13 to 18 months). The average heifer age farmers actually started with insemination was 15.9 months (SD ± 1.44; range 13.9 to 19.6 months). The majority of the farmers (60%) indicated that they used age to determine the moment of first insemination.

No disease problems in unweaned heifer calves were reported by 34% of the farms, whereas 44% of farms had either calf scours or BRD and 22% indicated that they had both calf scours and BRD. Using the farmers' estimates for the number of sick animals, calf scours incidence in heifer calves averaged 29% (SD ± 0.26; range 0 to 0.96) from birth to 1 year of age, which was especially concentrated in the time before weaning (on average, 9 days of age). BRD incidence averaged 11% (SD ± 0.20) from birth to 1 year of age, and ranged from 0 to 87%. Deworming was practiced by 63% of the farms, especially in grazing heifers. Vaccination of heifer calves was done by less than half of the farms, using lung worm vaccine (43%), bovine respiratory syncytial virus (BRSV) vaccine (34%), bluetongue vaccine (26%), infectious bovine rhinotracheitis vaccine (11%), bovine viral diarrhea vaccine (10%), rotavirus and coronavirus vaccine (5%), and *Escherichia coli* vaccine (1%).

4.4.3 Associations between Median FCA and Median 305 days FLP of the Herd with Rearing Management

The results of the univariate analysis on the association between rearing management and median FCA of the herd are presented in Tables 4.1 and 4.2. The final multivariate model included the variables minimum age to first insemination, giving calves waste milk, and the amount of milk given to a calf (Table 4.3). Increasing the minimum age to first insemination by 1 month resulted in higher odds of having a higher median FCA of the herd. Not giving waste milk and increasing the amount of milk by 1 Liter resulted in higher odds of having a lower median FCA of the herd.

The results of the univariate analysis on the association between median FLP of the herd and rearing management are presented in Tables 4.1 and 4.4. The final multivariate model included the variables vaccination status for BRSV and median FCA of the herd (Table 4.5). Not vaccinating heifers against BRSV lowered the farm's 305 days FLP by 493 kg (P= 0.063). Compared with median herd FCA of >24 to <27 months, a median herd FCA of ≤24 months was correlated to a higher median herd FLP (+573 kg per 305 d; P= 0.037).

4.4.4 Associations between FCA with 305 days FLP

Heifers that calved at 24 months of age produced, on average, 7,164 kg per 305 days (Table 4.6). Heifers that calved a month earlier (absolute FCA = 23 months) had an FLP of 143 kg per 305 d less, a significantly lower amount. Heifers that calved a month later (absolute FCA =

Table 4.1. Effect of management factors (continuous) during rearing on the median 305 days milk production of the herd during first lactation (n=85) and the median first calving age of the herd (n=86)[1]

Management factor	Months	Median first calving age of the herd			Median milk production of the herd at first lactation		
		N	Mean (±Sd)	*P*-value	N	Mean (±Sd)	*P*-value
Breeding							
Minimum age to start first insemination (months)	≤24	22	14.2 (0.612)	0.0013	-	-	-
	>24 to <27[2]	46	15.0 (0.728)	-			
	≥27	14	15.9 (1.384)	0.0036			
Colostrum management							
First colostrum amount (liters)	-	-	-	-	81	2 (0.68)	0.1640
Total colostrum amount first day (liters)	≤24	22	5.9 (1.914)	0.1720	80	5 (1.60)	0.1111
	>24 to <27[2]	46	5.3 (1.360)	-			
	≥27	12	4.6 (1.620)	0.0993			
Time after birth farmers give colostrum (minutes)	-	-	-	-	81	93 (77.43)	0.2051
Milk feeding							
Weaning age (days)	-	-	-	-	78	73 (24.62)	0.0507
Amount milk (liters/day)	≤24	23	5.3 (1.429)	0.3732	85	5 (1.23)	0.1587
	>24 to <27[2]	47	5.1 (0.989)	-			
	≥27	15	4.2 (1.147)	0.0203			
Disease							
Calf scours incidence (%)	-	-	-	-	80	29% (0.26)	0.2264
BRD[3] incidence (%)	-	-	-	-	85	11% (0.20)	0.2193

[1]All estimates are based on univariate analyses and only management factors with *P*-values <0.25 are reported
[2]Farm with first calving age of >24 to <27 months was the outcome reference group
[3]BRD=bovine respiratory disease

Table 4.2 Effect of management factors (categorical) during rearing on median first calving age of the herd (n=86) by univariate analyses with *P* <0.25 reported

Management factor	Category	Median first calving age of the herd (months)			
		≤24 (n)	>24-<27[1] (n)	≥27 (n)	*P*-value
Pre-weaning feeding					
Milk types	Cow	6	22	11	0.0123
	Artificial	16	16	3	-
	Both	2	9	1	-
Waste milk given to calf	No	18	24	6	0.0567
	Yes	6	23	9	-
Healthcare					
Lung worm vaccination	No	11	24	12	0.0733
	Yes	13	23	3	-
Deworming	No	11	15	8	0.2500
	Yes	13	32	7	-
BRSV[2] vaccination	No	15	27	13	0.0912
	Yes	9	20	2	-
Housing					
Keeping young stock					
Age group= 1 to 2 years	With cows	12	25	3	0.0622
	Separate barn	12	22	12	-
Type of bedding					
Age group =before weaning (individually)	Straw	10	29	4	0.0815
	Grid	12	17	9	-
Age group =before weaning (in group)	Straw	21	38	10	0.1365
	Others	2	3	4	-
Type of ventilation					
Age group= before weaning (in group)	Passive	8	11	7	0.2236
	Natural	10	32	4	-
Housed with dairy cows					
Age group= 1 to 2 years	Fan	3	1	1	-
	No	12	24	3	0.0797
	Yes	12	23	12	-

[1]Farm with first calving age of >24 to <27 months was the outcome reference group
[2]Bovine respiratory syncytial virus

Table 4.3. Results of the final multivariate model on the association between rearing management factors and median first calving age of the herd in 86 Dutch dairy farms that rear own young stock

Variable	Odds ratio	95% Wald confidence limits	P-value
Waste milk=not given			
≤24 months	3.656	0.953-14.034	0.0589
>24 to<27 months	Ref[1]	-	-
≥27 months	0.499	0.119-2.091	0.3413
Amount of milk (liters/d)			
≤24 months	1.776	0.932-3.384	0.0808
>24 to<27 months	Ref[1]	-	-
≥27 months	0.582	0.319-1.062	0.0779
Minimum age to start first insemination (month)			
≤24 months	0.201	0.076-0.530	0.0012
>24 to <27 months	Ref[1]	-	-
≥27 months	2.834	1.316-6.103	0.0078

[1]Ref= Reference group

25 months) had an FLP of 48 kg more per 305 d. Heifers that calved 2 months later (absolute FCA = 26 months), had an FLP of 144 kg more per 305 days, a significantly higher amount.

Heifers with a relative FCA of 0 (not deviating from the median FCA of the herd) had, on average, an FLP of 7,272 kg per 305 days (Table 4.6). Heifers calving 1 month earlier than this (relative FCA = −1) had an FLP of 90 kg per 305 days less, a significant difference, whereas those calving 2 months earlier (relative FCA = −2) produced 174 kg less than the median. Heifers calving a month later than their farm's median FCA (relative FCA = +1) had an extra FLP of 86 kg of milk per 305 days, and for those calving 2 months later than their farm's median FCA (relative FCA = +2), the yield difference was 163 kg. The 305 days FLP of heifers calving in winter was the highest (on average, 7,652 kg, SD ± 1,280). Heifers calving in the summer had the lowest 305 days FLP (on average, 7,312 kg, SD ± 1,282; P< 0.05).

Table 4.4. Effect of management factors (categorical) during rearing on median 305 days milk production of the herd (kg; n=85) at first lactation by univariate analyses, with *P* <0.25 reported

Management factors	Category	Median milk production of the herd at first lactation		
		N	Mean (±Sd)	P-value
Median herd first calving age	≤24 months	24	7,830 (978)	0.0774
	>24-<27months	46	7,356 (764)	-
	≥27 months	15	7,515 (693)	-
Feeding				
Water ad lib	No	20	7,331 (1,055)	0.1587
	Yes	65	7,568 (729)	-
Vaccinations				
BRSV[1] vaccination	No	55	7,403 (845)	0.0842
	Yes	30	7,730 (786)	-
Housing				
Intention to adapt barn at	No	48	7,423 (857)	0.2327
	Yes	37	7,641 (801)	-
Age group weaning to 1 year				
Age=1 to 2 years	No	35	7,379 (837)	0.2012
	Yes	50	7,615 (828)	-
Type of floor at				
Age=before weaning (in group)	Solid floor	49	7,598 (780)	0.2022
	Grid floor	29	7,356 (837)	-
Age=after weaning to 1 year	Solid floor	13	7,234 (682)	0.2001
	Grid floor	71	7,559 (855)	-
Type of ventilation at				
Age = before weaning (in group)	Passive	34	7,344 (672)	0.2099
	Natural	28	7,711 (932)	-
	Fan	7	7,597 (928)	-
Housed with dairy cows at				
Age = before weaning (individually)	No	81	7,547 (842)	0.1494
	Yes	4	6,929 (365)	-
Pregnant heifers kept with dairy cows	No	34	7,353 (785)	0.1376
	Yes	51	7,628 (857)	-

[1]Bovine respiratory syncytial virus

Table 4.5. Results of the final multivariate model on the association between rearing management factors and median 305 days milk production of the herd (kg) at first lactation in 85 Dutch dairy farms that rear own young stock

Variable	Category	β	SE (β)	Df	P-value
Intercept		7,369	619	1	<0.0001
Vaccinated with BRSV[1]	Yes	Ref[2]	-	-	-
	No	-493	258	1	0.0634
Median herd first calving age (months)	≤24	573	266	1	0.0374
	>24 to <27	Ref[2]	-	-	-
	≥27	696	390	1	0.0817

[1]Bovine respiratory syncytial virus
[2]Ref= Reference group

4.5 DISCUSSION

This study used data from farms in the western part of the Netherlands. Although this geographical distribution indicates that they were not randomly selected from the Dutch population of farms, the number of dairy cows and heifers, average FCA, and 305 days FLP are comparable with Dutch dairy heifer population averages (CRV, 2010). Incidences for both calf scours and BRD in this study were higher than earlier reports both for Norway and the Netherlands (Gulliksen et al., 2009; Perez et al., 1990). This could be related to the fact that the number of sick animals in the current study was based on the farmers' own estimations and not based on actual farm records. At the same time, as Dutch farmers are more known to underestimate disease incidences than to overestimate disease incidences (Huijps et al., 2008), it could very well be that the incidence of diseases has increased over time. Other young stock rearing management factors, such as weaning age and breeding moment, are comparable with the results of other previous Dutch study (Mourits et al., 2000b).

As our results show, the median FCA of the herd was associated with only

Table 4.6. The association between 305 days milk production (kg) at first lactation with first calving age of 8,454 heifers[1]

Absolute first calving age (months)													
Item	≤20	21	22	23	24[2]	25	26	27	28	29	30	31	≥32
n	19	30	180	825	1,756	1,733	1,372	854	610	391	257	149	323
305 days milk production at first lactation (kg)													
β^1	6,295***	6,697*	6,876***	7,021***	7,164	7,212	7,308***	7,454***	7,489***	7,545***	7,540***	7,760***	7,816***
SE (β)	244	199	112	89	85	85	86	88	91	96	102	115	99
Relative first calving age (months)													
Item	≤-6	-5	-4	-3	-2	-1	0[2]	+1	+2	+3	+4	+5	≥+6
n	23	18	44	210	856	1,957	2,063	1,253	772	476	282	181	319
305 days milk production at first lactation (kg)													
β^1	6,274***	7,125	6,738***	6,952***	7,098***	7,182**	7,272	7,358*	7,435***	7,542***	7,591***	7,643***	7,779***
SE (β)	231	251	171	105	85	81	81	83	86	90	187	107	96

[1]Heifers that calved at absolute first calving age of 24 months were the reference group because it has the highest number of heifers. Heifers that calved at relative first calving age=0 was reflecting heifers within a same farm and imposed with similar management. The deviation from this reflected heifers that are less developed (-ve sign) or more developed (+ve sign). The impact of calving at different absolute first calving age and the impact of deviation in relative first calving age and are shown in 305 days milk production at first lactation

[2]The reference groups

**P* < 0.05; ** *P* < 0.01; ****P* < 0.001

a few rearing management factors. These management factors are the amount of milk given to unweaned calves, whether waste milk is given to calves, and the minimum age at first insemination (Table 4.3). Further, only a few rearing management factors were associated with a herd's median FLP. These management factors were the median FCA of the herd the herd and whether calves were vaccinated against BRSV (Table 4.5). The near absence of management factors associated with the median FCA and FLP of the herd can be explained by several interconnected factors. First, the median FCA of the herd and the age of the heifers when farmers started first insemination were strongly associated. As rearing management on each farm can influence both growth and BW, farmers expect their heifers to be sufficiently developed at a certain minimum age. They, therefore, prefer to use age and not BW to determine the start of insemination. This risk-avoiding behavior may have masked the effect on median FCA and FLP of other management factors during rearing (such as colostrum management and disease incidences). Second, measuring the farmer's management is difficult and, with a relatively small number of farms (n = 86), could have resulted in the low number of statistically significant relations between young stock rearing management and FCA and FLP. In addition, data on several factors that can be seen as links between management and FCA/FLP (e.g., nutrition, feed intake, energy density and protein level, calving weight, and growth) were unavailable and, therefore, were not included in the model.

Still, as these results indicate, a lower median FCA of the herd (Table 4.3) was associated with a greater amount of milk given during the first months of life. Similar results have been shown in previous studies, which have indicated that a greater amount of milk is related to better growth and earlier insemination (Le Cozler et al., 2008; Svensson and Hultgren, 2008), which can result in a lower FCA. In our study, a lower FCA for the herd was also associated with not giving waste milk (Table 4.3). This finding may be explained by the fact that farms that did not giving waste milk were the farms that practiced good animal welfare (Vasseur et al., 2010) and good rearing management. supported by previous findings indicating that giving waste milk did not affect a heifer's growth during preweaning (Jamaluddin et al., 1996).

Interestingly, an association was found between median FLP of the herd and BRSV vaccination status. Bovine respiratory syncytial virus is one of the causes for BRD, which from previous studies is known to reduce growth in heifers (Van der Fels-Klerx et al., 2002). As growth and BW at calving are related to milk production (Le Cozler et al., 2008), growth reduction due to not vaccinating against BRSV may explain the found reduction of median FLP of the herd. In addition, in a previous study, a reduction in milk production was found after an outbreak of BRSV on a farm (Beaudeau et al., 2010).

In this study, the association between FCA and FLP was studied by using both absolute FCA and relative FCA (Table 4.6). In previous studies using field data, FLP was explained by absolute FCA. For instance, in an Italian study, a change in absolute FCA from 29 to 24 months reduced the 305 days FLP by 255 kg (Pirlo et al., 2000), whereas in the current study, this would be a reduction of 391 kg. To our knowledge, ours is the first study that explained 305 days FLP using relative FCA to reflect the development of each heifer relative to the management of the herd in which the heifer was raised. This required the assumption that within the same farm, heifers will have similar development because they were similarly managed. Rearing management can be reflected by median FCA of the herd and, therefore, a deviation in the heifer's FCA from the median FCA is thought to reflect the heifer's development relative to the herd's average. The advantage of using relative FCA was that it took into account that each farm in this study had a different rearing management strategy and, therefore, it was suitable to be used in a field situation. Lowering the relative FCA on a farm will reduce the rearing costs (Mohd Nor et al., 2012). However, when the FCA is lowered by earlier insemination without adjusting the management to ensure sufficient development, it will also lower the milk production at first lactation (Table 4.6). At the cow level, although a month lower relative FCA is expected to reduce the total cost of rearing by, on average, $77 per heifer (Mohd Nor et al., 2012), it creates additional loss in revenues by reducing milk yield by 90 kg in the first lactation. This means that with a net benefit per kilogram of milk of $0.32 (LEI, 2012), the reduced rearing costs from a month lower FCA should be adjusted to an estimated $48 per heifer. This was estimated to be 1.7% of the gross margin per cow per year (LEI, 2012). At the herd level, lowering the FCA will produce additional savings by reducing the number of replacement heifers needed (Mourits et al., 2000a). As our results also indicate, a higher relative FCA resulted in higher milk production (Table 4.6), but these higher benefits from milk production were associated with higher rearing costs. These results show that an economic optimum exists between rearing costs, FCA, and FLP, and, as a consequence, that decisions with regard to young stock management should be made with care.

In our study, the majority of the farmers (60%) indicated that age determined the moment of first insemination. The minimum age the farmers would like to start inseminating was, on average, 15 months, varying between 14 to 16 months (5–95% percentiles). This would indicate that the desired FCA would be 24 months, varying between 23 to 25 months (5–95% percentiles). The age at first insemination should be the result of a proactive goal in combination with (feeding) management that enables reaching the goal. However, it is our impression that the answers of the farmers reflected knowledge rather than a well-thought-out proactive goal. This impression is supported by the findings that young stock rearing is the least important element on Dutch dairy farms (Derks et al., 2012) and that the majority of Dutch farmers relate their rearing performance primarily to chronological target values instead of physiological target values (Mourits et al., 2000b). The lack of a proactive goal for insemination/FCA would mean that achieving a higher FLP at a lower FCA would be difficult because farmers would not actively work on adjusting the management and nutrition to ensure sufficient BW at calving. Previous studies have already stressed the importance of proactive FCA and BW at calving as the primary factors that influence FLP (Bach and Kertz, 2010; Fox et al., 1999; Van Amburgh et al., 1998). Unfortunately, in our study, as in other studies (Le Cozler et al., 2010; Ettema and Santos, 2004), that information was not available. Due to the lack of information on BW, nutrition, and growth, it was not possible to do a complete investigation on which factors influence the FLP.

4.6 CONCLUSIONS

First-calving age was found to be associated with several management factors during the rearing period: the amount of milk fed to the calves, waste milk feeding, and the minimum age the farmer used for starting the first insemination. First-lactation milk production was associated with FCA and BRSV vaccination status. To reduce the total costs of rearing, farmers can lower their heifers' FCA by earlier inseminations. However, earlier inseminations without adjustment of the rearing management to ensure sufficient development will cause lower FLP. These findings indicate that with regard to young stock rearing, an economic optimum exists between rearing costs and FCA.

References

Bach, A. and A. F. Kertz. 2010. Raising Dairy Replacements Objectively: The Value of Data-Based On-Farm Decisions. Pages 77-90 in Proc. Tri-State Dairy Nutr. Conf., Ft. Wayne, IN., The Ohio State Univ., Columbus.

Beaudeau, F., A. Ohlson, and U. Emanuelson. 2010. Associations between bovine coronavirus and bovine respiratory syncytial virus infections and animal performance in Swedish dairy herds. J. Dairy Sci. 93:1523-1533.

Berry, D. P. and A. R. Cromie. 2009. Associations between age at first calving and subsequent performance in Irish spring calving Holstein-Friesian dairy cows. Livest. Sci. 123:44-54.

CRV, 2010. CRV Jaarstatistieken Nederland (in Dutch). Accessed Jan. 1, 2012. https://www.cr-delta.nl/servlets/dbupload?id=27569.

Derks, M., L. M. A. van de Ven, T. van Werven, W. D. J. Kremer, and H. Hogeveen. 2012. The perception of veterinary herd health management by Dutch dairy farmers and its current status in the Netherlands: A survey. Prev. Vet. Med. 104:207-215.

Dobos, R. C., K. S. Nandra, K. Riley, W. J. Fulkerson, I. J. Lean, and R. C. Kellaway. 2001. Effects of age and liveweight at first calving on first lactation milk, protein and fat yield of Friesian heifers. Aust. J. Exp. Agr. 41:13-19.

Ettema, J. F. and J. E. P. Santos. 2004. Impact of age at calving on lactation, reproduction, health, and income in first-parity Holsteins on commercial farms. J. Dairy Sci. 87:2730-2742.

Fox, D. G., M. E. van Amburgh, and T. P. Tylutki. 1999. Predicting requirements for growth, maturity, and body reserves in dairy cattle. J. Dairy Sci. 82:1968-1977.

Gabler, M. T., P. R. Tozer, and A. J. Heinrichs. 2000. Development of a cost analysis spreadsheet for calculating the costs to raise a replacement dairy heifer. J. Dairy Sci. 83:1104-1109.

Gulliksen, S. M., K. I. Lie, and O. Østerås. 2009. Calf health monitoring in Norwegian dairy herds. J. Dairy Sci. 92:1660-1669.

Haworth, G. M., W. P. Tranter, J. N. Chuck, Z. Cheng, and D. C. Wathes. 2008. Relationships between age at first calving and first lactation milk yield, and lifetime productivity and longevity in dairy cows. Vet. Rec. 162:643-647.

Heinrichs, A. J. and B. S. Heinrichs. 2011. A prospective study of calf factors affecting first-lactation and lifetime milk production and age of cows when removed from the herd. J. Dairy Sci. 94:336-341.

Heinrichs, A. J., B. S. Heinrichs, O. Harel, G. W. Rogers, and N. T. Place. 2005. A prospective study of calf factors affecting age, body size, and body condition score at first calving of Holstein dairy heifers. J. Dairy Sci. 88:2828-2835.

Huijps, K., T. J. G. M. Lam, and H. Hogeveen. 2008. Costs of mastitis: facts and perception. J. Dairy Res. 75:113-120.

Hultgren, J., C. Svensson, D. O. Maizon, and P. A. Oltenacu. 2008. Rearing conditions, morbidity and breeding performance in dairy heifers in southwest Sweden. Prev. Vet. Med. 87:244-260.

Jamaluddin, A. A., T. E. Carpenter, D. W. Hird, and M. C. Thurmond. 1996. Economics of feeding pasteurized colostrum and pasteurized waste milk to dairy calves. J. Am. Vet. Med. Assoc. 209:751-756.

Le Cozler, Y., V. Lollivier, P. Lacasse, and C. Disenhaus. 2008. Rearing strategy and optimizing first-calving targets in dairy heifers: a review. Animal 2:1393-1404.

Le Cozler, Y., J. R. Peccatte, and L. Delaby. 2010. A comparative study of three growth profiles during rearing in dairy heifers: Effect of feeding intensity during two successive winters on performances and longevity. Livest. Sci. 127:238-247.

LEI, 2012. Agriculture prices. Accessed Aug. 29, 2012. http://www3.lei.wur.nl/bin_asp/frm_start_binternet.aspx?database=LTCandlanguage=1

Mohd Nor, N., W. Steeneveld, M. C. M. Mourits, and H. Hogeveen. 2012. Estimating the costs of rearing young dairy cattle in the Netherlands using a simulation model that accounts for uncertainty related to diseases. Prev. Vet. Med. 106:214-224.

Mourits, M. C. M., A. A. Dijkhuizen, R. B. M. Huirne, and D. T. Galligan. 1997. Technical and economic models to support heifer management decisions: Basic concepts. J. Dairy Sci. 80:1406-1415.

Mourits, M. C. M., D. T. Galligan, A. A. Dijkhuizen, and R. B. M. Huirne. 2000a. Optimization of dairy heifer management decisions based on production conditions of Pennsylvania. J. Dairy Sci. 83:1989-1997.

