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EVALUATING COSTS ASSOCIATED WITH MANAGEMENT DECISIONS OF REPLACEMENT DAIRY HEIFERS AND THEIR IMPACT ON THE TOTAL REARING INVESTMENT

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THESIS

A thesis submitted in partial fulfillment of the
requirements for the degree of Master of Science in the
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at the University of Kentucky

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ABSTRACT OF THESIS

EVALUATING COSTS ASSOCIATED WITH MANAGEMENT DECISIONS OF REPLACEMENT DAIRY HEIFERS AND THEIR IMPACT ON THE TOTAL REARING INVESTMENT

Replacement heifer rearing is critical for the future of the dairy operation, especially to improve genetic merit and maintain herd size. A replacement heifer from the day she is born to the day she calves herself is generally a 2-year investment without potential income. A myriad of options exists on how to manage, fed, and ultimately raise replacement heifers. This study quantifies the costs associated with replacement heifer management decisions from birth to calving related to housing, labor, feed and health. The heifer rearing period can be broken into pre and post weaning sections to allow for more understanding the variation of these different biological time periods. Variation can influence the investment per day and breakdown of resources required from a dairy producer. Total heifer raising cost varied broadly across all management scenarios in our study, with feed and labor consistently representing over 60% of the total cost. After determining the true cost on an individual farm, or providing developed assumed cost for a change in management, producers can better manage current expenses and be more prepared for future investment.

KEYWORDS: stochastic model, dairy economics, dairy calf, young stock

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07/16/2019

Date

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FREQUENCY USED ABBREVIATIONS

ADG = Average Daily Gain

AFC = Age at First Calving

BC = Barn Cost

BV = Barn Value

BW = Birth Weight

GH = Group Housing

IHI = Individual Housing Inside

IHO = Individual Housing Outside

LR = Labor Required

MR = Milk Replacer

PMT = Payment Function in Excel

PWM = Pasteurized Whole Milk

R1 = Silage Ration

R2 = Pasture based Ration

SD = Standard Deviation

TLH = Total Labor Hours

TLR = Total Labor Required

WM = Whole Milk

WW = Weaning Weight

CHAPTER 1: REVIEW OF LITERATURE

INTRODUCTION

One of the largest routine costs on a dairy farm is raising replacement females. Replacement heifers are critical to the continuing the success of the dairy enterprise, but are a long-term high-cost investment (Zanton and Heinrichs, 2005). Replacement heifers are grown generally over a two-year period before they enter the milk production system and begin making income for the operation. Over this two-year period, replacement heifers are fed, housed, bred, and cared for. Management decisions on dairy operations are a balance between what is economically most efficient and what is biologically reasonable (Bewley, 2010). Nevertheless, replacement heifers represent the future of the operation, potential for genetic improvement, and higher milk yields, being necessary for the sustainability of the dairy enterprise (Heinrichs et al., 2013).

Replacement heifer market prices vary broadly. An increased supply of dairy heifers was forecasted in the last decade, as the adoption of sexed semen has gained in popularity (De Vries et al., 2008). Sexed semen increases chances of a breeding resulting in a heifer to above 90% in comparison to conventional semen or natural service (Schenk et al., 2009). Many different systems can be used in the rearing process to raise these replacement heifers but each correspond with unique benefits and costs. Published heifer raising cost in research journals and extension articles varied greatly, where the cost to raise each animal ranging from $1,134.06 to $2,241.00 over the last 20 years (Gabler, 2000, Tranel, 2019). Beyond that, the perceived rearing costs are below the calculated costs. A recent study found that costs on average exceed 14.4% of what producers calculated (Mohd

Nor et al., 2015a), which can lead to misinformed economic decisions. Additionally, the management decisions made for the replacement heifer enterprise have an impact on the milking herd. Number of needed heifers as a function of cull rates in the milking herd (Mohd Nor et al., 2015b) and age at first calving (Heinrichs et al., 2013) both impact the cost to raise needed replacement heifer. However, little is known on how management practices influence the total cost of raising dairy heifers in the USA.