Mourits, M. C. M., R. B. M. Huirne, A. A. Dijkhuizen, and D. T. Galligan. 1999. Optimal heifer management decisions and the influence of price and production variables. Livest. Prod. Sci. 60:45-58.

Mourits, M. C. M., H. J. Van der Fels-Klerx, R. B. M. Huirne, and M. W. C. Huyben. 2000b. Dairy-heifer management in the Netherlands. Prev. Vet. Med. 46:197-208.

Perez, E., J. P. T. M. Noordhuizen, L. A. Vanwuijkhuise, and E. N. Stassen. 1990. Management Factors Related to Calf Morbidity and Mortality rates. Livest. Prod. Sci. 25:79-93.

Pirlo, G., F. Miglior, and M. Speroni. 2000. Effect of age at first calving on production traits and on difference between milk yield returns and rearing costs in Italian Holsteins. J. Dairy Sci. 83:603-608.

Rincker, L. E. D., M. J. VandeHaar, C. A. Wolf, J. S. Liesman, L. T. Chapin, and M. S. W. Nielsen. 2011. Effect of intensified feeding of heifer calves on growth, pubertal age, calving age, milk yield, and economics. J. Dairy Sci. 94:3554-3567.

Sejrsen, K., S. Purup, M. Vestergaard, and J. Foldager. 2000. High body weight gain and reduced bovine mammary growth: physiological basis and implications for milk yield potential. Domest. Anim. Endocrinol. 19:93-104.

Svensson, C. and J. Hultgren. 2008. Associations between housing, management, and morbidity during rearing and subsequent first-lactation milk production of dairy cows in southwest Sweden. J. Dairy Sci. 91:1510-1518.

Tozer, P. R. and A. J. Heinrichs. 2001. What affects the costs of raising replacement dairy heifers: A multiple-component analysis. J. Dairy Sci. 84:1836-1844.

Van Amburgh, M. E., D. M. Galton, D. E. Bauman, R. W. Everett, D. G. Fox, L. E. Chase, and H. N. Erb. 1998. Effects of three prepubertal body growth rates on performance of Holstein heifers during first lactation. J. Dairy Sci. 81:527-538.

Van der Fels-Klerx, H. J., S. W. Martin, M. Nielen, and R. B. M. Huirne. 2002. Effects on productivity and risk factors of Bovine Respiratory Disease in dairy heifers; a review for the Netherlands. Neth. J. Agr. Sci. 50:27-45.

Vasseur, E., F. Borderas, R. I. Cue, D. Lefebvre, D. Pellerin, J. Rushen, K. M. Wade, and A. M. de Passille. 2010. A survey of dairy calf management practices in Canada that affect animal welfare. J. Dairy Sci. 93:1307-1315.

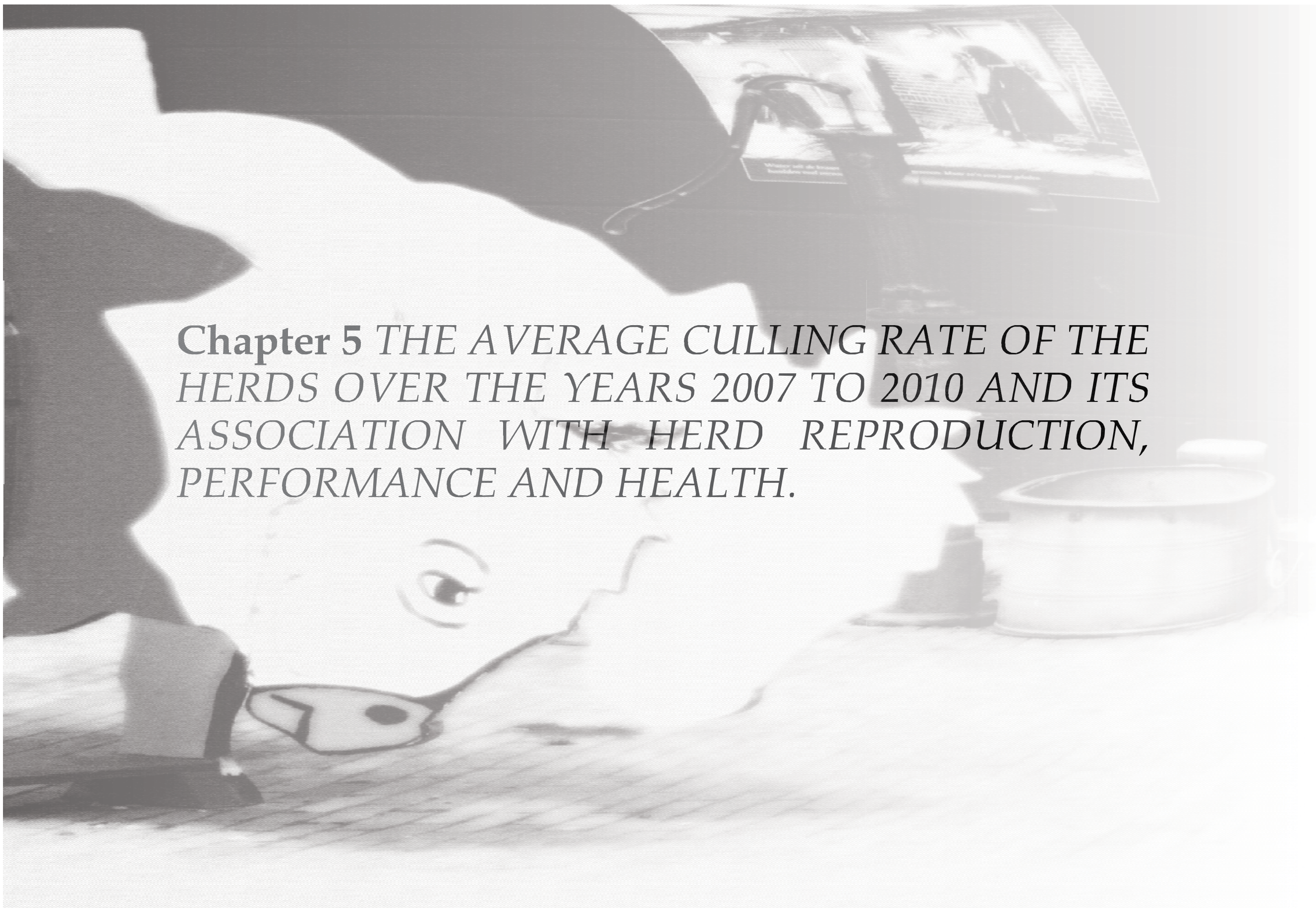
APPENDIX

Table A2. Detailed outline of the questionnaire design, which consisted of sections of topics containing information about management variables. Only main management variables were counted (n=98)

Section	Management variable	Type of question		
		Open ended (n)	Closed ended (n)	Semi-closed (n)
Farm information	Name, address, location, farm number (UBN)	5	-	-
Farm general description	Breed, number (milking cows, dry cows, unweaned calf, weaned to 1 year of age heifer, 1 to 2 years of age heifer), milk quota, farm size (ha), specialization (eg cheese making, organic etc)	7	2	1
Young stock description	Rear own young stock, outsourcing options, selection criteria, heifer calf kept in the farm, minimum age start first insemination	1	3	1
Housing				
Age=unweaned				
Individual	Housing status, days kept individually, type of bedding, barn cleaning frequency per year, type of ventilation, hygiene score	1	3	3
Group	Housing status, automatic drinking machine, days kept in group, housing type, floor type, type of bedding, barn cleaning frequency per year, type of ventilation, grazing status, hygiene score	1	7	4
Age= weaned to 1 year	Housing status, housing type, floor type, type of bedding, barn cleaning frequency per year, type of ventilation, grazing status, hygiene score	1	7	2
Age= 1 to 2 year	Housing status, housing type, floor type, type of bedding, barn cleaning frequency per year, type of ventilation, grazing status, practicing using milking parlour, hygiene score	2	8	3
Feeding				
Age= unweaned	Colostrum amount, type of colostrum, type of milk, amount of milk, waste milk status, water ad lib, type of concentrate, weaning age, weaning criteria	5	6	2
Health				
Birth until 1 year	Calf scours status and treatment, bovine respiratory disease status and treatment	4	-	4
Age= 1 to 2 year	Health problem during grazing season and in barn, vet visits per year, reason for vet visit	6	-	-
Vaccinations	Vaccinations performed for Infectious bovine rhinotrecheitis, Bovine viral diarrhea, Rotavirus/ coronavirus, E-coli, Bovine respiratory syncytial virus, lung worm and deworming	-	8	-

Table A3. The edited management variables with descriptions and categories. The continuous variables that were categorized were not included

Management factor	Description	Categories
Housing		
Type of barn	The types of group barn for unweaned calf (in group); others include igloo, cubicles and ligbox (a small area that is fenced off with steel bars)	Deep litter Other
Type flooring in group	The type of flooring for unweaned calf (in groups).	Grid Solid floor
Type of bedding	The types of bedding in group barn for unwean calf (in groups); the category others include saw dust, rubber and concrete.	Straw Other
Type of ventilation	The type of ventilation of individual housing for unweaned calves (individual).	Wall and ridge Natural and open front Fan
Barn cleanliness		
Average barn cleaning frequency per year	Assuming 1 to 12 times per year was not frequent and disinfection every time before receiving new animal was frequent; the farm average barn cleaning frequency was averaged across different age groups in the farm	Less frequent Moderate Frequent
Average farm hygiene score	The average hygiene score of the barn in the farm was calculated by averaging the hygiene score of the barn from different age groups in the farm.	Clean Moderate Dirty
Diseases incidence		
Incidence of calf scours	The incidence of calf scours in young stock below 1 year of age; it was calculated from the estimated number of young stock < 1 year of age infected with calf scours divided by the average number of young stock < 1 year of age	
Incidence of Bovine respiratory disease	The incidence of BRD in young stock <1 year of age. It was calculated from the estimated number of young stock <1 year of age infected with BRD divided by the average number of young stock <1 year of age	



Chapter 5 *THE AVERAGE CULLING RATE OF THE HERDS OVER THE YEARS 2007 TO 2010 AND ITS ASSOCIATION WITH HERD REPRODUCTION, PERFORMANCE AND HEALTH.*

This chapter has been adapted from published version: Norhariani Mohd Nor., Wilma Steeneveld, and Henk Hogeveen. 2013. The average culling rate of the herds over the years 2007 to 2010 and its association with herd reproduction, performance and health. J. Dairy Res. 81:1-8.

CHAPTER 5

5.1 ABSTRACT

Optimising the number of replacement heifers needed will have positive economic and environmental consequences on herds that rear their own young stock. The number of heifers needed to be kept is closely related with the number of culled dairy cows in the herd. This study therefore looked at the variation that exists in culling rate and herd level factors associated with it. A dataset from 1,903 dairy herds available included information at animal level (dates of culling, slaughter/death) and herd level (characteristics of reproduction, performance, health) over the years 2007 to 2010. The average culling rate for slaughter/death was defined for each year as the percentage of cows that left the farm and died within 30 days after they were culled. The analysis of the association between average culling rate for slaughter/death and the characteristics of the herd was performed using a mixed model. The results showed that the average culling rate for slaughter/death was 25.4% and varied between 23% (2007) and 28% (2010). More than 70% of the herds have an average culling rate for slaughter/death of less than 30%, showing that there is room for lowering the average culling rate for slaughter/death. A higher average culling rate for slaughter/death is associated with a longer average calving interval, a higher average 305 days protein production, a higher average somatic cell count (SCC), a higher percentage of new high SCC, a more than 5% decrease in herd size, and herds that bought more than 1% of animals per year. A lower average culling rate for slaughter/death is associated with a longer average age, herds that bought less than 1% of animals per year and a more than 5% increase in herd size. In conclusion, the average culling rate for slaughter/death is associated with fertility, udder health and openness of the herd.

Keywords: Average culling rate, dairy herd, replacement heifer, herd characteristic

5.2 INTRODUCTION

Most Dutch dairy herds rear their own replacement heifers. The costs of rearing them range from €1,400 to €1,700 per heifer (Mohd Nor et al., 2012). From an environmental point of view, additional replacement heifers reared could cause more nitrate leaching in the soil (Mourits et al., 2000), as well as increase the emission of greenhouse gases, mostly methane (Bell et al., 2011). Therefore, a reduction in the number of replacement heifers needed will have positive economic and environmental consequences.

The need for replacement heifers in Dutch dairy herds is normally closely related to the culling rate of dairy cows. Therefore, culling rates provide insights on the number of replacement heifers needed. By definition, culling rate describes the percentage of cows removed from a herd because of sale, slaughter, salvage or death (Fetrow et al., 2006). The annual culling rate in the Netherlands and UK was reported to range from 21 to 30% (Bell et al., 2010; Sol et al., 1984) while in the United States, the annual culling rate among herds ranged from 34 to 36% (Smith et al., 2000).

There are abundant studies that describe the reasons for culling. Culling a dairy cow was found to be associated with reproductive status and disorders(De Vries et al., 2010; Schneider et al., 2007; Stevenson and Lean, 1998), milk yield (Pinedo et al., 2010), and health related conditions such as ketosis, milk fever, retained placenta, metritis, lameness, teat injuries and mastitis (Chiumia et al., 2013; Rajala-Schultz and Gröhn, 1999a; Gröhn et al., 1998). These associations are known to differ with variation in age, parity and stage of lactation of the dairy cow (Rajala-Schultz and Gröhn, 1999a; Seegers et al., 1998). Reasons for culling a dairy cow may also differ according to culling policy in a herd owing to herd factors. For example, high milk production herds are protective against culling (Pinedo et al., 2010). In contrast, in high-producing herds more culling was observed (Smith et al., 2000). This latter study is, however, one of the few studies that were found on the association between culling rate of the herd and herd level management factors (Smith et al., 2000; Batra et al., 1971). Almost all studies on culling are on risk factors for individual cows within the herd. The association between culling rate and herd reproduction, herd performance, herd health and herd biosecurity is still unclear. This type of knowledge is useful to advise herd managers on an optimal culling rate and on the associated need for the number of rearing heifers needed.

The first objective of this study was to create insights into the average culling rates over the years 2007 to 2010 and their variation within Dutch dairy herds. The second objective was to determine the association between the average culling rate for slaughter/death over the years 2007 to 2010 with herd characteristics (e.g. herd size), herd reproduction characteristics (e.g. calving interval and first calving age), herd performance characteristics (e.g. 305 days milk, protein and fat production, lifetime milk production and age) and herd health characteristics (e.g. average SCC and percentage of dairy cows with claw problems).

5.3 MATERIALS AND METHODS

5.3.1 Available data

Data from 2,000 Dutch dairy herds that were randomly selected were obtained from the Cattle Improvement Cooperative (CRV, Arnhem, the Netherlands) and included information at animal and herd level over the years 2007–2010. For each year, the animal level data contained, for each herd, animal identification and registration information, including birth dates, arrival dates, calving dates, culling dates and death dates for all animals present in the herd. Information on parity, sex and breed of all individual animals within farms was also available. The animal level data was used to calculate the average culling rate which is described in the section culling rates. For the herd level, the data included herd characteristics, herd reproduction characteristics, herd performance characteristics and herd health characteristics. A detailed description of the available herd level data is given in the section about the herd level independent variables.

5.3.2 Data editing

Based on the years 2007–2010, 4 datasets were created and edited separately. After thorough examination, using animal level data, some herds were removed from the dataset. There were 30 herds in the 2007 dataset, 28 herds in the 2008 dataset, 33 herds in the 2009 dataset and 37 herds in the 2010 dataset that were assumed to be trading herds or herds that quit, that is, herds that had more than 90% of dairy cows culled, slaughtered or dead on the same date. In addition, there were 41 herds in the 2007 dataset, 21 herds in the 2008 dataset, 11 herds in the 2009 dataset and 53 herds in the 2010 dataset removed as they did not cull any female dairy cows. Next, the data on herd level, that is, the herd size of each year was used to remove herds. Fifty-two herds in the 2007 dataset, 63 herds in the 2008 dataset, 68 herds in the 2009 dataset and 17 herds in the 2010 dataset were removed as they did not have information about herd size which is essential information when studying culling rates. Finally, 9 herds in the 2007 dataset, 6 herds in the 2008 dataset, 3 herds in the 2009 dataset and 10 herds in the 2010 dataset, were removed because of a herd size less than 30 dairy cows. After exclusion of these herds, there were 1,868 herds in the 2007 dataset, 1,882 herds in the 2008 dataset, 1,885 herds in the 2009 dataset and 1,883 herds in the 2010 dataset. After merging the datasets of different years, the final dataset contained 1,903 herds. Within that dataset, 1,835 herds have data for 4 years, 50 herds have data for 3 years, 12 herds have data for 2 years and 6 herds have data for only 1 year. Data editing was performed using Statistical Analysis System (SAS) version 9.2 (SAS, 2008).

5.3.3 Culling rates

Overall culling in this study was defined as dairy cows that were sold, slaughtered, salvaged or died, similar to the definition used by Fetrow et al. (2006). By using the animal level data, within the 1,903 dairy herds, the dates of culling of individual dairy cows were used to determine whether they were culled in 2007, 2008, 2009 or 2010. In addition, they had to be female dairy cows that had at least one calving. The overall culling rate of each year for each herd was calculated as the total number of culled dairy cows divided by herd size of each year (Toma et al., 1999). For each herd, the overall culling rate was averaged over 4 years. Then, the average culling rates for slaughter/death and the average culling rates for sale for each herd were calculated separately for each year. To define culling for slaughter/death, within a year the dates of slaughter/death of a cow were compared with their culling dates to determine whether they were slaughtered or died immediately after culling or not. If the difference between the date of slaughter/death and the date of culling was less than or equal to 30 days, the cause of culling was assumed to be slaughter/death. If the difference between the date of slaughter/death and the date of culling was more than 30 days, the cause of culling was assumed to be sale. Also, when there was no date of slaughter/death available, the cause of culling was assumed to be sale. For each herd, culling rates for slaughter/death and for sale were averaged over 4 years.

5.3.4 Herd level independent variables

Data on herd characteristics included herd size (these data were also provided for 2006). Additionally, 3 new variables variables were created for herd characteristics: openness, rearing own young stock and change in herd size in current year as compared with its previous year. To establish whether the herds were of different size or not as compared with the previous year, the herd size in current year minus herd size in previous year, divided by herd size in current year was calculated. The variable was categorised into 3 groups; herd size remained the same (within and equal ± 5%), herd size increased by more than 5% and herd size decreased by more than 5%. To define open and closed farms within a particular year, closed farms were those buying on average fewer than or equal to 1% of animals in a year and open farms were those buying more animals than that. Within a particular year, herds that reared their own young stock were defined as being those that sold fewer than 80% of their female born calves, while herds not rearing their own young stock sold at least 80% of their female born calves and bought dairy cows of an age of at least or more than 550 days.

Data on the average herd performance characteristics were given in two groups: dairy cows that were still present in the herds and culled dairy cows. For dairy cows that were still present on the herd data on 305 days milk, fat and protein production were available. For both groups data on lifetime milk production, productive life and age were available. For each herd, herd performance characteristics were averaged over the 4 years.

Data on the average herd reproduction characteristics were first-calving age and calving interval. In addition, the percentage of non-return to oestrus at 56 days and the number of inseminations needed per cow present on the farm were available. For each herd, herd reproduction characteristics were averaged over the 4 years.

Data on the average herd health characteristics regarding udder health included SCC, the percentage of dairy cows with high SCC and the percentage of dairy cows with new high SCC. High SCC was defined as SCC that is, for first parity cows, over 150,000 cells/ml and over 250,000 cells/ml for older dairy cows, which are thresholds used in the Netherlands (Huijps et al., 2009; De Vliegher et al., 2004). The new high SCC was used to give a measure of recent udder infections and was defined as dairy cows having at least once a high SCC after a low SCC in the previous test day. In the Netherlands, approximately 5% of all dairy herds participate in the claw health programme. Within this programme, during routine claw trimming, the claws are observed and any claw problems such as sole bleeding, digital dermatitis, interdigital dermatitis, sole ulcer, interdigital hyperplasia and white line are reported for individual dairy cows. For this study, information on first parity and older dairy cows with claw problems were available for 157 herds. For each herd, herd health characteristics were averaged over the 4 years.

5

5.3.5 Data analysis

The analysis of the association between average culling rate for slaughter/death and herd-level characteristics, reproduction, performance and health was performed with a mixed model using PROC MIXED using Statistical Analysis System (SAS) version 9.2 (SAS, 2008) with herd as a random effect, assuming normality of residuals. Univariate analyses were performed to select independent variables possibly associated with average culling rate for slaughter/death with a $P \leq 0{\cdot}25$ based on F test. Collinearity was checked among these selected independent variables, where variables with Pearson correlation > 0·8 or <0·8 were considered as highly correlated. Owing to high correlations, 4 herd variables were excluded, productive life of dairy cows present in the herd, productive life of culled dairy cows (correlations with age and lifetime milk production of dairy cows present in the herd and culled dairy cows, respectively), percentage of non-return to oestrus in 56 days (correlations with number of inseminations) and percentage of dairy cows with high SCC (%) [correlations with average SCC and percentage of dairy cows with new high SCC (%)]. The selected independent variables were included in the multivariate model. The multivariate model was built using a backward selection procedure. In each step, the independent variable with the lowest significance level was excluded until all independent variables in the final multivariate model had the lowest significant value ($P < 0{\cdot}05$). The overall model fit was assessed by graphical examination of residuals and the Kolmogorov–Smirnov test, looking for outliers and checking for homoscedasticity.

5.4 RESULTS

The overall culling rate of the 1,903 herds was on average 29.6% (SD± 6·5) and ranged between 12.4 and 63% (Table 5.1). It consisted of the culling rate for slaughter/death which was on average 25.4% (SD± 6.3; range 6.2 to 56.5%) (Table 5.1) and the culling rate for sale which was on average 4.2% (SD± 5.3; range 0.0 to 42.3%) (Table 5.1). For the years 2007, 2008, 2009 and 2010, the overall culling rate was on average 27% (SD± 9), 28% (SD± 9), 32% (SD± 10) and 32% (SD± 9), respectively. The culling rate for slaughter/death for these years was on average 23% (SD± 9), 24% (SD± 8), 28% (SD± 9) and 28% (SD± 9), respectively. Also for these years, the culling rate for sale was on average 4% (SD± 6), 4% (SD± 7), 4% (SD± 7) and 4% (SD± 6), respectively.

The variation in average culling rate for slaughter/death among 1,903 Dutch dairy herds is shown in Figure 5.1.