The objective of this literature review is to discuss factors associated with the cost of raising a dairy replacement heifer from birth to calving and the influences of individual variables. First, we will describe the published surveys and model results of the total cost to raise a replacement heifer. Attention will be given to the option to custom raise replacement heifers, therefore replacing replacement heifer expenses with a contract raiser. Then, investigate the common management of milk source and allotment, housing, and health for pre-weaned replacement heifers. Post-weaning replacement heifers management focuses on growth and development of the next generation of the milking herd. Management styles to house, feed, and breed these heifers are described and potential effects on the milking herd based on replacement heifer management decisions. Finally, a brief overview of stochastic modeling and the main purpose of utilizing economic modeling.

TOTAL HEIFER RAISING COST

Many aspects of a dairy operation work collectively to produce a safe and economically efficient product. Managing risk of investments and thinking of future consequences can be critical when evaluating economic decisions. (Eberlein and System

Dynamics, 2003). The two year rearing phase of replacement heifers is a substantial investment in the future of the operation. Identifying an individual operation's total cost per replacement heifer is the first step in managing those expenses.

When determining the cost to raise a replacement heifer, self-reported variables are required from farm records. The reliability of self-reported on-farm data has been an area of concern for decades. In an extensive farm survey of housing and management a 13.4% error was found between responses to the same interview (Schukken, 1989). There was a discrepancy between model calculated cost of raising a replacement heifer and on-farm reported costs on Dutch dairy farms (Mohd Nor et al., 2015a). Separate studies were conducted, one in 2011 where producers were asked to estimate to cost of raising a heifer without looking at their records. This study found that the perceived average total cost per replacement heifer calculated by producers was $1,142.04 with a range of $450 to $2,205. The second study conducted in 2013 utilized an economic tool, Jonkos, to calculate the cost of rearing replacement heifers on the same farms. This tool is used to determine the total cost of raising all replacement heifers on a farm and the cost per replacement heifer. The Jonkos model calculated average total cost per heifer was $2,014.04 with a range of $1,034.02 to $3,307.91 . This represents an underestimation from the farm of over $850 per heifer or 14.4%. (Mohd Nor et al., 2015a). Based on these results, the producer estimation of replacement heifer costs is severely underestimated and can lead to misinformed decisions for the enterprise. Moreover, most believe that this cost is not being ignored by the producer. This cost is being misallocated to other sections of the operation, creating the appearance of a less costly expense than in reality.

Average published replacement heifer raising cost has ranged from $1,124.06 to $1,808.23 since 2000 (Gabler et al., 2000; 2013), shown in Table 1. Because of the extensive resources needed to conduct large surveys and the time sensitive results they provide, more recent replacement heifer raising cost has been published in non-peer reviewed extension articles. From those articles, heifer raising cost has increased over the last 5 years ranging from $1,730.29 to $2,241.00 in dairy farms in the USA (Adkins, 2015, Tranel, 2019). Furthermore, the range within each survey is a testament to the variation in cost between individual farms. Ranges within each study can exceed $3,000 (Adkins 2013, 2015), with reported SD reaching $700.00 (Adkins, 2015).

A study by Henrichs et al., 2013 in Pennsylvania looked at the management practices and economics to separate efficient from less efficient farms. A combination of the assumed inputs, heifer measurements, and farm reported values were entered into a data envelope analysis to create production possibility values and an efficiency frontier. Efficient farms on average were spending $1,137.40 and $140.62 per heifer in feed and labor. They were calving in at 23.7 months of age and producing 88.42% of the milk produced by multiparous cows in the milking herd. These can be compared to inefficient farm averages spending $226.87 more per heifer in feed, $77.81 more per heifer in labor and calving in at 25.3 months of age. While increases in labor cost and age at first calving can create a clear divide on efficient and less efficient farms, the management differences that create such variation is a critical component. Feed was found to be the largest expense in raising replacement heifers representing over 50% of the total cost (Adkins, 2015, Heinrichs, 2013). Labor costs were seen to have a large effect on efficiency. The analysis indicted herds with the lowest input costs were more efficient, but herds with higher input costs could reach the same efficiency score by increasing milk production or lower average feed costs (Heinrichs et al., 2013). To relieve the intensive management while trying to become more efficient with enterprises, a producer may choose to contract his part of the operation to a custom contract heifer raiser.