Table 5.1. The descriptive statistics of the average culling rates over the years 2007 to 2010 and the average herd level variables for each herd over the years 2007 to 2010

Variables	Herds, n	Average	±Sd	Minimum	Maximum
Culling					
Overall culling rate (%)	1,903	29.6	6.5	12.4	63.0
Culling rate for slaughter/death (%)	1,903	25.4	6.3	6.2	56.5
Culling rate for sale (%)	1,903	4.1	5.3	0	42.3
Herd characteristics and type					
Herd size (number of dairy cows)	1,903	83	39	34	470
Herd reproduction characteristics					
Calving interval (days)	1,903	421	24	353	618
Number of insemination (per cow present on the farm)	1,855	1.9	0.4	1	3.6
Non return to estrus in 56 days (% cows present on the farm)	1,855	68	12	0	100
First calving age (month)	1,730	27	2	22	46
Herd performance characteristics					
Dairy cows present in the herd					
305 days-milk production (kg)	1,903	8,282	1,033	3,858	12,050
305 days-fat production (kg)	1,903	439	19	367	612
305 days-protein production (kg)	1,903	353	8	326	422
Lifetime milk production (kg)	1,903	21,888	3,961	2,621	37,621
Productive life (months)	1,903	27	4	4	46
Age (months)	1,903	58	5	41	85
Culled dairy cows					
Lifetime milk production (kg)	1,903	30,490	6,471	0	58,711
Productive life (months)	1,903	39	7	0	68
Age (months)	1,903	72	8	0	108
Herd health characteristics					
Udder health					
SCC x 1,000 (cells/ml)	1,903	226	58	134	819
High SCC (%)	1,903	21	7	0	60
New high SCC (%)	1,903	9	2	0	18
Claw health					
Any claw problems (% older cows)	153	66	17	13	100
Any claw problems (% first parity)	153	59	18	9	100

5

5.4.1 Associations between average culling rate for slaughter/death and the herd level variables

The results of the univariate analyses are presented in Tables 5.2 and 5.3. A higher average culling rate for slaughter/death was shown to have univariate association (*P* <0.10) with open farms, herds decreasing in size, bigger herd size, longer calving intervals, higher 305 days fat and protein production of dairy cows present in the herd, higher average SCC, and higher percentage of dairy cows with high SCC and new high SCC. A lower average culling rate for slaughter/death was shown to have univariate association (*P* <0.10) with closed farms, herds increasing in size, higher age, higher lifetime milk production and higher productive life, both for dairy cows that were present and culled in the herds.

The final multivariate model presented in Table 5.4 showed that the average culling rate for slaughter/death was associated with year, variables of herd characteristics (openness, change of herd size), herd reproduction characteristics (calving interval), herd performance characteristics (dairy cows present on the herds: 305 days protein production, age; culled dairy cows: age) and herd health characteristics [average SCC and new high SCC (%)]. The results showed that, as compared with the year 2010, years 2007 and 2008 were associated with a lower average culling rate for slaughter/death by 3.9% (*P*< 0.0001) and 2.5% (*P*< 0.0001), respectively; while year 2009 was associated with a higher average culling rate for slaughter/death by 0.4% (*P*= 0.1021). The open farms, as compared with the closed farms were associated with a higher average culling rate for slaughter/death by 1.6% (*P*< 0.0001). Herds that increased in size were associated with a lower average culling rate for slaughter/death of 3% (*P*< 0.0001) while herds that decreased in size was associated with higher average culling rate for slaughter/death of 3.7% (*P*< 0.0001), and these were in comparison with herds that remained in the same size. It was also shown that a longer average

Table 5.2. Results of the univariate analyses on the association between average culling rate for slaughter/death over the years 2007 to 2010 according to categorical herd characteristics

Variable	Culling rate for slaughter/death (%)				
	Year	2007	2008	2009	2010
	Category	Average (±Sd) Herds, *n*	Average (±Sd) Herds, *n*	Average (±Sd) Herds, *n*	Average (±Sd) Herds, *n*
Herd characteristic					
Herds that rear own young stock	Yes[1]	22.6 (8.5) 1,844	23.9 (8.4) 1,857	27.6 (9.2) 1,864	27.7 (8.9) 1,855
	No*	24.1 (6.7) 24	26.1 (9.4) 25	29.3 (11.9) 21	31.2 (10.3) 15
Openness	Closed[1]	21.6 (8.0) 1,326	23.3 (8.1) 1,324	27.1 (9.0) 1,429	26.8 (8.6) 1,064
	Open**	25.1 (8.9) 542	25.3 (8.9) 558	29.1 (10.0) 456	29.0 (9.1) 806
Herd size in current year as compared to previous year	Same[1]	22.1 (8.0) 813	24.5 (7.8) 790	27.3 (8.5) 885	27.7 (8.3) 878
	Decreased**	26.9 (10.4) 275	29.3 (9.1) 243	31.8 (11.0) 410	31.4 (10.1) 440
	Increased**	21.5 (7.5) 760	21.7 (7.8) 845	25.2 (8.0) 584	24.9 (7.7) 550

[1]Reference group
*P-value >0.10 using mixed model with herd as random variable
**P-value <0.0001 using mixed model with herd as random variable

5

Table 5.3. Results of the univariate analyses on the association between average culling rate for slaughter/death over the years 2007 to 2010 and continuous herd-characteristics

Variable	Herds, n	Parameter estimate	P-value
Herd characteristics			
Herd size (number of dairy cows)	1,903	0.0088	0.0126
Herd reproduction characteristics			
Calving interval (day)	1,903	0.02717	<0.0001
Number of inseminations (per cow present on farm)	1,855	-1.9751	<0.0001
Non return to estrus in 56 days (% cows present on farm)	1,863	0.0333	<0.0001
First calving age (months)	1,730	0.0049641	0.9341
Herd performance characteristics			
Dairy cows present in the herd			
305 days-milk production (kg)	1,903	0.000189	0.1426
305 days-fat production (kg)	1,903	0.01834	0.0044
305 days-protein production (kg)	1,903	0.1278	<0.0001
Lifetime milk production (kg)	1,903	-0.0004	<0.0001
Productive life (months)	1,903	-0.5375	<0.0001
Age (months)	1,903	-0.4296	<0.0001
Culled dairy cows			
Lifetime milk production (kg)	1,903	-0.0001	<0.0001
Productive life (months)	1,903	-0.1669	<0.0001
Age (months)	1,903	-0.1408	<0.0001
Herd health characteristics			
Udder health			
SCC (x1,000 cells/ml)	1,903	0.0171	<0.0001
High SCC (%)	1,903	0.05348	0.0004
New high SCC (%)	1,903	0.2871	<0.0001
Claw health			
Any claw problems (% older cows)	153	0.01337	0.6729
Any claw problems (% first parity cows)	153	0.03549	0.1980

Table 5.4. Results of the final multivariate analysis on the association between average culling rate for slaughter/ death and herd-level variables over the years 2007 to 2010

Parameter	Category	β	SE (β)	P-value
Intercept		25.6755	4.6065	<0.0001
Year	2007	-3.8743	0.2298	<0.0001
	2008	-2.5136	0.2258	<0.0001
	2009	0.3682	0.2252	0.1021
	2010	0	-	-
Herd types				
Openness	Open	1.6379	0.2126	<0.0001
	Closed	0	-	-
Herd size in current year as compared to previous year				
	Increased	-2.9912	0.19	<0.0001
	Decreased	3.6985	0.2345	<0.0001
	Same	0	-	-
Herd reproduction				
Calving interval (days)		0.02641	0.00393	<0.0001
Herd performance				
Dairy cows present in herd				
305 days protein production (kg)		0.05499	0.01215	<0.0001
Age (months)		-0.4776	0.02061	<0.0001
Culled dairy cows				
Age (months)		-0.08531	0.009427	<0.0001
Herd health				
Average SCC (x1,000 cells/ml)		0.01255	0.001846	<0.0001
New high SCC (%)		0.1823	0.04414	<0.0001

calving interval by 1 day was associated with a higher average culling rate for slaughter/death of 0.03% ($P< 0.0001$). A higher average 305 days protein production of dairy cows present in the herd by 1 kg, was associated with a higher average culling rate for slaughter/death of 0.05% ($P< 0.0001$). A longer average age of dairy cows that were present in the herd by 1 month was associated with a lower average culling rate for slaughter/death of 0.5% ($P< 0.0001$). Similarly, a longer average age of culled dairy cows by 1 month was associated with a lower average culling rate for slaughter/death of 0.08% ($P< 0.0001$). A higher average SCC of the herd by 1,000 cells/ml was associated with a higher average culling rate for slaughter/death of 0.01% ($P< 0.0001$). A higher average percentage of new high SCC by 1% was associated with a higher average culling rate for slaughter/death of 0.18% ($P< 0.0001$)

5.5 DISCUSSION

This study used data from 1,903 dairy herds in the Netherlands over the years 2007 to 2010. The herds are representative for Dutch dairy herds as they were randomly selected and the average herd size is comparable to the Dutch population average (CRV, 2010). Additionally, the average 305 days milk production was also comparable to the Dutch population average (CRV, 2010). Within this study, we have calculated the overall culling rate on average as 29.6%, culling rate for slaughter/death on average as 25.4% and culling rate for sale on average as 4.1%. The results showed that the average overall culling rate and the average culling rate for slaughter/death are higher than those reported in the UK (Whitaker et al., 2004), similar to the culling rates reported previously in the Netherlands, France and Poland (Olechnowicz and Jaskowski, 2011; Raboisson et al., 2011; Sol et al., 1984) and lower than the annual culling rate in the United States (De Vries et al., 2010). The results also showed that average culling rate for sale is lower than in the United States (6%) (National Animal Health Moni-

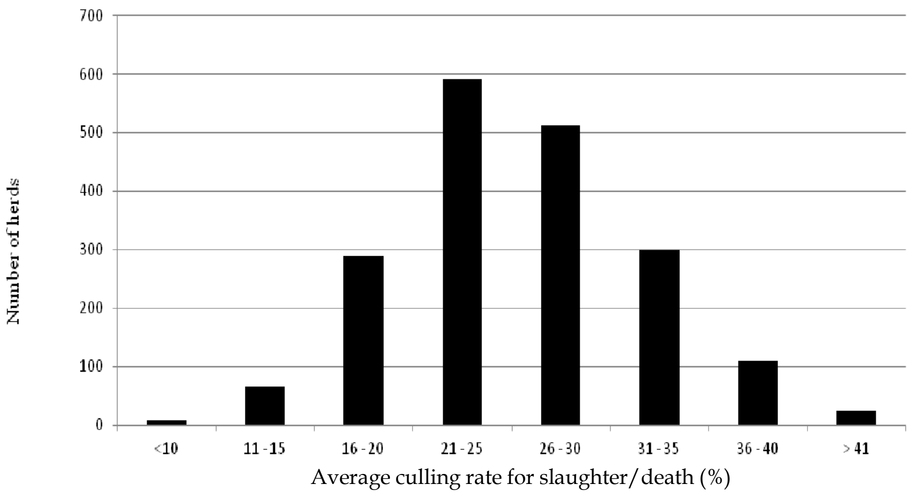


Figure 5.1. Distribution of average culling rate for slaughter/death (%) in 1,903 Dutch dairy herds over the years 2007 to 2010

toring system, 2002). The comparison is however difficult owing to the different definition for the culling rates used in previous studies. The results showed that as compared with the year 2008, in 2009 average culling rate for slaughter/death had a sudden increase to 28%. This sudden increase in average culling rate for slaughter/death might be explained by the lower milk price in 2009 when compared with 2008 (LEI, 2013a). Consequently, it might have caused farmers to cull more underperforming dairy cows owing to reduced gross margin which was shown to be the lowest in 2009 (LEI, 2013b). This study also showed that the average culling rate for slaughter/death varies among the Dutch dairy herds. More than 70% of dairy herds have average culling rate for slaughter/death over the years 2007 to 2010 of less than 30% (Figure 5.1). This indicates that there is room for lowering culling rate for slaughter/death.

We used the average culling rate for slaughter/death variable in the analysis to distinguish between cows that were culled for underperformance (e.g. infertile or poor health) and cows that were culled to be milked on another farm. Sometimes, a distinction is made between voluntary and involuntary culling. However, we were not able to distinguish these features on the basis of our data because the reasons for culling dairy cows were not available. Moreover, the terminology voluntary versus involuntary culling leaves much room for misinterpretation as was indicated by Fetrow et al. (2006).

We found several factors that were associated with average culling rate for slaughter/death. Other herd factors relevant in explaining the association, such as herd structure, herd management, type of replacement and culling policies and socio-psychological profile of the farmer (Beaudeau et al., 1993) were unfortunately not available in this study.

The results show that lower average culling rate for slaughter/death was associated with higher average age both for dairy cows present in the herds and culled dairy cows and this is to be expected. If the average age of dairy cows in the herd is higher, it means the herds keep their dairy cows longer. Dairy cows could be kept longer if they are fertile (De Vries et al., 2010; Faust et al., 2001; (Rajala-Schultz and Gröhn, 1999b) or they do not succumb as they age to any health problems (e.g. injury, disease, high SCC) that might cause them to be culled earlier (Monti et al., 1999; Seegers et al., 1998).

A longer average calving interval of 10 days was associated with a higher average culling rate for slaughter/death of the herd, by 0.2%. A longer average calving interval is associated with reproductive problems, which is an important reason for dairy cows to be culled, as found in previous studies (Bach, 2011; Brickell and Wathes, 2011; Bascom and Young, 1998). Therefore, it is advisable for farmers to have good herd reproduction management in order to prevent unnecessary culling.

Interestingly, in this study, the average 305 days protein production was retained in the final model but not the other 305 days herd performance characteristics. We could not explain this specific association although, of course, the average 305 days protein production is closely related to both the average 305 days milk and fat production. Why specifically the average 305 days protein production provided a better prediction than the average 305 days milk production is not clear. The relation between 305 days herd performance and average culling rate for slaughter/death (Table 5.3) is an interesting one and can be explained either by farms that have a higher culling rate having faster genetic progress because of faster follow-up between generations, or by higher 305 days milk production being also associated with more problems (Rauw et al., 1998) which might cause more culling.

Herds with a higher average SCC were shown to be associated with a higher average culling rate for slaughter/death and this is an expected result. A higher average culling rate for slaughter/death of the herd by 1% was associated with a 100,000 cells/ml higher in the average SCC. Additionally, the results showed a higher culling rate for slaughter/death of the herd by 2% was associated with a 10% higher percentage of the new high SCC. The SCC is a widely used indicator for subclinical udder problems. In previous studies, high SCC was found to be one of the most common reasons for farmers to cull dairy cows (Faust et al., 2001; Brickell and Wathes, 2011; Chiumia et al., 2013). When high SCC was not a direct reason for culling, poor udder health (high SCC) has been found to increase the likelihood of culling (Hadley et al., 2006). However, clinical mastitis is regarded to be the main cause for farmers to remove dairy cows from the herd (Gröhn et al., 1998). In the present study, unfortunately information on clinical mastitis was not available.

The average culling rate for slaughter/death was associated with change in herd size. As compared with herds that remained the same size, herds that increased in size had a lower average culling rate for slaughter/death. It seems that when herds are expanding, they will try to keep as many cows as possible. Previous work had shown that during expansion the likelihood of a dairy cow being culled is reduced (Hadley et al., 2006). Expanding dairy farms also culled fewer dairy cows on the grounds of low milk production, as compared with other involuntary reasons such as reproductive performance, mastitis and high SCC (Weigel et al., 2003; Faust et al., 2001).

Herds that were open had, on average, a 1.6% higher average culling rate for slaughter/death than herds that were closed. This is not an unexpected result because introduction of new animals in a herd is associated with higher risks of introduction of diseases. This study showed that openness does have an effect on culling, even after correction for udder health.

5.6 CONCLUSIONS

In conclusion, this study showed that over the years 2007 to 2010 the average overall culling rate based on 1,903 Dutch dairy herds was 29.6% (SD± 6.5), the average culling rate for slaughter/death as 25.4% (SD± 6.3) and the average culling rate for sale as 4.1% (SD± 5.3). About 70% of the herds have average culling rate for slaughter/death less than 30%, showing there is room for lowering average culling rate for slaughter/death. This study also showed that a higher average culling rate for slaughter/death is associated with a longer average calving interval, a higher average 305 days protein production, a higher average SCC, a higher percentage of new high SCC, a decrease in herd size, and open farms. Therefore, the average culling rate for slaughter/death is associated with the fertility, udder health and openness of the herd.

References

Bach, A. 2011. Associations between several aspects of heifer development and dairy cow survivability to second lactation. J. Dairy Sci. 94: 1052-1057.

Bascom, S. S. and A. J. Young. 1998. A summary of the reasons why farmers cull cows. J. Dairy Sci. 81: 2299-2305.

Batra, T. R., E. B. Burnside, and M. G. Freeman. 1971. Canadian dairy cows disposal .2. Effect of herd size and production level on dairy cow disposal patterns. Can. J. Anim. Sci. 51: 85-87.

Beaudeau, F., A. Henken, C . Fourichon, K . Frankena and H. Seegers. 1993. Associations between health disorders and culling of dairy cows- A review. Livest. Prod. Sci. 35: 213-236.

Bell, M. J., E . Wall, G. Russell, D. J. Roberts and G. Simm. 2010. Risk factors for culling in Holstein-Friesian dairy cows. Vet. Rec. 167: 238-240.

Bell, M. J., E. Wall, G. Russell, G. Simm and A. W. Stott. 2011. The effect of improving cow productivity, fertility, and longevity on the global warming potential of dairy systems. J. Dairy Sci. 94: 3662-3678.

Brickell, J. S. and D. C. Wathes. 2011. A descriptive study of the survival of Holstein-Friesian heifers through to third calving on English dairy farms. J. Dairy Sci. 94: 1831-1838.

Chiumia, D., M. G. G. Chagunda, A. I. Macrae and D. J. Roberts. 2013. Predisposing factors for involuntary culling in Holstein–Friesian dairy cows. J. Dairy Res. 80: 45-50.

CRV, 2010. CRV Jaarstatistieken Nederland [CRV yearly statistics the Netherlands]. Accessed Oct. 1, 2012. https://www.cr-delta.nl/servlets/dbupload?id=27569.

De Vliegher, S., H. W. Barkema, H. Stryhn, G. Opsomer and A. de Kruif. 2004. Impact of Early Lactation Somatic Cell Count in Heifers on Somatic Cell Counts Over the First Lactation. J. Dairy Sci. 87: 3672-3682

De Vries, A., J. D. Olson and P. J. Pinedo. 2010. Reproductive risk factors for culling and productive life in large dairy herds in the eastern United States between 2001 and 2006. J. Dairy Sci. 93: 613-623.

Faust, M. A., M. L. Kinsel and M. A. Kirkpatrick 2001 Characterizing biosecurity, health, and culling during dairy herd expansions. J. Dairy Sci. 84: 955-965.

5

Fetrow, J., K. V. Nordlund and H. D. Norman. 2006. Invited review: Culling: Nomenclature, definitions, and recommendations. J. Dairy Sci. 89: 1896-1905.

Gröhn, Y.T., S. W. Eicker, V. Ducrocq and J. A. Hertl. 1998. Effect of diseases on the culling of Holstein dairy cows in New York State. J. Dairy Sci. 81: 966-978.

Hadley, G. L., C. A. Wolf and S. B. Harsh. 2006. Dairy cattle culling patterns, explanations, and implications. J. Dairy Sci. 89: 2286-2296.

Huijps, K., S. De Vliegher, T. Lam and H. Hogeveen. 2009. Cost estimation of heifer mastitis in early lactation by stochastic modelling. Vet. Microbiol. 134: 121-127.

LEI,. 2013a. Agriculture prices. Accessed June 04, 2013. http://www3.lei.wur.nl/BIN_ASP/show.exe.

LEI., 2013b. Agriculture prices. Accessed June 04, 2013. http://www3.lei.wur.nl/bin_asp/frm_start_binternet.aspx?database=LTC&language=1.

Mohd Nor, N., W. Steeneveld, M. C. M. Mourits and H. Hogeveen. 2012. Estimating the costs of rearing young dairy cattle in the Netherlands using a simulation model that accounts for uncertainty related to diseases. Prev. Vet. Med. 106: 214-224.

Monti G., B. A. Tenhagen and W. Heuwieser. 1999. Culling policies in dairy herds. A review. J. Vet. Med. A-Physiol. Pathol. Cl. 46: 1-11.

Mourits M. C. M., P. B. M. Berentsen, R. B. M. Huirne and A. A. Dijkhuizen. 2000. Environmental impact of heifer management decisions on Dutch dairy farms. Neth. J. Agric. Sci. 48: 151-164.

National Animal Health Monitoring System. 2002. Part 1: Reference of dairy health and management in the United States. Accessed Oct. 1, 2012. http://www.aphis.usda.gov/animal_health/nahms/dairy/downloads/dairy02/Dairy02_dr_PartI.pdf.

Olechnowicz, J., and J. M. Jaskowski. 2011. Reasons for culling, culling due to lameness, and economic losses in dairy cows. Med. Weter. 67: 618-621.

Pinedo, P. J., A. De Vries and D. W. Webb. 2010. Dynamics of culling risk with disposal codes reported by Dairy Herd Improvement dairy herds. J. Dairy Sci. 93: 2250-2261.

Raboisson, D., E. Cahuzac, P. Sans and G. Allaire 2011. Herd-level and contextual factors influencing dairy cow mortality in France in 2005 and 2006. J. Dairy Sci. 94: 1790-1803.

Rajala-Schultz, P. J. and Y. T. Gröhn 1999a. Culling of dairy cows. Part I. Effects of diseases on culling in Finnish Ayrshire cows. Prev. Vet. Med. 41: 195-208.

Rajala-Schultz, P. J. and Y. T. Gröhn. 1999b. Culling of dairy cows. Part III. Effects of diseases, pregnancy status and milk yield on culling in Finnish Ayrshire cows. Prev. Vet. Med. 41: 295-309.

Rauw, W. M., E. Kanis, E. N. Noordhuizen-Stassen and F. J. Grommers. 1998. Undesirable side effects of selection for high production efficiency in farm animals: a review. Livest. Prod. Sci. 56: 15-33

SAS, 2008. SAS Institute Inc. (Cary, NC, USA)

Schneider, M. D., E. Strandberg, U. Emanuelson, K. Grandinson and A. Roth. 2007. The effect of veterinary-treated clinical mastitis and pregnancy status on culling in Swedish dairy cows. Prev. Vet. Med. 80: 179-192.

Seegers, H., F. Beaudeau, C. Fourichon and N. Bareille. 1998. Reasons for culling in French Holstein cows. Prev. Vet. Med. 36: 257-271.

Smith J. W., L. O. Ely and A. M. Chapa. 2000. Effect of region, herd size, and milk production on reasons cows leave the herd. J. Dairy Sci. 83: 2980-2987.

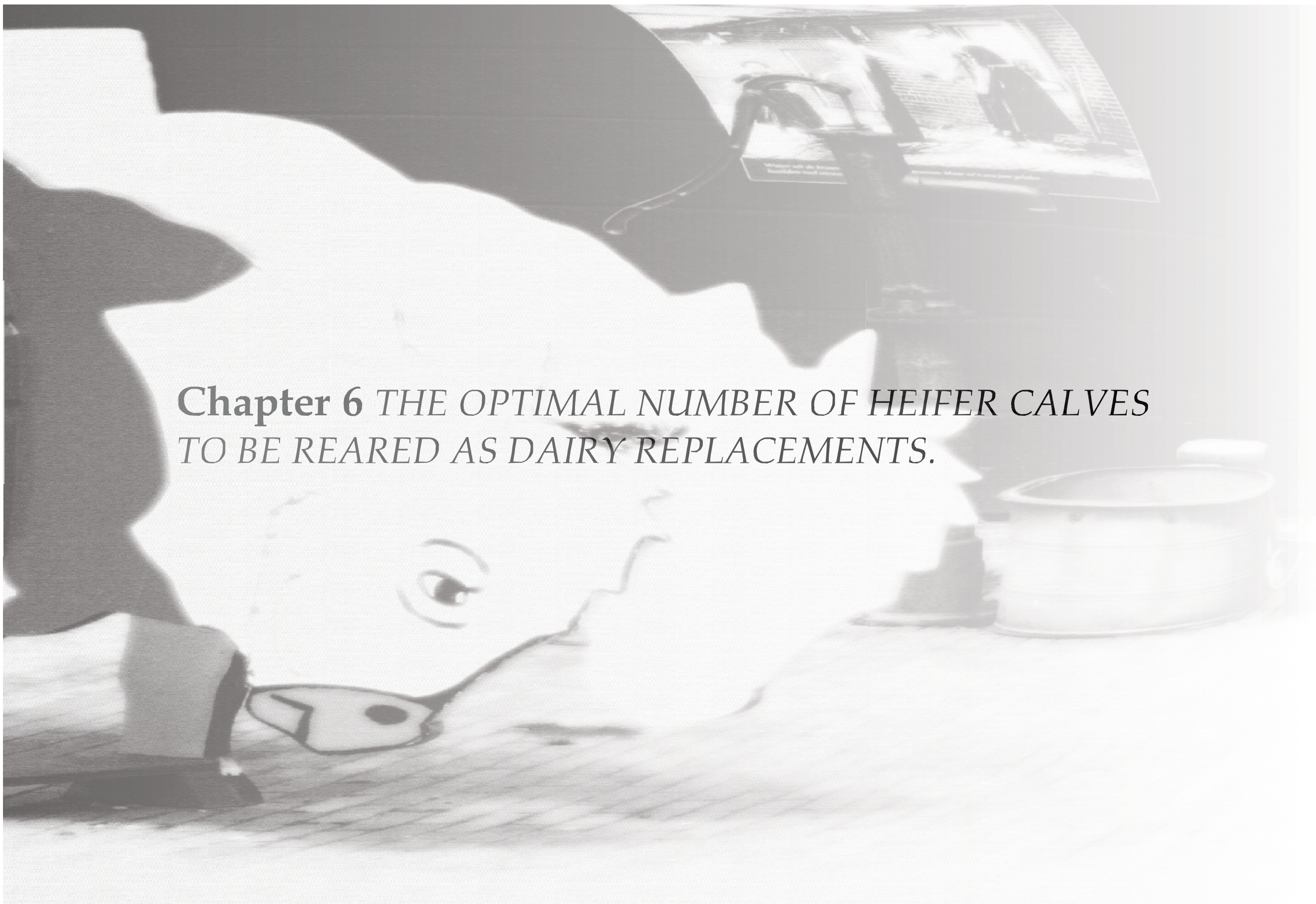
Sol, J., J. Stelwagen and A. A. Dijkhuizen. 1984. A 3 year herd health and management program on 30 Dutch dairy farms .2. Culling strategy and losses caused by forced replacement of dairy cows. Vet. Quart. 6: 149-157.

Stevenson, M. A. and I. J. Lean. 1998. Descriptive epidemiological study on culling and deaths in eight dairy herds. Aust. Vet. J. 76: 482-488.

Toma B., J. -P. Vaillancourt, B. Dufour, M. Eloit, F. Moutou, W. Marsh , J. -J. Bénet, M. Sanaa, P. Michel, P. Kass, M. Bigras-Poulin. 1999. Dictionary of veterinary epidemiology. Page 61. Iowa State University press, Iowa.

Weigel, K. A., R. W. Palmer and D. Z. Caraviello. 2003. Investigation of factors affecting voluntary and involuntary culling in expanding dairy herds in Wisconsin using survival analysis. J. Dairy Sci. 86: 1482-1486

Whitaker, D. A., A. I. Macrae and E. Burrough. 2004. Disposal and disease rates in British dairy herds between April 1998 and March 2002. Vet. Rec. 155: 43-47



Chapter 6 *THE OPTIMAL NUMBER OF HEIFER CALVES TO BE REARED AS DAIRY REPLACEMENTS.*

This chapter has been adapted from published version: Mohd Nor, N., W. Steeneveld, M. C. M. Mourits, and H. Hogeveen. 2015. The optimal number of heifer calves to be reared as dairy replacements. J. Dairy Sci. 98:861-871.

CHAPTER 6

6.1 ABSTRACT

Dairy farmers often keep almost all their newborn heifer calves despite the high cost of rearing. By rearing all heifer calves, farmers have more security and retain flexibility to cope with the uncertainty in the availability of replacement heifers in time. This uncertainty is due to mortality or infertility during the rearing period and the variation in culling rate of lactating cows. The objective of this study is to provide insight in the economically optimal number of heifer calves to be reared as replacements. A herd level stochastic simulation model was developed specific for this purpose, with a herd of 100 dairy cows. The biological part of the model consisted of a dairy herd unit and rearing unit for replacement heifers. The dairy herd unit included variation in the number of culled dairy cows. The rearing unit incorporated variation in the number of heifer present in the herd, by including uncertainty in mortality and variation in fertility. The dairy herd unit and rearing unit were linked by the number of replacement heifers and culled dairy cows. When not enough replacement heifers were available to replace culled dairy cows, the herd size was temporarily reduced, resulted in an additional cost for the empty slots. When the herd size reached 100 dairy cows, the available replacement heifers that were not needed were sold. It was assumed that no purchase of cows and calves occurred. The optimal percentage of 2-weeks-old heifer calves to be retained was defined as the percentage of heifer calves which minimized the average net costs of rearing replacement heifers. In the default scenario, the optimal retention was 73% and the total net cost of rearing was estimated at €40,939 per herd per year. This total net cost was 6.5% lower than when all heifer calves were kept. An earlier first calving age resulted in an optimal retention of 75%, and the net costs of rearing were € 581 per herd per year lower than in the default scenario. For herds with a lower or higher culling rate of dairy cows (10%

or 40% instead of 25% in the default scenario), it was optimal to retain 35% or 100% of the heifer calves per year. Herds that had a lower or higher cost of empty slots (€50 or €120 per month instead of €82 in the default scenario) had an optimal retention of 49% or 83% per year. It showed that the optimal retention percentage was dependent on farm and herd characteristics. For Dutch dairy farming conditions, it was not optimal to keep all heifer calves.

Key words: dairy replacement, young stock rearing, culling, cost

6.2 INTRODUCTION

Most Dutch dairy farmers, and many farmers in other major milk producing countries, rear their own young stock to provide replacement heifers. Heifer rearing is expensive, with high costs for feed, labor and housing (Tozer and Heinrichs, 2001; Gabler et al., 2000). Recent estimates of the cost of rearing a replacement heifer in the Netherlands range between €1,400 and €1,700 per heifer (Mohd Nor et al., 2012).

Farmers are aware that heifer rearing is expensive, however they still keep (almost) all their newborn heifer calves to ensure enough young stock are available to replace culled dairy cows. When too much young stock is kept, they are sold to other farms or sold for export. The uncertainty in the availability of full grown heifers occurs due to mortality, and growth and reproduction problems in the rearing period. The risk of mortality of calves after birth was reported to vary between 1% and 8% (Raboisson et al., 2013; Svensson et al., 2006; Mee, 2008). Growth and reproduction problems (e.g., infertility) reduce the number of heifer calves reaching their first calving because these heifers have either a higher probability to be culled during rearing (Brickell and Wathes, 2011; Hultgren et al., 2008; Brickell et al., 2009) or a high first calving age (and therefore delayed availability for replacement). Mohd Nor et al. (2014) reported that the average culling rate of lactating cows in Dutch dairy herds was 25%, ranging between

23% and 28% in different years. For individual herds, the variation between years was even higher. There are several reasons why the culling rate varies between years. One potential reason is an outbreak of an endemic disease such as bovine viral diarrhea or infectious bovine rhinotracheitis (Vonk Noordegraaf et al., 1998).

Various studies have evaluated the costs of heifer rearing (Mohd Nor et al., 2012; Gabler et al., 2000), the mortality of heifer calves (Raboisson et al., 2013; Svensson et al., 2006) and the culling of dairy cows (Mohd Nor et al., 2014; Pinedo et al., 2010). All this information is needed to determine the optimal number of heifer calves to be reared as replacements for culled dairy cows. No study, however, has incorporated the uncertainty of losing heifer calves and variation in the culling rate of dairy cows to determine the optimal number of replacement heifer calves. In addition, the economic consequences of keeping too few or too many heifer calves have not yet been investigated.

The objective of this study is to provide insight in the economically optimal number of heifer calves to be reared as replacement heifers, in order to support tactical management decisions. We developed a stochastic model that determined the optimal number of heifer calves to be reared by minimizing the net cost of rearing replacement heifers. The model included uncertainty in the mortality and fertility of heifer calves and the culling rate of dairy cows.

6.3 MATERIALS AND METHODS

6.3.1 Model development

To determine the optimal number of heifer calves that should be retained to replace culled dairy cows, a herd level Monte Carlo simulation model was developed in Microsoft Excel (Microsoft Corporation, Redmond, WA, USA) using @Risk add-in software (Palisade Corporation, Ithaca, NY, USA). The settings of the model were chosen to represent a Dutch dairy herd that rears its own replacement heifers.

The model simulated both the dairy herd unit and the young stock rearing unit of the herd. A closed herd, i.e., no purchase of cows and calves, was assumed. Moreover, a management approach ensuring good herd health was assumed. The model was simulated with monthly time steps (stages), and included 83 monthly stages. As the transportation of newborn calves before the age of 2 weeks is prohibited in the Netherlands, an additional stage was defined to capture these first 2 weeks, resulting in a total of 84 stages. Each replication covered in total a period of 7 years, and started with a herd of 100 dairy cows and no heifer calves present. At every stage, there are a number of young stock with an age varying between 2 weeks to first calving age. When the decision was made to retain all heifer calves, after the third year, the model reached the steady state. Thus, the average result for the years 3, 4, 5, 6 and 7 was similar. When the decision was made to keep less heifer calves, the model showed that it reached steady state at year 7. The economic analysis was therefore based on the simulated results of year 7. This has also allowed the simulated system to achieve a stable herd structure in accordance with the simulated scenarios (described in the next section).

In the dairy herd unit of the simulation model, the number of calvings and subsequent number of newborn heifer calves was simulated for each stage by using binomial distribution, based on the herd size, calving interval and the male/female ratio. The number of culled dairy cows was also simulated for each stage by using the binomial distribution.

In the rearing unit, the following states were defined: dead, inseminated, pregnant, infertile and first calving age. At each stage, the number of heifers in each state was simulated by using binomial distribution.

A replacement heifer was defined as a reared heifer that had reached first calving age.

At each stage, the heifer rearing unit and the dairy herd unit were linked by comparing the number of available replacement heifers in the heifer rearing unit with the number of culled dairy cows in the dairy herd unit. Available replacement heifers filled up the slots that were left empty when dairy cows were culled. If no replacement heifer was available to replace a culled dairy cow, the herd size was temporarily reduced, which resulted in an empty slot for at least 1 month. If more replacement heifers were available than required (i.e. the herd size had reached 100 dairy cows), the redundant replacement heifer was sold as an excess heifer.

The model contained a large number of possible combinations of states at each stage. Therefore, 10,000 replications were carried out to provide stable results and insight into the possible range of outcomes. Inputs were based on relevant scientific literature where available, followed by information from organizations and experts active in the Dutch dairy industry. If no information was available, the authors' expertise was used.

Biological input. The number of calves born was specified as a binomial distribution, with the herd size and calving interval as input. The probability of a female calf was assumed to be 50%. The number of culled dairy cows was specified as a binomial distribution with an average culling rate of dairy cows of 25% as input (Table 6.1).

6

Within the rearing unit, the number of calves that died per stage was also specified as a binomial distribution, using the number of calves in that stage and a stage-specific probability of death (Table 6.1) as inputs. The bodyweight of heifers during the rearing period was based on Koenen and Groen, (1996) (Table 6.1). The process of insemination

Table 6.1. Biological input used in the simulation model: default scenario settings

Variables	**Input value**	**Reference**
Heifer calf rearing unit		
Mortality (%)		
From 0 to 2 weeks of age	7	Raboisson et al., 2013; Svensson et al., 2006; Authors' expertise
From 2 weeks to 1 year of age (per month)	0.06-2.00	Raboisson et al., 2013; Svensson et al., 2006; Authors' expertise
From 1 year to first calving age (per month)	0.00-0.01	Raboisson et al., 2013; Svensson et al., 2006
Age at first insemination (months)	15	Authors' expertise
Bodyweight at first insemination (kg)	360	Authors' expertise
Estrus detection (%)	70	Båge, 2003
Conception 1st to 6th artificial inseminations (%)	19-61	Båge, 2003
Conception sexed semen (%)	39	Norman et al., 2010
Age at culling for infertile heifers (months)	20	Authors' expertise
Bodyweight at culling for infertile heifers (kg)	480	Authors' expertise
Dressing percentage of a culled infertile heifer (%)	55	Authors' expertise
Gestation period for culling aborted heifer (months)	6	Authors' expertise
Early embryonic death/ abortion per gestation month (%)	0.2-2.7	Silke et al., 2002; Carpenter et al., 2006; Bach, 2011; Authors' expertise
Dairy cow unit	25	Mohd Nor et al., 2014
Culling rate for slaughter (%)	50:50	Authors' expertise
Male:Female new born sex ratio	417	CRV, 2012
Calving interval (days)		

was started at the age of 15 months, we assumed a rearing strategy that resulted in a bodyweight of 360kg at that age. The number of heifers that became pregnant was simulated using a binomial distribution, with the number of non-pregnant heifers at an age of at least 15 months in that stage and the probability of becoming pregnant as inputs (Table 6.1). Conception rates were 60%, 61%, 61%, 46%, 32% and 19% at 1st, 2nd, 3rd, 4th, 5th and 6th artificial insemination (Båge, 2003). These conception rates ensure that early embryonic death is taken into account. Late embryonic death occurred with rates of 2.7% and 1.5% per month at second and third gestation months. Abortion, at fourth and fifth gestation months, occurred at 0.3% per month and in the remaining months it occurred at 0.2% per month (Bach, 2011; Carpenter et al., 2006; Silke et al., 2002). An aborted heifer before 20 months of age was re-inseminated unless the gestation month was more than 6 months. If a heifer failed to get pregnant after the 6th insemination (or after 29 months), aborted after 20 months of age or after gestation of 6 months, they were defined as being an infertile heifer and subsequently slaughtered. All probabilities parameters (mortality, estrus detection, conception rate, early embryonic death/abortion and culling rate) of the used binomial distributions are mentioned in Table 6.1.

Economic input. The economic analysis was restricted to variable costs only, as the intention of this study was to support tactical level planning (e.g. intermediate-term decision making). At each stage, the variable costs and revenues were calculated, based upon the simulated number of animals in each state. Subsequently, the total net cost of rearing was calculated by summing up the costs minus the revenues. The variable costs were the costs of rearing heifer calves (including feed, labor, health and breeding), the cost of carcass disposal for young stock (in case of death), and the cost of empty slots in the dairy herd unit. The revenues were the revenues obtained from selling infertile and excess heifers.

The cost of an empty slot was defined as the net revenues foregone from having 1 less dairy cow in the herd, calculated as the marginal revenues foregone minus the marginal reduced costs. A dairy cow was assumed to have a yearly milk production of 8,335 kg (LEI, 2012b). Savings in feed costs were based on the energy requirements (VEM) of a cow during a month. The VEM unit is used in the Dutch net energy system, and 1 VEM unit contains 1.650 Kcal (Van Es, 1978). The energy requirements for maintenance were set equal to 6,000 VEM per day, and for milk production to 450 VEM/kg kg of fat- and protein-corrected milk (Klaas et al., 2012). The fat- and protein- corrected milk was calculated by the formula:

$$\text{fat - and protein-corrected milk}=$$

$$(0.337 + (0.116 \text{ x } \% \text{ fat}) + (0.06 \text{ x } \% \text{ protein}) \text{ x average milk production (kg)}$$

A fat percentage of 4.38% and a protein percentage of 3.54% was assumed. The total energy requirement was therefore 513,750 VEM per month. The marginal feed cost savings for an empty slot during a period of 1 month were subsequently based on the amount of concentrates needed to cover the total energy requirements for an average cow. This was equal to 546.5426 kg (1 kg standard concentrates equals 940 VEM) at a price of € 23.60 per 100kg. The marginal savings for health care and other variable costs were estimated to be €5.31 per 100kg milk. The marginal revenues foregone per cow per month were calculated as the foregone milk production multiplied by the milk price (€35.60 per 100kg). Average price levels for the year 2012 were used. The total cost of an empty slot was €82 per month.

The variable costs of rearing a heifer calf were based on Mohd Nor et al. (2012). These costs consisted of feed, health, breeding, and labor costs. When a calf died, it was assumed to be disposed at a cost (Table 6.2).

Table 6.2. Economic input used in the simulation model: default scenario settings

Input variables	Input value	Reference
Heifer calf rearing unit		
Costs of rearing (€ per young stock/month)		
Birth until 3 months	126	Mohd Nor et al., 2012
3 months until 6 months	35	Mohd Nor et al., 2012
6 months until 14 months	42	Mohd Nor et al., 2012
14 months until pregnant	69	Mohd Nor et al., 2012
Pregnant until first calving age	59	Mohd Nor et al., 2012
Carcass disposal costs (€ per heifer calf)		
Less than 1 year of age	15	Rendac, 2013
More than 1 year of age	23	Rendac, 2013
Price of heifer calf at 2 weeks of age (€ per animal)	45	LEI, 2012a
Market value of excess heifer[a] (€ per animal)	985	LEI, 2012a
Slaughter value of infertile heifer[b] (€ per animal)	594	LEI, 2012a
Additional cost of sexed semen (€ per dose)	15.50	CRV, 2013
Dairy cow unit		
Cost per empty slot[c] (€ per slot/ month)	82	Based upon CRV, 2012; LEI, 2012b; Melkveehouderij, 2012

[a]An excess heifer was a replacement heifer for which there was no slot available in the dairy cow unit, and which was therefore sold.

[b]Slaughter value was calculated as the average bodyweight at 20 months (480kg), multiplied by the dressing percentage (55%), multiplied by the price of slaughtered meat per kg (€2.25).

[c]Cost per empty slot reflected the net revenues foregone of 1 dairy cow less. It was calculated as marginal revenues foregone minus marginal costs. Marginal revenue foregone was calculated from the milk production of an average cow in 2012 (8,335 kg) multiplied by the milk price (€35.60 per 100kg). Marginal costs of feeding used the amount of energy (VEM) needed for the maintenance and milk production (corrected for fat and protein production) of a cow. This was then translated into the amount of concentrate (546.5426 kg per month) and multiplied by the price of concentrate (€23.60 per 100kg). The marginal cost for health care and other costs were also included (€5.31 per 100kg milk). The fat and protein corrected milk was calculated using the formula fat- and protein- corrected milk=0.337 + (0.116 x % fat)+(0.06 x %protein) x kg milk. Fat% was 4.38 and protein% was 3.54.

Infertile heifers were assumed to be sold and slaughtered using a slaughter price of €2.25 per kg and a slaughter weight of 480kg per heifer. An excess heifer was sold for life (Table 6.2). The net cost of rearing young stock was calculated as the sum of the variable costs of rearing, the cost of carcass disposal, and the cost of empty slots, minus the revenues from selling infertile and excess heifers.

Optimal retention percentage of heifer calves. In the Dutch dairy farming system, a heifer calf is either sold at 2 weeks of age or kept for raising as replacement stock. Transport of calves less than 2 weeks old is prohibited in the Netherlands. The decision to retain or sell calves is therefore made when the calves are 2 weeks old. The optimal number of heifer calves to be retained was defined as the number of heifer calves which minimized the total net cost of rearing replacement heifers. This was also expressed as a percentage: the optimal percentage of heifer calves that should be retained in order to minimize the total net cost of rearing replacement heifers.

6.3.2 Scenarios and sensitivity analysis

Scenarios. The default scenario represents a situation characterized by the input values as shown in Tables 6.1 and 6.2. Two additional scenarios were evaluated.

i) The first alternative scenario considered an earlier first calving age, achieved by reducing the age at first insemination without compromising milk production in the first lactation. For this scenario, an increased growth pattern was assumed so that 360kg BW was reached at 13 months of age, and consequently first insemination occurred 2 months earlier than in the default situation. Due to the reduction in the rearing period, the first calving age ranged from 22 months until 27 months of age. With the increased growth rate, the costs of rearing were increased. The monthly costs to rear a heifer calf from birth to 3 months, 3 to 6 months, 6 to 14 months, 14 months to pregnant, and pregnant heifers were €126, €42, €46, €76 and €59, respectively (Mohd Nor et al., 2012).

ii) The second scenario considered the insemination of heifers with sexed semen. In Dutch herds, sexed semen is commonly used in heifers. For this scenario, it was assumed that all heifers were inseminated with sexed semen (until 6th insemination), and that the chance of having a heifer calf by sexed semen was 91.6% (Frijters et al., 2009) and the conception rate was 39% (Norman et al., 2010). The additional costs of sexed semen was assumed to be €15.50 per dose (Table 6.2).

Sensitivity analysis. Two sets of sensitivity analyses were performed. The first set explored the effect of individual variables on the net rearing costs. In these analyses the retention percentage of replacement heifers was fixed at the optimal level as determined in the default scenario. For each variable, a value higher and lower than the default value was used. These values reflected a realistic range for the input variable, with values taken from literature, and organizations and experts in the Dutch dairy sector. The following biological variables were investigated: calving interval (+10 days and -10 days), mortality of young stock per month (+0.5% and -0.5%), culling rate of dairy cows (+5% and -5%), conception rate (+10% and -10%), and estrus detection rate (+20% and -20%). In addition, a situation was analyzed where a sudden increase in the disease incidence in the dairy herd unit occurred. This lead to an increase in the culling rate of dairy cows to 35% once every 10 years (disease event probability of 0.1) and once every 4 years (disease event probability of 0.25). In the default situation there was no sudden increase, and the probability of the disease event was therefore 0. The following economic variables were investigated: cost of empty slots (€56 and €126 per slot month), average cost of rearing a heifer (€1,370 and €1,640), meat price for slaughtering (€1.60/kg and €2.35/kg), and market value of an excess heifer (€825 and €1,045). The values for the cost of empty slots were created by using a lower (€32/100kg) and higher (€42/100kg) milk price. The values for the average cost of rearing a heifer were created by increasing and decreasing the rearing costs by €5 per month.

The second set of sensitivity analyses explored the effect of different herd characteristics and management factors on the optimal retention percentage of replacement heifers and the associated total net cost of rearing. For each variable, a range of possible values was investigated. The following variables were investigated: calving interval (385 to 445 days), average mortality of young stock (0% to 18%), culling rate of dairy cows (10% to 40%), disease event probability (0.0 to 0.5), cost of empty slot (€20 to €140) and average costs of rearing (€1,000 to €2,000).

6.4 RESULTS

The optimal retention of 2-week-old heifer calves was 73% in the default scenario (Figure 6.1). The results (mean, 5^{th} and 95^{th} percentile results) for the herd characteristics in the default scenario are presented in Table 6.3 and expressed as a number per herd per year. At the optimal retention percentage, the average size of the herd was 93 dairy cows, and varied between 83 and 99 dairy cows (5th and 95th percentiles). An average of 23 dairy cows were culled per year, with a variation between 16 and 31 dairy cows (5th and 95th percentiles). The average number of heifer calves born was 41. On average, 3 heifer calves died before they reached 2 weeks of age, and 1 heifer calf died between the ages of 2 weeks and first calving. In addition, 4 heifers were culled due to infertility and 1 heifer had aborted. The average number of young stock present during the rearing period was 54, and ranged between 44 and 64 (5^{th} and 95^{th} percentiles). On average, 24 heifers successfully reached first calving age and 1 heifer was sold as excess heifers. The average first calving age of the herd was 25 months.