Contract heifer raising presents its own set of unique challenges to a producer. The quality growth of heifers is expected to be at the level, or above, care of the original producer (Olynk and Wolf, 2010). In a retrospective approach of Wisconsin dairy farms, 46 out of 177 farmers were utilizing custom raising, and in some situations showed a relationship to increased involuntary culling of the milking herd (Weigel et al., 2003). To combat this potential discrepancy recommend benchmarks in contracts as a form of liability (Olynk and Wolf, 2010). Some of the main advantages for the farm for contract heifer raising is to more effectively use limited labor resources, freeing up facilities and feed for the milking herd (Wolf, 2003). These benefits are not without costs, including giving up management control while introducing another potential conflict area, increased cash flow, and biosecurity risks. Therefore, contract replacement heifer raising allows for specialization and streamlining of resources into one section of the dairy operation (Olynk and Wolf, 2010).

Total cost of raising replacement heifers is a large two-year investment for the dairy enterprise, however farms vary broadly in cost of raising a replacement heifer. Thus, the following sections of this literature review will further examine additional management decisions during the pre-weaning and post-weaning development phase that impact total cost.

PRE-WEANED HEIFER MANAGEMENT

Raising replacement females from birth to weaning is a critical time period which requires time and resources on farm. Management decisions based on milk feeding strategies, housing and health have a large impact on the total cost.

Feeding

Replacement heifer calves are most feed efficient during the pre-weaning period (Shivley et al., 2018), making a window of opportunity to economically capitalize on feed efficiency and growth of replacement heifers. Newborn calves digestive systems behave similar to a monogastric, allowing for the consumption and digestion of milk. However, they must develop into a functioning ruminant early in life. Through consumption of starter and forage, the anaerobic microbial environment is created, triggering the development of the rumen (Khan et al., 2011). Understanding that calves must develop their rumen to be successful provides understanding for the need for investment in proactive milk feeding strategies.

The total investment to provide milk for calves ranges from $58.50 to $199.64 per replacement heifer (Adkins, 2015). Some of this variation may be contributed to the source of milk. Whole milk and milk replacer are the two most common sources of milk for dairy operations in the United States (Heinrichs et al., 1994, USDA, 2016). Whole milk was significantly more popular as a feeding strategy in the Western US, while milk replacer was more popular in the East (Granger, 2012). Feeding whole milk can present sanitation challenges for the operation and the calf. A positive association was found between high bacteria counts in the milk and increased health scores in calves (Jorgensen et al., 2017). Nutritional quality can sometimes be a concern for farms utilizing milk replacer. Calves fed milk replacer showed a reduction in growth rates, weaning weight and an increased risk of requiring treatment compared to pasteurized whole milk (Godden et al., 2005).

Additionally, the allowed allotment of milk and nutritional benchmarks can impact overall cost of milk during the preweaning period. Strategies can be classified as conventional (roughly 20% protein, 20% fat milk replacer at a dry-matter basis of 8-10% of BW) and intensive (increased to 28% protein and 18% fat milk replacer at a dry-matter basis of 16-20% BW) (Raeth-Knight et al., 2009, Davis Rincker et al., 2011, Akins, 2016). Intensive feeding programs result in a higher feed cost, but additional benefits have the potential to alleviate some of the additional investment (Akins, 2016). An intensive diet has been shown to increase body weight (Jasper and Weary, 2002), decrease age at conception and lower the age at first calving (Raeth-Knight et al., 2009, Davis Rincker et al., 2011). When offered *ad libitum* milk calves consumed around 10 L per day (Jasper and Weary, 2002), providing insight to natural feeding behavior of calves. Consequently, starter intake was reduced in comparison to milk-fed restricted calves (Jasper and Weary, 2002).

A third source of variation in milk cost is the method of delivering the milk to calves. While there are many variations in feeding systems, there are two distinct categories of feeding methods: automatic calf feeders or feeding stations versus daily scheduled delivery of milk. A recent survey found that the average difference in feed cost utilizing an automatic calf feeder versus scheduled feeding calves is $36.47 per replacement heifer. Feed cost represent 40% of the total cost in scheduled feeding and 47% in an automatic feeder (Adkins, 2017). An automatic feeder also requires the transition to group housing, creating additional costs outlined in the following housing section. The ease of gradual weaning using an automatic calf feeder can reduce the effects of a growth check and other problems during weaning, but calves were still not able to completely replace calories from milk intake with required starter intake (Sweeney et al., 2010). The method of providing milk to calves can vary from one producer to the next but has a large impact on growth and development of the calf as well as total required investment.

Furthermore, Kertz et al. (1985) proved a reduction in weight gain by 38% and 31% in starter intake when calves were deprived of water during the first four weeks of life. Most, if not all, research presented in this literature review related to feed intake specified *ad libitum* water in materials and methods, and it was not included as an effect.

Housing

Housing for calves can influence potential costs and management practices. When evaluating replacement heifer calf housing, four main welfare areas should be considered: thermal, physical, psychologic, and behavior. These areas can be used to reduce stress and promote positive growth and development. (Stull and Reynolds, 2008)

In 2012, 42.1% of replacement heifer calves were housed in individual housing outside, 36.8% inside individually (heated and unheated), and 15.8% in group housing. (Granger, 2012). These numbers vary slightly from a more recent survey where 86.6% of heifers were kept in individual housing while the remaining 13.4% were housed in groups

(Urie et al., 2018). When the US was broken down by East and West, trends start to become more apparent in heifer housing (Urie et al., 2018). The Western part of the United States in 2012 and 2014 had minimal use of group housing at 0% and 0.9%, respectively. The Eastern part of the United States has 19.4% and 16% of their operations using group housing (Urie et al., 2018). Globally, 11 of 14 western and central European dairy producers report individual housing as the most frequent housing form. Contrary, 90% of reporting Ireland farms use group housing (Marcé et al., 2010). A larger study of 179 producers in Brazil show an increased utilization of group housing (55%) in comparison to the United States (Santos and Bittar, 2015). Decisions made by producers can change the investment for preweaned heifers. Comparing one farm to the next can be misleading if management systems are not considered. For example, producers from 11 Wisconsin dairy operations utilizing individual housing spent on average $363.69 on pre-weaning, while 15 who used automatic calf feeders spent $401.58. The variation in cost is mostly contributed to fixed costs including housing and equipment. The variable cost for each system had little variation at $322.80 and $323.89 for individual and automatic, respectively. Thirty eight percent of the total individual housing cost was contributed to labor needs, which is much higher than 24% in an automatic system (Akins et al., 2017).

Cost is not always the sole factor when determining how calves will be housed. Many producers choose to keep calves in individual housing to reduce the contact from calf to calf in reducing horizontal spread of illness (Broucek et al., 2009). Early research considers comingling under the same level stressor on immune function as extreme changes in temperature and surgical procedures (Whiteley et al., 1992). But recent studies show that pairing calves early (5 versus 28 days) can serve as a buffer to potential stress.

No growth or concentration intake was shown to improve, but overall behavior indicated less stress (Bolt et al., 2017). These results growth contradict Costa et al. (2015) as they found higher intake for early paired calves and an increase in ADG over the experimental period. When calves were followed post weaning, TMR intake did not differ (Rushen et al., 2008). Goals of the individual producer can sway management decisions, opting to intentionally increase cost to obtain a select outcome. Another management opportunity provided to producers is how feeding is managed for pre-weaned calves. The following section will examine the impact of milk source, allotment and delivery method on the individual calf and total cost.

Health

Health of replacement heifers can also be related to management factors and can highly influence the cost of raising replacement heifers. For example, risk of contracting bovine respiratory complex has been associated with increased stress factors such as poor ventilation and high humidity (Whiteley et al., 1992, Callan and Garry, 2002). It has even been debated if management is the largest influence on health outcomes versus housing or feeding system alone (Rushen et al., 2008). Health costs represent 9% of the total cost of model calculated costs (Boulton et al., 2017b) and range from $5.00 to $20.00 as reported through extension publications (Akins et al., 2017). While additional costs may be incurred from implementation of intervention, it can increase gross margins by 13 to 35% (Razzaque, 2009). In 2007, producers reported 23.9% of replacement heifer calves to be affected by diarrhea and 12.4% experiencing a respiratory illness (USDA, 2010). Lower prevalence were reported by Austrian dairy producers with less than 10% reporting incidences of diarrhea incidence and 10% calf mortality (Klein-Jöbstl et al., 2015). Like most diseases, it is more cost-effective to implement preventative measures than treatment (Cho and Yoon, 2014). Expenses become much larger when calves are lost to these diseases. According to the National Animal Health Monitoring System 56% of all calf deaths were associated with diarrhea or digestive problems (NAHMS, 2010). However, a lack of information in this topic is found in the literature and total cost associated with long term influences of disease is unknown.