The economic results (mean, 5^{th} and 95^{th} percentiles) for the default scenario are presented in Table 6.4, the variables are expressed per herd per year. The average total cost of rearing replacement heifers was €37,854, and varied from €31,063 to €44,609 (5th and 95th percen-

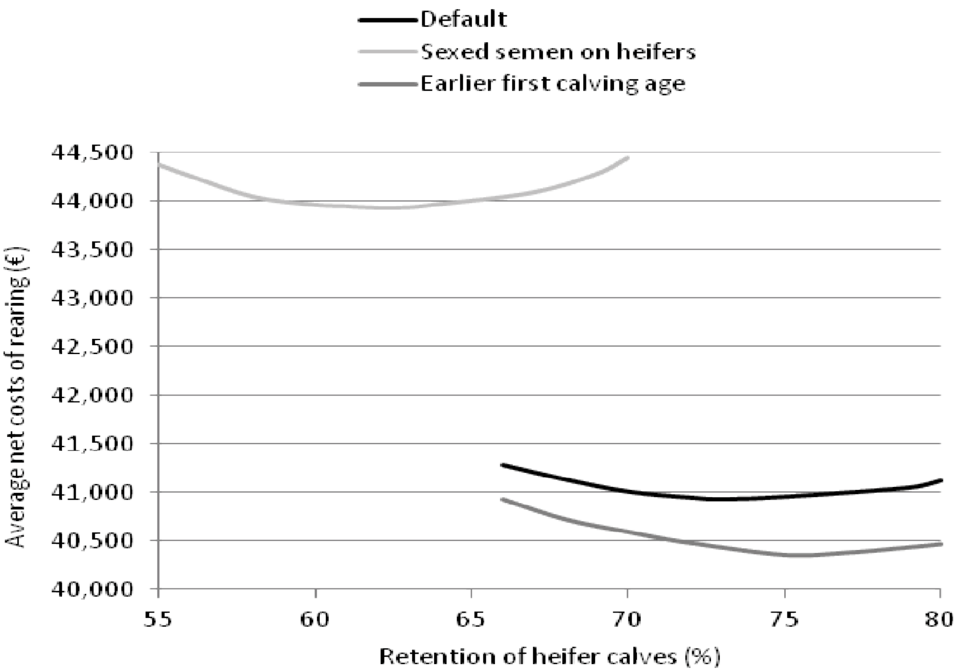


Figure 6.1. The net cost of rearing for different retention percentages of heifer calves for the 3 scenarios: default, earlier first calving, and sexed semen

Table 6.3. Herd characteristics for the default scenario, expressed per herd per year, with an optimal retention of 73% of 2-week-old heifer calves

Variables	Average	5%	95%
Heifer calf rearing unit			
Number of newborn heifer calves	41	30	52
Number of dead heifer calves, before 2 weeks of age	3	0	6
Number of dead heifers, 2 weeks to 1 year of age	1	0	2
Number of dead heifers, more than 1 year of age	0.03	0	0.22
Number of infertile heifers	4	1	8
Number of aborted heifers	1	0	3
Number of first calving heifers	24	17	31
Number of excess first calving heifers	1	0	7
First calving age (months)	25	25	26
Number of young stock present	54	44	64
Dairy cow unit			
Number of culled dairy cows	23	16	31
Number of empty slot months	88	12	206
Herd size	93	83	99

tiles). The average cost of empty slots in the dairy herd unit was €7,190, and varied between €983 and €16,870 (5th and 95th percentiles). The average cost of carcass disposal was €55. The average revenues from selling infertile and excess heifers were €2,318 and €1,335. The net cost of rearing was estimated at an average of €40,939, and varied from €29,261 to €52,132 (5th to 95th percentiles).

Table 6.4. Economic results for the default scenario, expressed as €/herd/year, with an optimal retention of 73% of 2-week-old heifer calves. The average herd size is 93 dairy cows per year

Variable	Average	5%	95%
Costs (€/herd/year)			
Rearing[a]	37,854	31,063	44,609
Empty slots[b]	7,190	983	16,870
Carcass disposal young stock	55	15	105
Revenues (€/herd/year)			
2 weeks old heifer calves	459	315	585
Infertile heifers	2,318	594	4,749
Excess heifers[c]	1,335	0	6,895
Net costs of rearing (€/herd/year)	40,939	29,261	52,132

[a]The total cost of rearing was the sum of feed cost, labor costs, health costs and breeding costs
[b]Cost per empty slot reflected the net revenues foregone of 1 less dairy cow in the herd.
[c]The excess heifers were pre-calving heifers for which there was no free slot available in the dairy cow unit, and thus needed to be sold.

In the scenario with an earlier first calving age, it was optimal to retain 75% of 2-week-old heifer calves. At this optimal retention percentage, the average number of young stock present in the rearing unit was 51 and the average herd size was 94 dairy cows. The average net cost of rearing at the optimal retention percentage was €40,358 per herd per year (Figure 6.1). In the scenario using sexed semen on heifers, it was optimal to retain 62% of 2-week-old heifer calves. At this retention percentage, the average number of young stock in the rearing unit was 55 and the average herd size was 91 dairy cows per herd per year. The average net cost of rearing at the optimal percentage was €43,937 per herd per year (Figure 6.1).

The results for the first set of sensitivity analyses, where the optimal retention percentage was fixed at the optimal level for the default scenario (73%), are presented in Figure 6.2 (biological variables) and Figure 6.3 (economic variables). The results showed that herds with a higher culling rate (+5%), a higher mortality of young stock (+0.5% per month) or a disease event probability of 25% experienced an increase in the average net cost of rearing of €2,986 to €7,924 per herd per year, compared to the default scenario. A herd that kept 73% of the heifer calves and had either a lower conception rate (-10%) or lower estrus detection rate (-20%) had respectively, €1,909 and €3,196 higher average net rearing costs per herd per year compared to the default scenario (Figure 6.2).

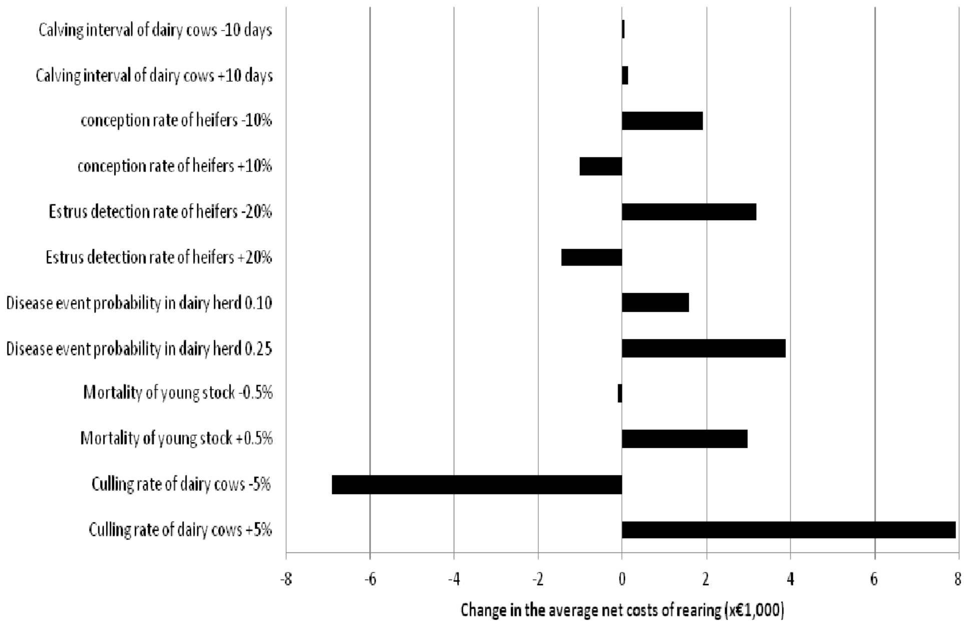


Figure 6.2. Sensitivity of the net cost of rearing to variation in biological inputs, with the retention percentage of heifer calves fixed at the optimal level for the default situation (73%)

The economic results showed that, in a herd that kept 73% of 2-week-old heifer calves, a higher cost of an empty slot (€126 per slot month due to a higher milk price of €42/100 kg) resulted in an increase in the average net cost of rearing of €3,972 per herd per year. The effect of a higher average total cost of rearing (€1,640 per heifer) was increase in the average net cost of rearing by €3,470 per herd per year. A lower market value of an excess heifer (€825 per heifer) increased the average net cost of rearing by €294 per herd per year (Figure 6.3). Effects of

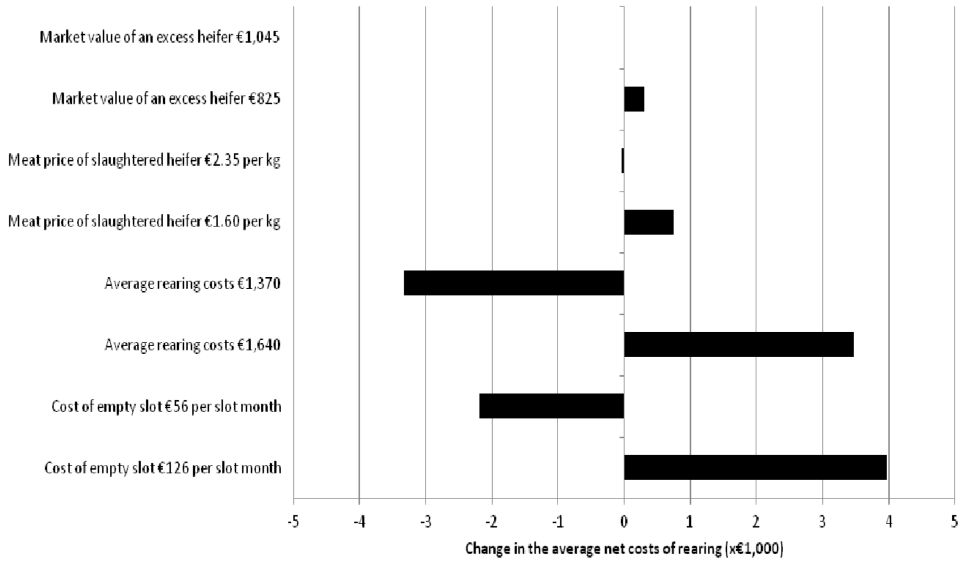


Figure 6.3. Sensitivity of the net cost of rearing to variation in economic inputs, with the retention percentage of heifer calves fixed at the optimal level for the default situation (73%)

different herd characteristics and management factors on the optimal retention percentage of 2-week-old heifer calves are presented in Figure 6.4. For a herd that had a culling rate of dairy cows of 10%, 20%, 30%, or 40%, it was optimal to keep 35%, 62%, 84%, or 100% of heifer calves, respectively (Figure 6.4). A herd that had a disease event probability of 0.5, 0.25 or 0.1 had an optimal retention of 82%, 77%, or 75% of heifer calves per year, respectively. The calving interval also had an effect on the optimal retention percentage. With a lower calving interval (407 days), the optimal retention percentage decreased (71%) and with a higher calving interval (427 days), the optimal retention percentage increased (77%). A similar effect could be seen for mortality of young stock. No mortality lead to a lower optimal retention of 67% and a mortality of 12% lead to an optimal retention of 77%. With a lower (€50 per slot per month) or a higher (€120 per slot per month) cost of empty slots, the optimal retention was 49% and 83%. The rearing costs also had an effect on the optimal retention percentage. Average rearing costs of €1,200, €1,600, and €2,000 lead to an optimal retention of 98%, 75%, and 59% of heifer calves, respectively.

6.5 DISCUSSION

The model developed in our study included the economic costs and revenues associated with the decision to keep heifer calves for rearing. The model was stochastic, and therefore also able to capture the uncertainty associated with this decision. The model included the uncertainty in mortality of young stock, variation in reproduction of heifers, and in the culling rate of dairy cows. Therefore the model was able to simulate the occurrence of not having enough replacement heifers to timely replace culled dairy cows. As with every simulation model, not all aspects were modelled in a detailed way. For example, the cost of an empty slot and heifer growth rates were based on averages from a previous model (Mohd Nor et al., 2012). The dairy herd enterprise was not modeled in detailed manner and culling of dairy cows was modeled using the involuntary culling rate from a previous Dutch study as an input value (Mohd Nor et al., 2014). In reality, the farmer can delay culling the dairy cow until a replacement heifer is available, and this is not covered in the model. Another limitation of the model was the strict limit on the maximum number of dairy cows (we ran the model with 100 dairy cows). In reality, some flexibility exists in herd size, as overstocking is possible to a certain extent. The discussion on overstocking requires a complex economic calculation in itself, there-

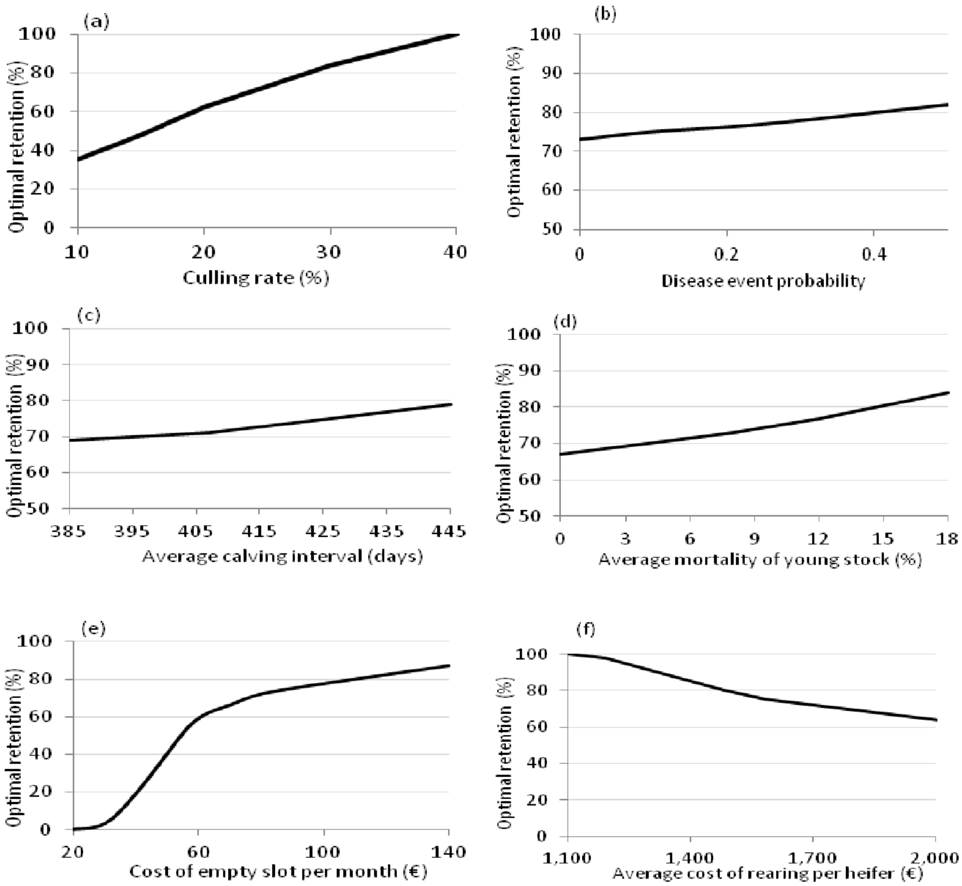


Figure 6.4. Optimal retention percentage of heifer calves at different (a) culling rates, (b) disease event probabilities, (c) average mortalities of young stock, (d) average calving intervals, (e) costs of empty slots per month, and (f) average costs of rearing per heifer

fore we restricted the model to exclude overstocking. In our study, the number of slots was a restriction, and milk quota fulfilment was not taken into account. Milk quota will be abolished in the Netherlands in 2015 and the modeled farm represents a near future scenario without milk quota. A further limitation of the model was the assumption of a closed herd, i.e., no replacement heifers were bought, while in reality herds sometimes buy replacement heifers. We also assumed that enough space was available to raise all heifer calves, and the impact of limited space for heifer calves was not taken into account. In spite of these limitations, the model provided a useful estimate of the total and net costs of rearing replacement heifers. When a herd kept all heifer calves, the average total cost of rearing was €53,880 per herd per year (data not shown). This was equivalent to an average total cost per heifer per year of €1,584, which corresponded with a previous Dutch study (Mohd Nor et al., 2012). To calculate the total net cost of heifer rearing, we included the revenues of excess and infertile heifers, as well as revenues forgone due to a (temporary) lack of replacement heifers when dairy cows were culled. Therefore, all costs and revenues associated with the decision to retain heifer calves were taken into account.

Our study showed that it was optimal to keep 73% of 2-week-old heifer calves, with an average net cost of rearing of €40,939 per herd per year. Because there are, to our knowledge, no other studies on the optimal number of heifer calves to be reared as dairy replacements, we were unable to compare our outcome with other studies. Keeping the optimal number of heifers instead of rearing all heifer calves reduced the cost of rearing young stock, but also meant that there were less replacement heifers available and, therefore, more empty slots. This meant that the dairy herd unit had a smaller average herd size (93 dairy cows) compared to the situation where all heifer calves were reared (average herd size of 98 dairy cows; data not shown). Dutch herds that rear their own replacement heifers generally keep (almost) all of their newborn heifer calves. A common reason for this practice is to ensure that enough replacement heifers are available to replace culled dairy cows in time. The decision to retain heifer calves for rearing is a decision with high levels of uncertainty. This uncertainty is due to calf mortality, delay in conception during the rearing period, and variation in the culling rate of lactating cows. Rearing all available heifer calves is a management approach which gives more security to farmers, in the sense that is more likely that a replacement heifer is available in time. The results of our study support this, the model showed that situations where a replacement heifer was not available were more frequent when the optimal number of heifer calves were kept. It showed (data not shown), as less heifer calves are retained, the probability of an empty slot increased, by 1.9% (retained all) to 2.8% (retained 90%), 4.8% (retained 80%) and 8.7% (retained 70%). However, when (almost) all available heifer calves were reared, this approach has a financial disadvantage; the average net cost of rearing was €2,663 (6.5%) higher per year instead of the optimal number. Moreover, feed costs varies greatly from year to year and affecting costs of raising heifers. A previous study from the US estimated, for a herd of 100 cows, that the total cost of rearing heifers was $32,344 (€23,928) (Tozer and Heinrichs, 2001). Comparing this estimate with the result of our model is difficult, as the parameterization of our model focused on the Dutch dairy farming system. Moreover, our total net cost of rearing also included the consequential losses and returns (empty slots and excess and infertile heifers) associated with the decision to rear heifer calves.

To our knowledge, this is the first study that has linked the heifer rearing and dairy cow units of a dairy herd to determine the optimal number of heifer calves to be kept in a herd that rears its own young stock. Under default circumstances, we estimated the cost of an empty slot to be €82 per slot month or €980 per cow per year. In our model, these costs can be seen as a penalty when the herd size is less than 100 dairy cows. The cost of an empty slot is related to the milk price. With a milk price of €32/100 kg, the cost of an empty slot was €56 per month, causing a reduction in the total net cost of rearing (Figure 6.3). As was expected, the optimal percentage of calves to be retained for rearing decreased when the cost of an empty slot was lower, as shown in Figure 6.4(e). With low costs of empty slots (below €62 per slot per month; €744 per cow per year), the reduction in the optimal retention of heifer calves decreased steeply, from 61% to 0%. From this threshold, the annual cost of rearing replacement heifers was higher than the cost of an empty slot. Under these circumstances, it is optimal not to rear any replacement heifers, as the investment in rearing does not pay back. Average costs of rearing equal to the sales price of raised heifers (both approximately €1,000) resulted in an optimal retention of 100% (Figure 6.4 (f)). In the Netherlands, however, the costs for raising heifers are higher than the sales price, and therefore it is not optimal to retain all heifer calves. Dutch farmers raise almost all of their heifers because they underestimate the costs of rearing (Mourits et al., 2000). The underestimation occurs because farmers do not value the costs for feed, housing and labor. Consequently, farmers who are not aware about the costs of young stock raising retain all heifer calves.

The optimal retention percentage of heifer calves can be influenced by changes in the supply of replacement heifers and changes in the demand from the dairy herd unit. For instance, when the supply of heifer calves was lower due to a higher mortality of young stock, or more dairy cows were needed due to a higher culling rate, the optimal retention percentage of heifer calves increased (Figure 6.4), as did the total net cost of rearing. With a higher mortality of young stock (18%), the total net cost of rearing increased by €4,452. The culling rate of dairy cows had a much higher effect on the net cost of rearing. With a culling rate of 40%, the optimal retention percentage of heifer calves was 100%, and the total net cost of rearing increased by €20,510. In addition to the normal variation in culling (in our model simulated using a binomial distribution), disease events may occur that lead to a sudden increase in culling. We modelled this as the probability of a disease event, in which case there was a short (1-year) increase in the culling rate. When the probability of a disease event increased to 0.5, the optimal retention of heifer calves increased to 82%, and the total net cost of rearing was €7,379 higher.

In the scenario with an earlier first calving age, the optimal retention of heifer calves was 75%. It was also shown that in this scenario, fewer young stock were present during the rearing period as compared to the default situation. As a result, the total net cost of rearing reduced slightly, by €581 per year (Figure 6.1). The advantages of a low first calving age due to a reduction in heifer rearing costs have been documented in other studies (Tozer and Heinrichs, 2001; Pirlo et al., 2000). It was shown that a 1-month-lower first calving age (assuming 6% higher feed costs) in a herd of 100 cows would reduce the total cost of the replacement program by $1,400 (€1,016) (Tozer and Heinrichs, 2001). This is more than our estimate, but our results also confirm the economic benefits of a lower first calving age.

In our study, sexed semen was assumed to be used only on first calving heifers. In a previous study, it was demonstrated that the use of sexed semen is more effective when applied to heifers due to a higher conception rate than older dairy cows (especially high producing cows) (Frijters et al., 2009). Therefore, in the Netherlands, sexed semen is predominantly used on heifers. In accordance with our expectations, more heifer calves were produced when sexed semen was used. It was therefore optimal to keep a lower percentage (62%) of 2-week-old heifer calves. However, at the optimal percentage, the costs of rearing is higher (€43,937) than in the default situation because of the higher costs for insemination and lower conception rate.

In our model, we assumed that all 2-weeks of age heifer calves are similar and as they become replacement heifer, they were also assumed to have similar milk production as the culled dairy cow. In reality, however, some heifer calves are superior to others and with genomic selection, the best heifer calves can be selected (Thomasen et al., 2013). The genomic test can be applied to every heifer calve born and recently this has been accepted and is widely use in practice by farmers as it is relatively cheap and accurate (Hayes et al., 2013). However, future research is needed to determine the economic value of applying genomic selection at commercial dairy farms. Likewise, beef semen was another method used on lower tier dairy cows to automatically keep only the best heifer calves for the next generation and at the same time to get a higher price for the calves that are sold.

Assuming the average outcomes of the model in the default scenario (optimal retention of 73% of heifer calves, total net cost of rearing of €40,939, and a herd size of 93 dairy cows with an average milk production of 8,335 kg per cow per year), the average net cost of rearing accounted for 12% of the cost price of milk (€44.29/100kg) (LEI, 2012c). This means that the rearing of replacement heifers is an important part of the cost of milk production. However, by optimizing the number of heifer calves to be kept for rearing, the average net cost of heifer rearing can be reduced.