Another cost associated with the health of replacement heifers are preventive measures, such as vaccination. While each farm has vaccination protocols specific to their operation, a 2014-15 survey of producers revealed a few vaccinations are very common (Urie et al., 2018). Over 50% of all calves received an infectious bovine rhinotracheitis and parainfluenza 3 vaccine, 46% received a bovine respiratory syncytial virus vaccine and 21% were vaccinated for coronavirus. All other reported vaccines were reported to be given to less than 18% of all 2,545 calves surveyed (Urie et al., 2018).

The pre-weaning period is a management intensive time for calves with multiple inputs affecting the total cost of production. While the pre-weaning period is only 2 months of the replacement heifer rearing process, milk source and allotment, housing and health can all play a significant role in the total investment required from a dairy producer. The following section of this literature review will focus on management after weaning.

WEANED REPLACEMENT HEIFER MANAGEMENT

Feeding

Feed is the largest contributor to replacement heifer cost after weaning representing from 60 to 73% of total (Gabler et al., 2000, Heinrichs et al., 2013). Feed can be used as a tool to increase average daily gain and health, but producers must be careful not to overfeed risking impairing future milk production or underfeeding which can lead to a delay in maturity (Bach and Ahedo, 2008). The first published work on accelerated growth of heifers and the effect on growth as a breeding indicator was Gardner et al. (1977, Heinrichs, 2017). Heifers on a low plane of nutrition produced 7% less milk than those on a diet of higher nutritional value during the first lactation but had no significant difference in the following lactation (Macdonald et al., 2005). Feed represents a large financial investment that must be balanced with the biological needs of replacement heifers to generate the most profitable future.

Producers are creative when it comes to heifer raising feeding systems, trying to optimize available land and maintain high levels of growth and development. The annual cost of maintaining, and associated value of pastures planted with four different seed (big bluestem, Indian grass, legumes, and switchgrass) ranged from $131.38-$277.07 per hectare. This assumed a 10 year useful life (Lowe et al., 2016). Fermented warm season grasses are similar to that of cool season grasses and producers could potentially use them without concern to rumen health (Ruh et al., 2018). Producers may also increase the addition of straw in diets to decrease the total cost. Diets comprised of 20% straw still allowed animals to consume enough nutrients to maintain an ADG of 0.9 kg. As straw percentage increased, the amount of sorting increased and dry matter intake decreased, but not an amount that would be detrimental to growth. It may even concluded the additional sorting and diet addition of low quality forage may provide increased opportunity for heifers to exhibit nature foraging behavior (Keyserlingk et al., 2008). The use of pasture and additions of other feedstuffs has the potential to provide alternative feed sources to heifers while maintaining average daily gain goals.

Housing

Decisions producers make involving housing options can impact total cost, development of heifers and labor utilization. In 2014 the most common housing types for weaned heifers was 1) group housing in a barn and 2) open, dry lot areas with a barn or shed shelter. While these two housing systems represent over half (54.6%) of all heifers in the United States, over 10 different housing management styles were represented (USDA, 2014). Housing of replacement heifers accounted for 17% of the total cost to raise a weaned heifer (Akins et al., 2017).

Pasture is utilized by 13.1% of producers for weaned heifers (USDA, 2016). Dairy operations in the Eastern region of the USA are utilizing pasture more than those in the West (Granger, 2012). Whether heifers are kept on pasture for the entire period or a select time frame, the adjustment period appears to be quick. Heifers in the milking herd that were housed previously in confinement for at least a year acclimated to pasture within 3 days. Walking time and milk production was no longer significant in comparison to heifers who had previous exposure to pasture (Lopes et al., 2013).

Concerns for future udder health of heifers raised on pasture and confinement have be studied. In confinement, housing close up heifers with older cows increased risk of clinical mastitis (Bareille et al., 2004) and increased SCC moving close-up replacement heifers the day of calving to confinement instead of before (Svensson et al., 2006). Bacteria cultured from heifers reared on pasture leading up to calving were found to be skin-opportunistic bacteria. The primary culprit outside of CNS was *Strep. Uberis* for new inframammary infections (Compton et al., 2007). Heifer mastitis can impact future profitability because of possible damage to the mammary gland (De Vliegher et al., 2012). Current infrastructure on farm and pasture availability can impact the housing system used to raise replacement heifers, but each need to be well managed to prevent negative effects, like mastitis.