6.6 CONCLUSIONS

A simulation model was developed, that determined the optimal number of heifer calves to be kept and reared as replacement heifers in a closed dairy herd. For default Dutch circumstances, the optimal retention of 2-week-old heifer calves was 73%. By keeping the optimal number of heifer calves, a herd could reduce the total net cost of rearing by 6.5%, as compared to the situation in which all heifer calves were kept and reared. Specific herd characteristics (culling rate of dairy cattle, risk of disease events, and young stock mortality) and economic variables (cost of rearing, cost of an empty slot, and price of a replacement heifer) had a large effect on the optimal retention percentage of heifer calves to be reared as dairy replacements.

References

Bach, A. 2011. Associations between several aspects of heifer development and dairy cow survivability to second lactation. J. Dairy Sci. 94:1052-1057.

Båge, R. 2003. Conception rates after AI in Swedish red and white dairy heifers: Relationship with progesterone concentrations at AI. Reprod. in Domest. Anim. 38: 199-203.

Brickell, J. S., N. Bourne, M. M. McGowan, and D. C. Wathes. 2009. Effect of growth and development during the rearing period on the subsequent fertility of nulliparous Holstein-Friesian heifers. Theriogenology 72: 408-416.

Brickell, J. S. and D. C. Wathes. 2011. A descriptive study of the survival of Holstein-Friesian heifers through to third calving on English dairy farms. J. Dairy Sci. 94: 1831-1838.

Carpenter, T. E., M. Chriél, M. M. Andersen, L. Wulfson, A. M. Jensen, H. Houe, and M. Greiner. 2006. An epidemiologic study of late-term abortions in dairy cattle in Denmark, July 2000- August 2003. Prev. Vet. Med. 77:215-229.

CRV, 2012. Table 2 (in dutch, vocabulary in English). Accessed Nov. 14, 2013 https://www.crv4all.nl/over-crv/publicaties/jaarverslagen/327327/

CRV, 2013. (in dutch, vocabulary in English). Accessed Nov. 14, 2013 https://www.crv4all.nl/producten-diensten/genetica/algemeen/stierenkaarten/stierenkaart_roodbont_zwartbont/

Frijters, A. C. J., E. Mullaart, R. M. G. Roelof, R. P. van Hoorne, J. F. Moreno, O. Moreno, and J. S. Merton. 2009. What affects fertility of sexed bull semen more, low sperm dosage or the sorting process? Theriogenology 71: 64-67.

Gabler, M. T., P. R. Tozer, and A. J. Heinrichs. 2000. Development of a cost analysis spreadsheet for calculating the costs to raise a replacement dairy heifer. J. Dairy Sci. 83: 1104-1109.

Hayes, B. J., H. A. Lewin, and M. E. Goddard. 2013. The future of livestock breeding: genomic selection for efficiency, reduced emissions intensity, and adaptation. Trends Genet. 29:206-214.

Hultgren, J., C. Svensson, D. O. Maizon, and P. A. Oltenacu. 2008. Rearing conditions, morbidity and breeding performance in dairy heifers in southwest Sweden. Prev. Vet. Med. 87: 244-260.

Koenen, E. P. C., Groen, A. F., 1996. Genetic analysis of growth patterns of black and white dairy heifers. J. Dairy Sci. 79, 495-501.

LEI, 2012a. Animal prices. Accessed Nov. 14, 2013. http://www3.lei.wur.nl/BIN_ASP/show.exe?aktie=vindtoonandbj=2010andej=2013andlanguage=USandValuta=2andpublicatieID=1andkiestabel=8.01andDatabase=Prijzen

LEI, 2012b. Feed price. Accessed Nov. 14, 2013. http://www3.lei.wur.nl/BIN_ASP/show.exe?aktie=vindtoonandbj=2010andej=2013andlanguage=NLandValuta=2andpublicatieID=1andkiestabel=2.04andDatabase=Prijzen

LEI, 2012c. Milk price. Accessed Nov. 14, 2013. http://www3.lei.wur.nl/BIN_ASP/show.exe?aktie=vindtoonandbj=2010andej=2013andlanguage=NLandValuta=2andpublicatieID=1andkiestabel=7.04andDatabase=Prijzen

Mee, J. F. 2008. Perinatal mortality in heifers - an emerging problem. Cattle Pract. 16: 166-173.

Melkveehouderij, 2012. In: Klaas, B., van Middelkoop, J., Ouweltjes, W., Remmelink, G., Wemmenhove., H. (Eds), Handboek Melkveehouderij, Roodbont Publishers B.V., The Netherlands, p.179 (In Dutch)

Mohd Nor, N., W. Steeneveld, and H. Hogeveen. 2014. The average culling rate of Dutch dairy herds over the years 2007 to 2010 and its association with herd reproduction, performance and health. J. Dairy Res. 81: 811-8.

Mohd Nor, N., W. Steeneveld, M. C. M. Mourits, and H. Hogeveen. 2012. Estimating the costs of rearing young dairy cattle in the Netherlands using a simulation model that accounts for uncertainty related to diseases. Prev. Vet. Med. 106: 214-224.

Mourits, M. C. M., H. J. Van der Fels-Klerx, R. B. M. Huirne, and M. W. C. Huyben. 2000. Dairy-heifer management in the Netherlands. Prev. Vet. Med. 46:197-208.

Norman, H. D., J. L. Hutchison, and R. H. Miller. 2010. Use of sexed semen and its effect on conception rate, calf sex, dystocia, and stillbirth of Holsteins in the United States. J. Dairy Sci. 93:3880-3890.

Pinedo, P. J., A. De Vries, and D. W. Webb. 2010. Dynamics of culling risk with disposal codes reported by Dairy Herd Improvement dairy herds. J. Dairy Sci. 93: 2250-2261.

Pirlo, G., F. Miglior, and M. Speroni. 2000. Effect of age at first calving on production traits and on difference between milk yield returns and rearing costs in Italian Holsteins. J. Dairy Sci. 83: 603-608.

Raboisson, D., F. Delor, E. Cahuzac, C. Gendre, P. Sans, and G. Allaire. 2013. Perinatal, neonatal, and rearing period mortality of dairy calves and replacement heifers in France. J. Dairy Sci. 96: 2913-2924.

Rendac, 2013, Tarievenlijst (in Dutch) Accessed Feb. 3, 2014. http://www.rendac.nl/nl/footer-quicklinks/rendac-tarieven/

Silke, V., M. G. Diskin, D. A. Kenny, M. P. Boland, P. Dillon, J. F. Mee, and J. M. Sreenan. 2002. Extent, pattern and factors associated with late embryonic loss in dairy cows. Anim. Reprod. Sci. 71:1-12.

Svensson, C., A. Linder, and S. O. Olsson. 2006. Mortality in Swedish dairy calves and replacement heifers. J. Dairy Sci. 89: 4769-4777.

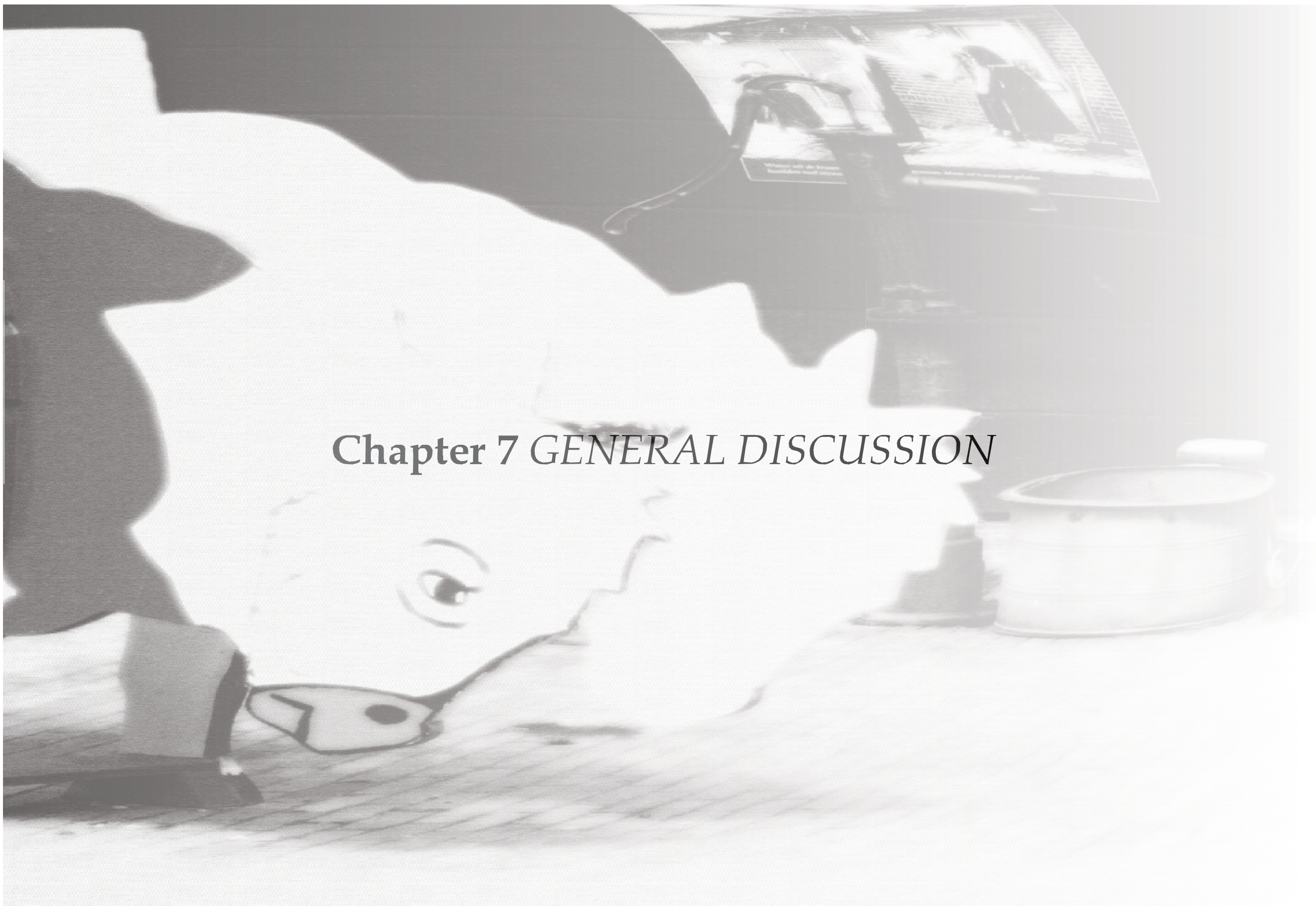
Thomasen, J. R., C. Egger-Danner, A. Willam, B. Guldbrandtsen, M. S. Lund, and A. C. Sørensen. 2013. Genomic selection strategies in a small dairy cattle population evaluated for genetic gain and profit. J. Dairy Sci. 97: 458-470.

Tozer, P. R. and A. J. Heinrichs. 2001. What affects the costs of raising replacement dairy heifers: A multiple-component analysis. J. Dairy Sci. 84: 1836-1844.

Van Es, A.J.H., 1978. Feed evaluation for ruminants. I. The system in use from May 1977 onwards in The Netherlands. Livest. Prod. Sci. 5: 331-345.

Vonk Noordegraaf, A., J. A. A. M. Buijtels, A. A. Dijkhuizen, P. Franken, J. A. Stegeman, and J. Verhoeff. 1998. An epidemiological and economic simulation model to evaluate the spread and control of infectious bovine rhinotracheitis in the Netherlands. Prev. Vet. Med. 36: 219-238.

Chapter 7 *GENERAL DISCUSSION*



CHAPTER 7

7. General discussion

This research was motivated by the lack of attention given to young stock rearing, even though young stock are the producing dairy cows of the future. In addition, we saw an opportunity to achieve more sustainable dairy farms by improving the decision making during young stock rearing. The general objective of this thesis was to provide insight in the economic consequences of the decisions taken during young stock rearing.

We studied 2 important decisions taken during young stock rearing. First, we investigated the decision about the first calving age (FCA) (chapter 4), and subsequently we investigated the decision about the number of 2-week-old heifer calves to retain (chapter 6). Both of these decisions required a lot of inputs, some of which were not readily available. Therefore, we studied 2 important inputs for which data were lacking for the Netherlands. These were the cost of rearing and the culling rate of dairy cows. The cost of rearing was estimated using the stochastic model described in chapter 2. This model was validated in chapter 3. The culling rate of dairy cows was studied in chapter 5.

In chapters 2 to 6, the individual results were discussed. In the present chapter, the main results of this thesis are summarized. Discussion points that have not been mentioned in the earlier chapters are discussed. Finally, recommendations and conclusions are described.

7.1 Main results of the thesis

Chapter 2 Estimating the costs of rearing young dairy cattle in the Netherlands using a simulation model that accounts for uncertainty related to diseases. We hypothesized that farmers are not fully aware of the costs of young stock rearing and that they therefore underestimate these costs. As a consequence, economically non-optimal decisions on young stock rearing can be made. Therefore, it is important that farmers become more aware of the costs of rearing.

In chapter 2, the distribution of the cost of young stock rearing from 2 weeks of age until FCA was estimated using a stochastic calf level simulation model. Uncertainties related to calf diseases (calf scours and bovine respiratory disease) were included in the model, for which both the probabilities of the diseases and the effects of the diseases (growth reduction) differed at different ages.

Results showed that 91% of young stock successfully reached FCA, 6% died prematurely (from 2 weeks of age to FCA), and 3% were culled due to reproductive failure. The heifers had an average FCA of 25 months with an average bodyweight of 542kg. The total cost of rearing was estimated at €1,567 per heifer and varied between €1,423 and €1,715 per heifer. Reducing the FCA by 1 month reduced the total cost of rearing between 2.6% and 5.7%. Sensitivity analysis showed that the average rearing costs were especially influenced by labor efficiency and the cost of feed.

The model showed that the total cost of rearing contributed approximately 13% to the cost price of milk. We think that this value is high enough to justify the need for dairy farmers to become more aware of the economic importance of optimizing young stock rearing. Information from this model can be used by farmers to start prioritizing young stock rearing, and it provides a starting point for making improved decisions about the rearing of young stock.

Chapter 3 The total cost of rearing a heifer: calculated versus perceived cost. To validate the costs estimated in chapter 2, a newly developed economic tool (Jonkos) was used. With this tool, farmers can fill in herd specific values for general information, numbers of animals, and the following costs: ration, roughage, livestock, land and buildings, manure, labor and installation, and water and energy. We obtained data from 2 separate studies, in which a total of 75 farms were visited. The farmers filled in the tool together with a student. Prior to filling in the tool, 36 of the 75 farms were also asked to provide the farmers' own estimation of the total cost of rearing a heifer (perceived costs).

On average, the calculated total cost of rearing (including labor and barn costs) was €1,790 per heifer (with a range from €919 to €3,307 per heifer). This value was higher than the estimated cost of young stock rearing obtained in chapter 2, mainly due to a different method of calculating the cost for roughage. The average perceived total cost of rearing (for farms that included labor and barn costs, n=20 farms) was €1,030 per heifer (with a range from €750 to €1,600 per heifer). This showed that most farmers in the study underestimated the total cost of young stock rearing.

Chapter 4 First calving age and first-lactation milk production on Dutch dairy farms. To provide a foundation for making informed and better decisions on the FCA, we used data from 8,454 heifers to study the association between FCA and first lactation milk production (FLP). Moreover, the effect of management factors on the FCA was investigated. The management factors were general management, healthcare, calf disease incidence, pre-weaned colostrum and milk feeding, housing, cleanliness, and breeding. Subsequently, the same approach was used for the FLP. The study used data from a survey of 100 Dutch dairy farms conducted in 2010. The median FCA of the herd was 25.4 months and the median FLP of the herd was 7,518 kg per 305 days.

The median FCA of the herd was associated with a minimum age at first insemination, feeding of waste milk, and the amount of milk given pre-weaning. The median FLP of the herd was associated with the median FCA of the herd and vaccination status for bovine respiratory syncytial virus. Heifers with a FCA of 24 months produced, on average, 7,164 kg of milk per 305 days, and calving 1 month earlier gave 143 kg less milk per 305 days. When the FCA did not deviate from the median FCA of the herd, heifers produced on average 7,272 kg milk per 305 days. Heifers calving 1 month earlier than the median FCA of the herd produced 90 kg milk per 305 days less. Heifers calving 1 month later than the median FCA of the herd produced 86 kg per 305 days more.

This is the first study that explains FLP using deviation of FCA from the median FCA of the herd. It assumes that heifers raised within the same farm have similar development since they are similarly managed. Similar management is reflected by the median FCA of the herd, with a deviation of the heifer's FCA from the median FCA reflecting the heifer's development relative to the herd's average. The advantage of using the deviation of FCA is that it accounts for between-farm differences in rearing management. These results show that the FCA can be lowered by starting inseminations earlier. However, earlier inseminations need to be accompanied by an adjustment of the rearing management to ensure sufficient development, otherwise earlier inseminations will lead to lower FLP. These findings show that an economic optimum exists between rearing costs and FCA.

Chapter 5 The average culling rate of Dutch dairy farms over the years 2007 to 2010 and its association with herd reproduction, performance, and health. The culling rate of dairy cows determines the number of replacement heifers required, which is important information for the decision about the number of 2-week-old heifer calves to retain (chapter 6). In chapter 5, the average culling rates during the period from 2007 to 2010 and their variation within Dutch dairy farms was investigated. We used a dataset of 1,903 dairy farms, which included information on the dates of culling and slaughter/death for the years 2007 to 2010. The average culling rate for slaughter/death was defined for each year as the percentage of cows that left the farm and died within 30 days after they were culled. The average culling rate for slaughter/death was 25.4% and varied between 23% (2007) and 28% (2010). More than 70% of the farms had an average culling rate for slaughter/death of less than 30%.

Chapter 6 The optimal number of heifer calves to be reared as dairy replacements. To provide insight in the economic consequences of the decision on the number of 2-week-old heifer calves to retain, we developed a stochastic herd level simulation model. The optimal percentage of 2-week-old heifer calves to be retained was defined as the percentage of heifer calves, which minimized the average net cost of rearing replacement heifers. Inputs for this model were based on literature, expert opinion, authors' expertise, and the results from chapters 2 and 5.

The optimal retention of 2-week-old heifer calves was 73%. At the optimal retention percentage, the average size of the herd was 93 dairy cows and 54 young stock were present. The average FCA was 25 months. The net cost of rearing when retaining the optimal percentage of heifer calves was estimated at €40,939 per herd per year. This was 6.5% lower than the net cost of rearing when all heifer calves were retained. An earlier FCA resulted in an optimal retention of 75%, and the net cost of rearing was €581 per herd per year lower than in the default scenario. For farms with a lower or higher culling rate of dairy cows (10% or 40% instead of 25% in the default scenario), it was optimal to retain 35% or 100% of the heifer calves per year. Results of this chapter indicated that a farm could reduce the net cost of young stock rearing by 6.5%, by retaining the optimal number of heifer calves instead of retaining all heifer calves.

7.2 More sustainable dairy farming through heifer rearing

More attention for the sustainability of dairy farms is needed in the Netherlands. In a more sustainable production system, dairy farms use less resources, produce less wastes (e.g. manure and greenhouse gas emissions such as methane), emphasize a preventive approach towards animal health, and maintain their profitability (Van Calker et al., 2005). One way to achieve an economically sustainable dairy farm is to reduce costs. Our results show that cost reduction can be achieved through reducing the number of young stock reared (chapter 6). For example, by retaining the optimum number of heifer calves instead of all heifer calves, on average €2,663 per herd per year can be gained on a farm with 100 dairy cows. Moreover, the number of young stock present is even lower on a farm with a lower FCA, and this means that an additional €581 per herd per year could be gained.

Retaining fewer heifer calves, and to a lesser extent also lowering the FCA, has an impact on the environmental sustainability of a dairy farm. Fewer heifers on the farm means lower use of resources (e.g. water) and lower production of waste (e.g. manure and greenhouse gas). The water intake of a young animal ranges between 11.5 and 32 L per day, and water use (e.g. for cleaning and sanitation) is between 9 and 25 L per day (Omafra, 2007). Young stock excrete wastes such as manure and greenhouse gases. A young stock reared in a stable produces between 4,000 and 6,500 kg of manure per year (CBS, 2008). Based on these numbers, methane gas emissions can be calculated (the emission factor in a stable is 0.00180 kg CH_4 per kg animal manure) (Van der Hoek, 2006).

In a 100 cow-herd characterized with a culling rate of 25% per year and retention of all heifer calves (40 heifer calves), an average of 76 young stock are present per year (chapter 6). When the optimal number of 2-week-old heifer calves are retained, 28 heifer calves are retained per year, and on average 54 young stock are present per year (chapter 6). This means, with 22 fewer young stock present per year, a farm reduces its water use and intake by 432,657 L per year (5th and 95th percentile: 142,792 and 199,533 L per year), reduces manure production by 109,763 kg per year (5th and 95th percentiles: 67,291 and 176,708 kg per herd per year), and reduces methane emissions by 197 kg CH_4 (5th and 95th percentiles: 121 and 318 kg CH_4) per year. Exact calculations on water use, manure production, and methane emissions are more complex due to management factors such as the type of feed consumed and the grazing period (Van der Hoek, 2006).

Previous studies have also shown the effect of the number of young stock present on the amount of wastes on the farm. Rearing a lower number of young stock was suggested to effectively meet the Dutch environmental regulations (Ondersteijn et al., 2002). Van Calker et al. (2005) showed that with a lower replacement rate (from 38% to 33%), the CH_4 and N_2O emissions produced by a farm were 8% lower.

7.3 Methodology

Both the empirical and the normative approach were used in this thesis. The empirical approach was applied in chapters 3, 4, and 5 by analyzing data using multivariate regression analyses. The normative approach was applied in chapters 2 and 6 by developing and applying stochastic models. In chapter 6, the model included information from chapters 2 and 5.

Empirical approach. The empirical approach can be defined as the systematic process of deriving and analyzing data from direct or indirect observations (Roth, 2007). Previous studies related to young stock rearing that used the empirical method covered the following areas: growth (Bach et al., 2011; Stanton et al., 2010), diseases (Marce et al., 2010; Donovan et al., 1998), fertility (Bell et al., 2010; Brickell et al., 2009), FCA (Heinrichs et al., 2011; Losinger and Heinrich, 1997), FLP (Hultgren et al., 2011; Ettema and Santos, 2004), and udder health (Svensson et al., 2006).

Data can be from commercial farms (field data or observational data) or from experiments. For experiments, the study is usually done in small groups making generalization more difficult. For field data, disadvantages are the variation and the existence of many confounding factors. Consequently, a large amount of data is needed (e.g. many farms or data from many years) making it difficult to edit and check the data. For instance, in chapter 5, we used culling data at cow level from 1,903 farms during the period from 2007 to 2010, making it difficult to distinguish culling due to slaughter or life.

Data from commercial Dutch dairy farms are usually readily available. For instance, in this thesis, field data were readily available in chapters 4 and 5. By using this type of data, specifically, farm accounting data and data on the number of calves, we could have, extended the empirical approach to chapter 6, and analyzed the association between the number of heifer calves retained and the cost of young stock rearing. Such data would, however, contain noise (meaningless data). For instance, good young stock management is related to good dairy cow management and vice versa. Thus, because of an overall good herd management, some farms might have even lower costs of rearing than others, which makes it is difficult to capture true association. Moreover, on most Dutch dairy farms, some costs of young stock rearing are not clearly separated from dairy cows, for instance feed costs due to same type of feed given/used in the herd, and veterinary bills. Finally, missing data would commonly occur because farmers do not always keep their records consistently. As these reasons can interfere with the analysis, we chose to use the normative approach in chapter 6.

Normative approach. Then normative approach uses computer simulation techniques. Computer simulation is a method for analyzing a problem by creating a simplified mathematical model of the system under consideration, which can then be manipulated by input modification (Dijkhuizen, 1992). It is especially attractive where real-life experiments would be either impossible or too costly. Many previous young stock rearing studies have used the normative approach. Examples include studies on diseases (Lassen et al., 2012; De Vries., 2004), growth (Mourits et al., 1999), reproduction (Rajala-Schultz, et al., 2000), and costs (Tozer and Heinrichs, 2000).

The models described in chapters 2 and 6 are stochastic simulation models, and this type of model has also been used in other studies (Lassen et al., 2012; Ettema et al., 2011; Kudahl et al., 2007). The advantage of a stochastic simulation model is that variation in inputs can be taken into account and that variation is visible in the outcomes. In a previous study on young stock rearing, a stochastic model was developed on decision making in parasite control (Lassen et al., 2012). This is the only model, to our knowledge, that has a dairy herd model with a young stock rearing model as an extension. However, this model did not include much detail on young stock rearing, such as disease incidence and mortality rate.

Other studies related to young stock rearing that developed optimization models and used dynamic programming techniques were Mourits et al. (1999; 2000a; 2000b). The disadvantage of an optimization model is that, in the biological part of the model, it cannot include much detail because this requires a large memory to run the model. Moreover, variation in outcomes is not provided as an output of the model. The advantage of using this type of model is that it can provide an optimal solution for a given goal. We could have, therefore, developed an optimization model to determine the optimal number of heifer calves to retain in chapter 6. We chose a stochastic simulation model because it is easier to model detailed relationships. Moreover, we were also interested in the variation and uncertainty in the number of heifer calves to be retained because there is a large variation in the inputs, such as the culling of dairy cows, the mortality of heifer calves, and different prices and costs.

External validation of the model. Model validation is defined as substantiation that a model within its domain of applicability possesses a satisfactory range of accuracy, consistent with the intended application of the model (Sargent, 2013). Although performing model validation is time consuming and costly, it increases the confidence that a model is valid and increases the value of the model to users (Sargent, 2013; Anshoff and Hayes, 1973). There are no hard rules in model validation because no specific tests can be applied to determine the correctness of a model. In this thesis we chose to follow the approach proposed by Sargent (2013), and used internal validation (i.e. model replications) and external validation (i.e. comparison with another model that uses real data or another valid model).

Internal validation was applied for the stochastic models in chapters 2 and 6. External validation was applied for the stochastic model in chapter 2, using the tool in chapter 3 that calculates the cost of young stock rearing and which we used to obtain the inputs of 75 Dutch farmers. On average, the calculated cost from the tool in chapter 3 was €1,790 per heifer, whereas the estimated cost of rearing from the simulation model in chapter 2 was, on average, €1,567 per heifer. The difference was not due to poor models but mostly to differences in the assumptions on the costs of young stock rearing. Our estimate in chapter 3 included additional costs, which were not taken into account in chapter 2. The additional costs were costs of land ownership, crops, machinery, and contract work. These costs are made to produce feed and were not included in the estimate in chapter 2, as the Jonkos tool assumes that feed is bought. The total feed cost in chapter 3 was €849 per heifer, whereas in chapter 2, it was estimated at €698 per heifer. The higher cost of feed in chapter 3 may suggest that it is more expensive for farmers to produce their own feed, however this feed could be of a much higher quality. The estimates of the total cost of young stock rearing were quite similar when the difference in feed cost was taken into account, which therefore validates the model in chapter 2.

External validation of the model outcome on the cost of young stock rearing in chapter 6 was also conducted with the model outcome in chapter 2. The total cost of young stock rearing in chapter 6 was €1,584 per heifer, which therefore validates this model in comparison to the model in chapter 2. Following these validations, we therefore concluded that the models in chapters 2 and 6 are valid. Many stochastic models were only validated internally (Mourits et al., 2000a; Lassen et al., 2012), and our external validation provides an extra confirmation of the models validity.

7.4 Veterinary advice on young stock rearing

The results of this thesis show that young stock rearing is an expensive investment for a farm (chapter 2) and that the health of young stock influences the cost of young stock rearing (chapters 2 and 6). For instance, we demonstrated that, the average total costs of rearing was €1,567 per heifer (chapter 2). The cost of rearing a heifer that is sick at least once is €95 higher than for a healthy heifer (chapter 2). Additionally, the more calves the farmer loses (due to higher mortality), the higher the optimal number of replacement heifers that needs to be retained and therefore, the higher the cost of young stock rearing (chapter 6). We showed that, with higher young stock mortality (12%), the optimal retention was 77% of 2-week-old heifer calves, and the net cost of rearing per herd was €1,436 higher than in the default situation (retain 73% heifer calves and 8% young stock mortality) (chapter 6). Results also showed that a good colostrum management influences the FCA (chapter 4), and thus also the cost of rearing.

The result in this thesis is therefore useful for veterinarian mainly because they are the appropriate person to advise farmers on health related issues for young stock. At the same time, they can emphasize to farmers that decisions related to the health of young stock can influence the total cost of young stock rearing. This advice is important because during young stock rearing no immediate returns can be gained, unlike for dairy cows.

In the Netherlands, about 50% to 70% dairy farms participated in on farm veterinary herd health and production management (VHHM) program where, within this program veterinarians visited the dairy farms on regular basis. The VHHM program was implemented to support shifting of dairy management from curative to preventive health management. This program included young stock rearing as one of the theme that veterinarians and farmer has to discuss. (Derks et al., 2012; Lievaart et al., 2008). Based on previous study that evaluated the program, young stock rearing are, however, almost never discussed during the visits (Derks et al., 2012). Whereas, our results in this thesis showed that young stock rearing needs more attention. These circumstances present an opportunity for veterinarians to advice farmers on the decisions made during young stock rearing. Veterinarians need to mention, that is worth the farmer's time and attention.

To improve the advice about young stock rearing, veterinarians have to understand the nature of young stock rearing. Young stock rearing takes on average 26 months, with many interrelationships between the biological processes at heifer level (disease, growth, reproduction) and herd level (number of replacement heifers, diseased, inseminated, dairy cows culled). This means that there are many interrelated decisions that a farmer has to make, and that the decision making process is more complex than it first appears. This complexity was represented in our models (chapters 2 and 6) and the tool that was built (chapter 3). The support by veterinarians must therefore be an ongoing process, and focused on ensuring that the farmer is aware that it is important to have healthy replacement heifers with minimal rearing costs. Given the complexity of the decisions, it may be beneficial to focus on the important elements, rather than the entire decision process.

7.5 The generalization of findings to other region

This study focused on Dutch dairy farming, which is characterized by intensive dairy farms with specialized and modern technology and good herd health management. Generalization of findings to herds that have an equal system is relatively easy, however it is more difficult to generalize to herds that have different systems, such as in the tropics. The generalization of findings to the tropics is useful as studies on dairy young stock rearing in the tropics, such as in Southeast Asia, are even more scarce than for the more developed dairy system (Moran, 2011; de Jong, 2000; Imaizumi and Devendra, 1984). Dairy farms in Southeast Asia and in the Netherlands share the characteristic that farmers do not give much attention to young stock rearing (Devendra, 2001). If dairy farmers in tropics are aware on the economic consequences of decisions taken during young stock rearing, they can give more attention and make optimal decisions on young stock rearing. This can enable a sustainable dairy farming and support food security in developing countries (de Jong, 1996).

Differences in herds. Dairy farms in the tropics differ from their counterparts in the Netherlands in the following areas: different types of breeds (e.g. Sahiwal, Local Indian dairy, Jersey, Zebu, and crossbreeds), the tropical climate (heat stress, both indoors and outdoors), different herd sizes (e.g. more small holder farms and possibility to expand), lower level of technology, and lower feed quality (McDermott et al., 2010, Moran, 2011; de Jong, 1996). The mortality of young stock is higher (15% to 45%) (Moran, 2011). The FCA of heifers in the tropics, such as in Kenya, is higher, on average 28.1 months (with a range of 24 to 38 months) (Wanjala and Njehia, 2014). The bodyweight targeted at calving is lower, 350kg for Zebu and crossbreeds, and 450kg for grade Friesian (Moran, 2005), and this explains the lower milk production during the first lactation. These differences mean that our findings are mostly not generalizable to tropical dairy farms.

Total cost of rearing. The costs that are associated with young stock rearing in chapter 2 are prevention costs, treatment costs, carcass removal costs, feed costs, labor costs, breeding costs, sales costs, barn costs, and costs related to the loss of young stock due to death and culling. The carcass removal costs are not relevant to dairy farms in the tropics, as carcass removal by private company is not a common practice. The other types of costs are the same, but the size of the costs will be different due to different currencies, costs, prices, and biological aspects such as the growth curve. The length of rearing a young stock in tropics is also long. We can conclude that, rearing a heifer is likely to be expensive for dairy farms in tropics.

Reducing FCA to reduce the cost of rearing. The decision to reduce the FCA will also reduce the total cost of rearing for farms in the tropics. This is because the types of costs calculated are the same for both places. The amount however, will be different because of different costs and prices. The reduction of FCA without an adjustment in bodyweight might lower the FLP. This is because bodyweight at calving determines the FLP and heifers, regardless of where they are reared, have a similar physiological development pattern. However, the size of the decrease in milk production could be different because the breed, growth rate, management, and quality of feed given are all different. This strategy may have potential to reduce the cost of rearing in the tropics, but more research needs to be done to find the optimum between FCA and FLP.

Model re-parameterization. It is difficult to generalize our findings to tropical dairy farms. However, it is relatively easy to re-parameterize the models in chapter 2, 3, and 6 according to the characteristics of dairy farms in the tropics. In previous studies on young stock rearing, Mourits et al, (2000b) adapted a dynamic optimization model from the Dutch situation to the US (Pennsylvania) situation, and Lassen et al. (2012) adapted a stochastic model from the Danish situation to Estonian dairy farms.

7.6 Further research and recommendations

Simulating the effects of disease prevention. Our models in chapters 2 and 6 did not explore the decisions about preventive measures for calf diseases, even though these decisions may be important from an economic point of view. To provide insight in such decisions, more inputs are required in the model, such as the effect of preventive measures (e.g. vaccinations on young stock) on the diseases incidence, mortality of young stock, and growth of young stock. This information might be lacking. An example of this lack of data is for the parasite infection (e.g *Dictyocaulus viviparus*). Due to lack of data, we did not include this parasite infection in the definition of bovine respiratory disease in the stochastic model in chapter 2. Instead, we assumed that farms practice good herd health and use anthelmintic as a preventive measure. This assumption is supported by the finding that the protection from *Dictyocaulus viviparus* on Dutch dairy farms is good, due to the use of anthelmintic (Ploeger et al., 2000). Similar to this example, we expect that data is lacking for other calf diseases, which makes modelling this decision particularly challenging.

Optimal insemination decisions. There are other important decisions during young stock rearing, for example on breeding. In the models presented in chapters 2 and 6, we assumed that a heifer could have up to 6 inseminations. If all 6 inseminations were unsuccessful then the decision was made to cull the young stock. We did not examine the optimal time to quit insemination. It is useful to investigate the optimal number of inseminations before quitting and culling the young stock. Our results showed that earlier successful inseminations reduce the rearing costs (chapter 2), but that the future FLP will be affected unless the heifers are well developed (chapter 4). Therefore, it would be useful to investigate in more detail the relationship between a well-developed heifer, and the FCA and future FLP.

Retaining decisions. We only looked at the decision to retain the optimal number of heifer calves at 2 weeks of age, whereas there are more moments when farmers make decisions on retaining or culling. For instance, at weaning, before inseminating, or after the FCA. It might be worthwhile to build an optimization model for these decision moments, but this would require a different model from the current model (chapter 6). Using such a model, the optimal retaining decisions can be made, given the current knowledge of prices and uncertainties about future price developments.

Introduce the tool to farms. In chapter 3, the 75 participating farms showed interest in calculating the cost of rearing young stock. Therefore, we recommend introducing the economic tool to dairy farmers and veterinarians, so that they can benefit from using this tool. The tool can increase the awareness of farmers and veterinarians about the cost of young stock rearing. This is most effective if the perception of costs is asked prior to filling in the tool. We also recommend that the tool be made as herd specific as possible, for instance by being able to include calving interval, culling rate, and FCA of the herd.

More research on the number of young stock to retain. Previous studies on young stock rearing were more focused on growth (Mourits et al., (1997; 1999; 2000a)), reproduction (De Vries et al., 2008), and diseases of young stock (Lassen et al., 2012; Van der Fels-Klerx et al., 2001). More research should be done on the number of young stock to retain. This presents an important opportunity for a farmer to improve the profitability of the farm (chapter 6), and therefore the sustainability of the farm. More research is also needed on the practical side of this decision, such as the opportunity to choose which heifer calf to retain.

7.7 CONCLUSIONS

The main objective of this thesis was to provide insight in the economic consequences of decisions taken during young stock rearing on Dutch dairy farms. The decisions studied were about the FCA and the number of 2-week-old heifer calves to be retained in the herd. In reaching the general objective, we defined 4 sub-objectives. In the following subsections we describe the conclusions for these 4 sub-objectives.

- ***Cost of rearing.*** The cost of rearing a young stock was on average, €1,567 and varied between €1,423 and €1,715 (chapter 2). In practice (from farm data), the cost of rearing was on average, €1,790 (range from €919 to €3,307) (chapter 3). Given that the cost of rearing is 13-14% of the cost price of milk, we concluded that heifer rearing is an expensive investment (chapters 2 and 6). The average perceived total cost of rearing a heifer was €1,030 (range from €750 to €1,600), meaning that most farmers underestimated the total cost of rearing (chapter 3).

- ***Decision about lowering FCA on FLP.*** When the FCA of the heifers did not deviate from the median FCA of the herd, heifers produced, on average, 7,272 kg of milk per 305 days. When heifers calved 1 month earlier without adjusting the bodyweight (they are less developed), they produced 90 kg of milk per 305 days less. When heifers calved 1 month later (they are more developed), they produced an extra 86 kg of milk per 305 days. To reduce the total costs of rearing, farmers can lower their heifer's FCA by earlier inseminations. However earlier inseminations without adjustment of the rearing management to ensure sufficient development will cause lower FLP. These findings show that an economic optimum exists between rearing costs and FCA (chapter 4).

- ***Culling rate.*** The average culling rate for slaughter/death was 25.4% and varied between 23% (2007) and 28% (2010) (chapter 5).

- ***Decision to retain heifer calves.*** In a 100-cow dairy herd, the optimal retention of 2-week-old heifer calves was 73%. The total net cost when retaining the optimal percentage of heifer calves was estimated at €40,939 per herd per year. This total net cost was 6.5% lower than the estimate for the situation where all heifer calves were retained. For Dutch dairy farms, it is economically optimal not to retain all heifer calves (chapter 6).

References

Anshoff, H.I. and R.L. Hayes. 1973. Roles of models in corporate decision making. Proceedings of the Sixth IFORS International Conference on Operational Research. Amsterdam.

Bach, A. 2011. Associations between several aspects of heifer development and dairy cow survivability to second lactation. J. Dairy Sci. 94:1052-1057.

Bell, M. J., E. Wall, G. Russell, D. J. Roberts, and G. Simm. 2010. Risk factors for culling in Holstein-Friesian dairy cows. Vet. Rec. 167:238-240.

Buys, L., K. Mengersen, S. Johnson, N. van Buuren, and A. Chauvin. 2014. Creating a Sustainability Scorecard as a predictive tool for measuring the complex social, economic and environmental impacts of industries, a case study: Assessing the viability and sustainability of the dairy industry. J. Environ. Manage. 133:184-192.

Brickell, J. S., N. Bourne, M. M. McGowan, and D. C. Wathes. 2009. Effect of growth and development during the rearing period on the subsequent fertility of nulliparous Holstein-Friesian heifers. Theriogenology 72:408-416.

de Jong, R. 1996. Dairy stock development and milk production with smallholders. Page 308. PhD thesis. Wageningen University.

CBS, 2008. Standardised calculation methods for animal manure and nutrients Accessed Oct. 1, 2014. http://www.cbs.nl/NR/rdonlyres/424DD391-C1CB-4955-942F-D6C75BEBF630/0/2012c173pub.pdf.

De Vries, A. 2004. Economics of delayed replacement when cow performance is seasonal. J. Dairy Sci. 87:2947-2958.

De Vries, A., M. Overton, J. Fetrow, K. Leslie, S. Eicker, and G. Rogers. 2008. Exploring the Impact of Sexed Semen on the Structure of the Dairy Industry. J. Dairy Sci. 91:847-856.

Derks, M., L. M. A. van de Ven, T. van Werven, W. D. J. Kremer, and H. Hogeveen. 2012. The perception of veterinary herd health management by Dutch dairy farmers and its current status in the Netherlands: A survey. Prev. Vet. Med. 104:207-215.

Devendra, C. 2001. Smallholder dairy production systems in developing countries: Characteristics, potential and opportunities for improvement. Review. Asian Australas. J. Anim. Sci. 14:104-113.

Dijkhuizen, A.A. 1992. Modelling animal health economics: Inaugural speech. Wageningen University, The Netherlands. 29p. Accessed Nov. 5, 2014.

http://edepot.wur.nl/231187.

Donovan, G. A., I. R. Dohoo, D. M. Montgomery, and F. L. Bennett. 1998. Calf and disease factors affecting growth in female Holstein calves in Florida, USA. Prev. Vet. Med. 33:1-10.

Ettema, J. F. and J. E. P. Santos. 2004. Impact of age at calving on lactation, reproduction, health, and income in first-parity Holsteins on commercial farms. J. Dairy Sci. 87:2730-2742.

Ettema, J. F., S. Ostergaard, and M. K. Sorensen. 2011. Effect of including genetic progress in milk yield on evaluating the use of sexed semen and other reproduction strategies in a dairy herd. Anim. 5:1887-1897.

Gabler, M. T., P. R. Tozer, and A. J. Heinrichs. 2000. Development of a cost analysis spreadsheet for calculating the costs to raise a replacement dairy heifer. J. Dairy Sci. 83:1104-1109.

Heikkila, A. M., J. I. Nousiainen, and L. Jauhiainen. 2008. Optimal replacement policy and economic value of dairy cows with diverse health status and production capacity. J. Dairy Sci. 91:2342-2352.

Heinrichs, A. J. and B. S. Heinrichs. 2011. A prospective study of calf factors affecting first-lactation and lifetime milk production and age of cows when removed from the herd. J. Dairy Sci. 94:336-341.

Heinrichs, A. J., B. S. Heinrichs, O. Harel, G. W. Rogers, and N. T. Place. 2005. A prospective study of calf factors affecting age, body size, and body condition score at first calving of Holstein dairy heifers. J. Dairy Sci. 88:2828-2835.

Hultgren, J., C. Svensson, and M. Pehrsson. 2011. Rearing conditions and lifetime milk revenues in Swedish dairy cows. Livest. Sci. 137:108-115.

Kudahl, A. B., S. Ostergaard, J. T. Sorensen, and S. S. Nielsen. 2007. A stochastic model simulating paratuberculosis in a dairy herd. Prev. Vet. Med. 78:97-117.

Imaizumi, E. and C. Devendra. 1984. Improvement of raising method of dairy calves in Malaysia. 1. Utilization of local agriculture products and by-products as energy source for calf starter rations. Jarq-Jpn. Agr. Res. Q. 18:148-157.

Lassen, B. and S. Ostergaard. 2012. Estimation of the economical effects of Eimeria infections in Estonian dairy herds using a stochastic model. Prev. Vet. Med. 106:258-265.

Lievaart, J. J., J. Noordhuizen, D. Buckley, and S. C. L. Van Winden. 2008. The marketing of herd health and production management services on Dutch dairy farms: Perceptions of dairy farmers and their veterinary surgeons. Irish Vet. J. 61:668-676.

Losinger, W. C. and A. J. Heinrichs. 1997. An analysis of age and body weight at first calving for Holsteins in the United States. Prev. Vet. Med. 32:193-205.

Marce, C., R. Guatteo, N. Bareille, and C. Fourichon. 2010. Dairy calf housing systems across Europe and risk for calf infectious diseases. Anim. 4:1588-1596.

McDermott, J. J., S. J. Staal, H. A. Freeman, M. Herrero, and J. A. Van de Steeg. 2010. Sustaining intensification of smallholder livestock systems in the tropics. Livest. Sci. 130:95-109.

Moran, J. B. 2005. Tropical dairy farming. Feeding management for small holder dairy farmers in the humid tropics. 290 pp. CSIRO Publications, Melbourne. Accessed Oct. 1, 2014. http://www.publish.csiro.au/ nid/197/issue/3363.htm

Moran, J. B. 2009. Key Performance Indicators to Diagnose Poor Farm Performance and Profitability of Smallholder Dairy Farmers in Asia. Asian Australas. J. Anim. Sci. 22:1709-1717.

Moran, J. B. 2011. Factors Affecting High Mortality Rates of Dairy Replacement Calves and Heifers in the Tropics and Strategies for Their Reduction. Asian Australas. J. Anim. Sci. 24:1318-1328.

Mourits, M. C. M., P. B. M. Berentsen, R. B. M. Huirne, and A. A. Dijkhuizen. 2000a. Environmental impact of heifer management decisions on Dutch dairy farms. Neth. J. Agr. Sci. 48:151-164.

Mourits, M. C. M., A. A. Dijkhuizen, R. B. M. Huirne, and D. T. Galligan. 1997. Technical and economic models to support heifer management decisions: Basic concepts. J. Dairy Sci. 80:1406-1415.

Mourits, M. C. M., D. T. Galligan, A. A. Dijkhuizen, and R. B. M. Huirne. 2000b. Optimization of dairy heifer management decisions based on production conditions of Pennsylvania. J. Dairy Sci. 83:1989-1997.

Mourits, M. C. M., R. B. M. Huirne, A. A. Dijkhuizen, and D. T. Galligan. 1999. Optimal heifer management decisions and the influence of price and production variables. Livest. Prod. Sci. 60:45-58.

Omafra, 2007. Water Requirements of Livestock. Accessed Oct. 1, 2014. http://www.omafra.gov.on.ca/english/engineer/facts/07-023.pdf.

Ondersteijn, C. J. M., S. B. Harsh, G. W. J. Giesen, A. C. G. Beldman, and R. B. M. Huirne. 2002. Management strategies on Dutch dairy farms to meet environmental regulations; a multi-case study. Neth. J. Agr. Sci. 50:47-65.

Ploeger, H. W., F. H. M. Borgsteede, J. Sol, M. H. Mirck, M. W. C. Huyben, F. N. J. Kooyman, and M. Eysker. 2000. Cross-sectional serological survey on gastrointestinal and lung nematode infections in first and second-year replacement stock in The Netherlands: relation with management practices and use of anthelmintics. Vet. Parasitol. 90:285-304.

Rajala-Schultz, P. J., Y. T. Grohn, and H. G. Allore. 2000. Optimizing replacement decisions for Finnish dairy herds. Acta Vet. Scand. 41:185-198.

Roth, A.V. 2007. Applications of empirical science in manufacturing and service operations. Manufacturing and Service Operations Management. 9:353-367.

Sargent, R. G. 2013. Verification and validation of simulation models. J. Simulat. 7:12-24.

Stanton, A. L., D. F. Kelton, S. J. LeBlanc, S. T. Millman, J. Wormuth, R. T. Dingwell, and K. E. Leslie. 2010. The effect of treatment with long-acting antibiotic at postweaning movement on respiratory disease and on growth in commercial dairy calves. J. Dairy Sci. 93:574-581.

Stott, A. W., G. M. Jones, G. J. Gunn, M. Chase-Topping, R. W. Humphry, H. Richardson, and D. N. Logue. 2002. Optimum replacement policies for the control of subclinical mastitis due to S.aureus in dairy cows. J. Agric. Econ. 53:627-644.

Svensson, C., A. K. Nyman, K. P. Waller, and U. Emanuelson. 2006. Effects of housing, management, and health of dairy heifers on first-lactation udder health in Southwest Sweden. J. Dairy Sci. 89:1990-1999.

Tozer, P. R. and A. J. Heinrichs. 2001. What affects the costs of raising replacement dairy heifers: A multiple-component analysis. J. Dairy Sci. 84:1836-1844.

Van Calker, K. J., P. B. M. Berentsen, G. W. J. Giesen, and R. B. M. Huirne. 2005. Identifying and ranking attributes that determine sustainability in Dutch dairy farming. Agr. Hum. Values 22:53-63.

Van der Fels-Klerx, H. J., J. T. Sorensen, A. W. Jalvingh, and R. B. M. Huirne. 2001. An economic model to calculate farm-specific losses due to bovine respiratory disease in dairy heifers. Prev. Vet. Med. 51:75-94.

Van der Hoek, K.W., M.W. van Schijndel, 2006. Methane and nitrous oxide emissions from animal manure management, 1990 - 2003. Background document on the calculation method for the Dutch National Inventory Report. RIVM report 680.125.002, MNP report 500080002, Bilthoven, Nederland.

Wanjala, S. P. O. and B. K. Njehia. 2014. Herd Characteristics on Smallholder Dairy Farms in Western Kenya. J. Anim. Sci. Adv. 4:996-1003.

7

Samenvatting

Ringkasan

Samenvatting

Ten gevolge van stijgende kosten en variabele opbrengstprijzen hebben Nederlandse melkveehouders te maken met een toenemende druk op de economische resultaten van hun bedrijf. Daarnaast wordt de melkveehouderij en Nederlandse melkveebedrijven gezien als een bron van vervuiling voor de omgeving, vooral door de productie van mest en broeikasgassen. Het is daarom belangrijk dat melkveebedrijven duurzamer worden, met daarin aandacht voor zowel economische resultaten als voor de omgeving. De jongveeopfok van een melkveebedrijf draagt bij aan de economische resultaten van het bedrijf en heeft ook invloed op de omgeving van het bedrijf. Vooral het aantal stuks vrouwelijk jongvee wat wordt opgefokt draagt, in combinatie met de lengte van de opfokperiode (de afkalfleeftijd van vaarzen), bij aan de totale kosten die op een bedrijf gemaakt worden en aan de hoeveelheid mest en broeikasgassen die geproduceerd worden. Op veel Nederlandse melkveebedrijven zijn het aantal dieren dat aangehouden wordt ter vervanging van melkvee en lengte van de opfokperiode niet optimaal. Door het nemen van optimale beslissingen rondom de jongveeopfok kan een meer duurzame manier van jongveeopfok bereikt worden. Deze beslissingen zijn echter complex en er kunnen negatieve gevolgen optreden als de verkeerde beslissingen worden genomen. Bijvoorbeeld, een te lage afkalfleeftijd kan de toekomstige melkproductie negatief beïnvloeden en te weinig kalveren aanhouden kan ertoe leiden dat er te weinig vaarzen zijn om de afgevoerde koeien te vervangen.

Het doel van het in dit proefschrift beschreven onderzoek is om inzicht te krijgen in de economische consequenties van beslissingen die genomen worden tijdens de jongveeopfok periode. Het uiteindelijke doel is om een meer duurzame manier van jongveeopfok te bereiken. Dit proefschrift richt zich specifiek op de beslissingen over de afkalfleeftijd van vaarzen en het aantal kalveren wat aangehouden moet worden.

Om inzicht te krijgen in de economische consequenties van beslissingen die genomen worden tijdens de jongveeopfok periode is het eerst belangrijk om inzicht te krijgen in de kosten van jongveeopfok. In **hoofdstuk 2** is er daarom een stochastisch Monte Carlo simulatie model beschreven om de kosten van jongveeopfok te bepalen. Het model simuleert het leven van een kalf vanaf 2 weken leeftijd tot de eerste afkalving. Het optreden van ziektes, de effecten van ziektes op de groei, tocht detectie, en conceptie zijn in detail meegenomen in het model. De input voor het model was gebaseerd op literatuur en kennis van experts. De gemiddelde kosten van de jongveeopfok werden geschat op €1,567 per opgefokte vaars, variërend tussen €1,423 en €1,715 per opgefokte vaars. De kosten van jongveeopfok droegen ongeveer 13% bij aan de kostprijs van melk. Het verlagen van de afkalfleeftijd met 1 maand verlaagde de kosten van jongveeopfok met 2.6% tot 5.7%. Resultaten van de gevoeligheidsanalyse lieten zien dat de kosten van jongveeopfok vooral beïnvloedt werden door de arbeidskosten en de voerkosten.

Er werd verwacht dat veel melkveehouders de kosten van jongveeopfok onderschatten, en daardoor economisch suboptimale beslissingen nemen. Bovendien was het model beschreven in hoofdstuk 2 alleen intern gevalideerd. Daarom werd er ten behoeve van **hoofdstuk 3** een externe validatie van de kosten van jongveeopfok uitgevoerd. De kosten van jongveeopfok zijn bepaald voor 75 Nederlandse melkveebedrijven. Deze veehouders hebben gedetailleerde informatie over hun melkveebedrijf ingevuld in een economisch rekenmodel (Jonkos).

Voor het invullen van dit model is de veehouders gevraagd naar een schatting van de kosten van jongveeopfok op hun bedrijf. Gemiddeld waren de kosten van jongveeopfok, berekend door het economische rekenmodel, €1,790 per opgefokte vaars. Deze waarde is hoger dan de kosten berekend in hoofdstuk 2, en dit komt vooral door een andere manier van berekening van de kosten van ruwvoer. Vooraf hadden de melkveehouders de kosten van jongveeopfok geschat op gemiddeld €1,030. Dit geeft aan dat melkveehouders de kosten van jongveeopfok inderdaad onderschatten. Het gebruik van een economische rekentool, zoals Jonkos, kan de veehouders helpen om meer inzicht te krijgen in de kosten van jongveeopfok. Mogelijk kan een beter inzicht in de kosten helpen om betere beslissingen te nemen gedurende de jongveeopfok.

Om optimale beslissingen te kunnen nemen over de afkalfleeftijd bij vaarzen is het belangrijk om meer inzicht te hebben in de associaties tussen management maatregelen, afkalfleeftijd en melkproductie in de eerste lactatie. In **hoofdstuk 4** zijn deze associaties nader onderzocht met behulp van gegevens van 8,454 vaarzen van 100 Nederlandse melkveebedrijven. De mediaan van de afkalfleeftijd was 25.4 maanden en de mediaan van de melkproductie in de eerste lactatie was 7,518 kg in 305 dagen. De mediaan van de afkalfleeftijd was geassocieerd met de leeftijd bij eerste inseminatie, het verstrekken van antibioticamelk, en de hoeveelheid verstrekte melk. De mediaan van de melkproductie in de eerste lactatie was geassocieerd met de mediaan van de afkalfleeftijd en of er gevaccineerd werd tegen BRSV. Vaarzen met een afkalfleeftijd van 24 maanden produceerden gemiddeld 7,164 kg in 305 dagen, en vaarzen die een maand eerder afkalfden produceerden 143 kg minder melk. Als de afkalfleeftijd van een vaars niet afweek van de mediaan van de afkalfleeftijd van het bedrijf produceerden de vaarzen gemiddeld 7,272 kg in 305 dagen. Vaarzen die één maand eerder afkalfden dan de mediaan van het bedrijf produceerden 90 kg minder melk in 305 dagen, en vaarzen die een maand later afkalfden dat de mediaan van het bedrijf produceerden 86 kg meer melk in 305 dagen. Resultaten lieten zien dat de afkalfleeftijd verlaagd kan worden door eerder te starten met insemineren. Het is daarbij van groot belang dat de ontwikkeling van de vaarzen ver genoeg is wanneer ze geïnsemineerd worden. Op basis van de resultaten lijkt het waarschijnlijk dat de ontwikkeling ook daadwerkelijk goed genoeg is. In de praktijk zal dit geverifieerd moeten worden en eventueel moet dan het management van de jongveeopfok aangepast worden om voldoende ontwikkeling van de vaarzen te garanderen.

Het aantal kalveren wat aangehouden moet worden op een melkveebedrijf wordt mede bepaald door het afvoerpercentage van melkkoeien. In **hoofdstuk 5** werd er daarom nader gekeken naar het afvoerpercentage van melkkoeien op Nederlandse melkveebedrijven. Afvoergegevens van individuele koeien van de jaren 2007 tot en met 2010 van 1,903 Nederlandse melkveebedrijven was beschikbaar. Een onvrijwillig afgevoerde koe was gedefinieerd als een koe die binnen 30 dagen na de afvoerdatum werd geslacht. Het gemiddelde afvoerpercentage op Nederlandse melkveebedrijven was 25.4%, en varieerde tussen 23% (2007) en 28% (2010). Meer dan 70% van de melkveebedrijven had een gemiddeld afvoerpercentage van minder dan 30%. Dit geeft aan dat er op veel Nederlandse melkveebedrijven ruimte is om het afvoerpercentage te verlagen

Om inzicht te krijgen in de economische consequenties van het aanhouden van verschillende aantallen vrouwelijk jongvee is er een tweede stochastisch Monte Carlo simulatie model gemaakt. Dit model is beschreven in **hoofdstuk 6** en het model simuleert een melkveebedrijf met 100 koeien. Het optimale percentage kalveren wat aangehouden moet worden is gedefinieerd als het percentage waarbij de gemiddelde netto kosten van jongveeopfok minimaal zijn. Input voor het model is gebaseerd op literatuur, kennis van experts en resultaten van de hoofdstukken 2 en 5. Het optimale aantal kalveren wat aangehouden moet worden, bij een tussenkalftijd van 417 dagen en een afvoerpercentage van melkkoeien van 25%, was 30 stuks (73%). Bij dit aantal waren de netto kosten van jongveeopfok €40,939 per jaar. Als alle kalveren werden aangehouden dan waren de netto kosten van jongveeopfok 6.5% hoger. Voor bedrijven met een lager (10%) of hoger afvoerpercentage (40%) van de melkkoeien was het optimaal om 35% en 100% van de kalveren aan te houden. Voor de meeste bedrijven is het, vanuit een economisch perspectief, dus niet aantrekkelijk om alle kalveren aan te houden.

In **hoofdstuk 7** zijn een aantal belangrijke aspecten van dit proefschrift bediscussieerd, zoals het gebruik van de normatieve en empirische aanpak in dit proefschrift. Ook de mogelijke rol van dierenartsen bij het nemen van beslissingen gedurende de jongveeopfok en het nemen van beslissingen over jongveeopfok in tropische regio's was bediscussieerd.

De resultaten van dit proefschrift laten zien dat het mogelijk is om de economische resultaten van een melkveebedrijf te verbeteren door optimale beslissingen te nemen rondom de afkalfleeftijd en het aanhouden van kalveren. Naast een verbeterd inkomen leidt optimaal jongveeopfok management ook tot minder druk op het milieu omdat de mest- en broeikasgasproductie per kg geproduceerde melk dan lager is.

Ringkasan

Peningkatan kos dan ketidaktentuan harga berkaitan sektor tenusu telah meningkatkan tekanan terhadap penternak lembu tenusu, contohnya di negara Belanda, untuk mengekalkan kemapanan ekonomi ladang mereka. Di samping itu, ladang lembu tenusu menyumbang kepada pencemaran alam sekitar melalui pengeluaran gas rumah hijau dan sisa kumbahan. Justeru, adalah penting ladang lembu tenusu menjadi lebih mampan dari segi ekonomi dan alam sekitar. Penternakan anak lembu betina/ lembu dara tenusu turut mempengaruhi kemampanan ekonomi ladang lembu tenusu dan alam sekitar. Bilangan anak lembu betina yang lebih banyak diternak digabungkan dengan umur lembu dara semasa kali pertama beranak (UPB) yang lebih berusia, boleh mempengaruhi jumlah kos menternak lembu dara, dan jumlah sisa kumbahan dan gas rumah hijau yang dihasilkan. Keputusan yang diambil dalam menentukan bilangan anak lembu betina untuk dikekalkan dan tempoh lembu dara diternak sebelum ia boleh menggantikan lembu susu yang ditakai, di kebanyakan ladang lembu tenusu di Belanda selalunya dibuat secara tidak optimum. Keputusan yang diambil secara optimum boleh mewujudkan penternakan lembu dara yang lebih mampan. Bagaimanapun, keputusan-keputusan ini adalah kompleks dan jika keputusan yang diambil adalah salah, ia boleh memberi kesan yang buruk. Contohnya, UPB yang diawalkan boleh menjejaskan potensi pengeluaran susu pada masa akan datang, dan mengekalkan bilangan anak-anak lembu betina yang sedikit, boleh menyebabkan lembu dara yang diperlukan untuk menggantikan lembu tenusu yang ditakai tidak mencukupi.

Kajian dalam tesis ini bertujuan untuk mendalami kesan ekonomi dari keputusan-keputusan yang diambil dalam penternakan lembu dara tenusu. Matlamat utama adalah untuk mencapai penternakan lembu dara tenusu yang lebih mampan. Tumpuan tesis adalah berkenaan keputusan mengenai UPB dan bilangan anak-anak lembu betina yang mesti dikekalkan dalam ladang.

Bagi mendalami kesan ekonomi dari keputusan-keputusan yang diambil semasa menternak lembu dara, pertama sekali, penting untuk penternak memahami kos penternakan lembu dara. Jadi, di dalam **Bab** 2, model simulasi stokastik Monte Carlo telah dibina untuk menggambarkan dan menentukan kos penternakan lembu dara. Model ini menggambarkan kehidupan seekor anak lembu betina dari usia 2 minggu sehinggalah ia beranak kali pertama. Model ini diperincikan dengan input seperti insiden penyakit, kesan penyakit pada tumbesaran, kadar pengesanan estrus dan kadar kebuntingan. Input untuk model ini adalah berdasarkan artikel dan pengetahuan pakar. Secara purata, kos penternakan lembu dara adalah dianggarkan sebanyak € 1,567 seekor dengan varian di antara €1,423 dan €1,715 seekor. Kos penternakan lembu dara menyumbang kira-kira 13% dari harga kos untuk menghasilkan susu. Jika UPB diawalkan 1 bulan, ia mengurangkan kos penternakan lembu dara di antara 2.6% dan 5.7%. Keputusan analisis sensitiviti menunjukkan bahawa kos penternakan lembu dara dipengaruhi terutamanya oleh kos buruh dan kos makanan.

Kami menjangkakan kebanyakan penternak lembu tenusu memandang rendah kos penternakan lembu dara, dan disebabkan oleh itu, mereka mungkin telah membuat keputusan suboptimal dari segi ekonomi. Tambahan pula, model yang telah dibina dalam Bab 2 hanya disahkan secara internal. Kos penternakan lembu dara dari model tersebut boleh disahkan secara eksternal melalui **Bab 3**. Untuk tujuan itu, kos penternakan lembu dara telah ditentukan untuk 75 ladang tenusu di Belanda. Maklumat terperinci ladang telah direkodkan oleh penternak menggunakan alat pengiraan ekonomi (Jonkos). Sebelum mengisi Jonkos, penternak ditanya tanggapan mereka terhadap kos penternakan lembu dara. Secara purata, kos penternakan lembu dara yang dikira menggunakan Jonkos ialah € 1,790 seekor. Nilai ini adalah lebih tinggi daripada kos yang dikira dalam Bab 2, disebabkan perbezaan cara pengiraan kos rumput. Manakala, secara purata, tanggapan penternak terhadap kos penternakan lembu dara adalah €1,030 seekor. Ini menunjukkan penternak sememangnya memandang rendah kos penternakan lembu dara. Penggunaan alat pengiraan ekonomi Jonkos boleh membantu penternak untuk memahami kos penternakan lembu dara. Dengan memahami kos tersebut, penternak boleh membuat keputusan yang lebih baik semasa menternak lembu dara.

Untuk membuat keputusan yang optimum mengenai UPB, penting untuk mempunyai pemahaman terhadap pengurusan sekumpulan lembu dara di ladang, UPB dan pengeluaran susu pada laktasi pertama (PLP) bagi seekor atau sekumpulan lembu dara. Dalam **bab 4**, kajian mengenai UPB telah dijalankan menggunakan data dari 8,454 lembu dara di 100 ladang tenusu di Belanda. Purata median UPB bagi kumpulan ialah 25.4 bulan dan purata median PLP bagi kumpulan ialah 7,518 kg per 305 hari. Purata median UPB kumpulan dikaitkan dengan umur semasa permanian berhadas pertama dilakukan, jika anak lembu minum susu mengandungi sisa antibiotik dan jumlah susu yang diberi (sebelum cerai susu). Purata median jumlah PLP kumpulan dikaitkan dengan median UPB dan status vaksinasi terhadap virus sinsistium pernafasan bovin. Lembu-lembu dara berumur 24 bulan semasa beranak kali pertama mengeluarkan secara purata 7,164 kg susu dalam 305 hari, dan bagi lembu-lembu dara yang beranak anak pertama sebulan lebih awal, susu yang terhasil berkurang sebanyak 143 kg. UPB seekor lembu dara yang tidak menyimpang daripada median UPB kumpulan mengeluarkan secara purata, 7,272 kg susu dalam 305 hari semasa laktasi pertama. Bila UPB diawalkan satu bulan daripada median UPB kumpulan, PLP berkurang sebanyak 90 kg per 305 hari, dan bila UPB sebulan lewat dari median UPB kumpulan, PLP bertambah sebanyak 86 kg per 305 hari. Keputusan menunjukkan bahawa UPB dapat dikurangkan dengan mengawalkan masa lembu dara mula bunting. Namun, amat penting tumbesaran lembu dara mencukupi apabila ia menjalani permanian berhadas lebih awal. Jika tidak PLP akan berkurang. Berasaskan pada penemuan ini, umur semasa kali pertama permanian berhadas dilakukan perlu diselaraskan dengan pengurusan lembu dara untuk memastikan tumbesaran lembu dara mencukupi semasa dibiakkan.

Keputusan untuk mengekalkan anak-anak lembu betina untuk diternak di sesebuah ladang tenusu ditentukan oleh kadar penakaian lembu tenusu. Dalam **bab 5**, kami mengkaji dengan teliti kadar penakaian lembu tenusu di ladang tenusu di Belanda. Kami menggunakan data individu lembu tenusu daripada tahun 2007 hingga 2010 dari 1,903 ladang tenusu di Belanda. Lembu yang ditakai secara sembelihan/kematian (secara mengejut) telah ditakrifkan sebagai lembu yang telah disembelih dalam tempoh 30 hari selepas tarikh penakaian. Secara purata, kadar penakaian secara sembelihan/kematian di ladang tenusu Belanda adalah 25.4%, dengan varian di antara 23% (2007) dan 28% (2010). Lebih daripada 70% daripada keseluruhan ladang lembu tenusu mempunyai purata kadar penakaian kurang daripada 30%. Ini menunjukkan bahawa terdapat banyak ruang untuk mengurangkan kadar penakaian di ladang lembu tenusu di Belanda.

Untuk mendalami kesan ekonomi dalam keputusan bilangan anak lembu betina untuk dikekalkan, model stokastik simulasi Monte Carlo telah dibina. Model tersebut diperincikan di dalam **Bab 6** di mana, model itu menggambarkan sebuah ladang tenusu dengan 100 ekor lembu. Peratusan optimum anak lembu betina yang akan dikekalkan ditakrifkan sebagai kadar di mana purata kos bersih penternakan lembu dara adalah pada kadar minimum. Input bagi model ini adalah dari artikel, pengetahuan penulis dan pakar, dan berdasarkan keputusan dari Bab 2 dan 5. Bilangan optimum anak lembu berusia 2 minggu yang mesti dikekalkan, dengan selang antara kelahiran sebanyak 417 hari dan kadar penakaian lembu tenusu sebanyak 25%, adalah 30 ekor (73 %). Jumlah kos bersih penternakan lembu dara pada peratusan optimal ialah € 40,939 setahun. Kos bersih penternakan lembu dara ini adalah 6.5% lebih rendah berbanding jika kesemua (100%) anak lembu betina berusia 2 minggu dikekalkan. Bagi ladang dengan kadar penakaian yang lebih rendah (10%) atau kadar penakaian lembu tenusu yang lebih tinggi (40%) adalah optimum untuk mengekalkan 35% dan 100% daripada anak-anak lembu betina. Dari perspektif ekonomi, bagi kebanyakan ladang lembu tenusu Belanda, adalah lebih baik untuk tidak mengekalkan kesemua anak-anak lembu betina yang berusia 2 minggu di dalam ladang.

Menerusi **Bab 7**, beberapa aspek penting dalam tesis ini, contohnya penggunaan pendekatan normatif dan empirikal dalam kajian, peranan doktor haiwan dalam memberi khidmat nasihat kepada penternak dalam membuat keputusan berkaitan penternakan lembu dara dan generalisasi keputusan kajian kepada kawasan tropika telah dibincangkan.

Hasil kajian dalam tesis ini menunjukkan bahawa ekonomi kemampanan sesebuah ladang tenusu boleh ditingkatkan dengan mengambil keputusan yang optimum berkenaan UPB dan bilangan anak-anak lembu betina yang perlu dikekalkan. Pengurusan penternakan lembu dara secara optimum bukan sahaja menambahkan pendapatan tetapi turut mengurangkan tekanan terhadap alam sekitar kerana pengeluaran sisa kumbahan dan gas rumah hijau adalah lebih rendah berbanding per kg susu yang dihasilkan.

About the Author

Norhariani Binti Mohd Nor (Yani) was born on 20th October 1981 in Malacca, Malaysia. She had her primary and secondary education in Kelantan, Malaysia. In 1999, she pursued her study at Kolej Matrikulasi Melaka, Malacca. Afterwards, she went to Universiti Putra Malaysia (UPM) to study veterinary medicine and graduated in 2006.

She joined UPM in 2007 as a tutor in Praclinical veterinary studies department. After obtaining scholarship in 2008 from Malaysian Ministry of Higher Education, she did her master in veterinary epidemiology and economics at Utrecht University (UU). She graduated in March, 2010 and at the same time, she obtained scholarship from UPM to pursue her PhD at UU in animal health economics with the topic of economics of young stock rearing decisions on Dutch dairy farms. The strong relations between farm animal health department, UU and Business economics group, Wageningen university enabled her to get guidance from both universities.

Upon completion of her PhD study, she will be appointed as a lecturer in UPM to teach veterinary business and economics. She can be contacted at Jabatan Sains Praklinical Veterinar, Fakulti Perubatan Veterinar, UPM, 43400 Serdang, Selangor, Malaysia. E-mel: norhariani@upm.edu.my.