Labor

Labor is another factor that influences replacement heifers cost substantially, but it is dependent on what kind of housing system is utilized by the producer. There is a lack of published literature on the labor demand of raising replacement heifers on farm, especially within the United States. Over 350 of 445 French producers quantified the time to care for heifers between 30 mins-2 hours per day (Cozler, 2012). Providing an insight to the large possible range of values. Even though, there are unpublished extension surveys quantifying the amount of time and corresponding expense. Labor contributed 18.2% of the total cost to raise a replacement heifer post-weaning, totaling on average $307.05, but ranging from $80.99 to $1,538.31 (Akins et al., 2017). Future work should further investigate this topic.

Breeding

When and how replacement heifers are bred can have a large influence on the overall cost of rearing a heifer and repercussions for the milking herd. The NRC, 2001 recommends heifers be 55% of their body weight at breeding. But, weight alone cannot be the deciding factor for when to breed a heifer. The replacement heifer must be metabolic and physically mature. The correct kind of growth is necessary for heifers to reach the recommended height and weight for breeding, but has also been shown to impact milk performance in the first lactation. Withers height at calving was found to be very heritable for milk production and for heart girth (Lin et al., 1987). Once heifers are at the correct maturity, the protocol used to get them bred can influence total cost.

The cost associated with breeding decisions and protocols are needed to establish the investment of a pregnancy in a replacement heifer. In 2006, 87% of herds were using some kind of hormonal syncing program within their operations (Caraviello et al., 2006). Putting a dollar value on each of these steps incorporates cost of the injections and labor ($0.20/injection) required to successfully administer (Lima et al., 2010). Each dose of prostaglandin was $2.04 and GnRH was valued at $1.84 per shot. In addition, $0.03 in supplies was accounted for and $3.00 per each pregnancy diagnosis. Total cost per head for timed AI program was $67.80 with all cost and returns. Accounting for only the cost of timed AI, the total investment per head was found to be $83.91 (Lima et al., 2010). Average natural service bull price was $1,148 and sold for an average of $1,116 (77%) after 400 days. Those culled early were sold for $670 (23%). Daily feed for bull ranged $2.37-$3.30 on off and on time frame (Lima et al., 2010). These additional costs required to keep a bull would be totaled and distributed over all heifers in the breeding program increasing the total cost just as a hormone protocol. In 2011, 50% of herds were using both natural service and AI technology to breed replacement heifers (Granger, 2012.) Interestingly, this is a decrease in 59.5% of Pennsylvania herds in 1987 reporting to only use AI technology

(Heinrichs et al., 1987). Breeding cost is an example of many small expenses that combined can have a large impact on the milking herd. The resulting calving interval from breeding decisions and cull rates are further described in the next section.

Culling rate and replacement cost

Economic models have taken breeding information and corresponding dollar values, to improve predictions of heifer raising costs. Many researchers have used the dynamic programming (DP) method to make recommendations for replacement dairy heifers and breeding decisions. While, DP models can become very large and complicated they provide valuable insight to management concerns such as cull rates and calving intervals (Smith et al., 1993). Using a DP model with a base farm of 100 cows and the following parameters: 25 months at first calving, 13 month calving interval, 25% herd cull rate, and pre-weaned calf mortality at 10%. Total heifer replacement cost was $32,344. When the cull rate was decreased to 20% the net cost dropped $7,968 (Tozer and Heinrichs, 2001). A reduction in annual replacement rearing cost was also observed by Mohd Nor et al. (2015b). A 5% decrease in cull rate of a 93 cow herd reduced the number of required replacement heifers and therefore decreased costs by over $6,500 annually. When age at calving was reduced to 24 months, the cost decreased $1,400 annually (Tozer and Heinrichs, 2001). The recommended age at first calving has been found to be 22-23 months. After 24 months of age at first calving milk production decreases each month, While reducing the age at first calving below 22 months is not as profitable for the operation (Nilforooshan and Edriss, 2004). Total number of heifers raised and age at first calving were the two main variables resulting in a significant drop in cost (Tozer and Heinrichs, 2001). These represent management decisions that can be implemented on farm.

An additional management decision to supplement determining how many heifers should be raised is genomic testing of heifers. Genomic testing has become increasingly more popular to help cull heifers at an early age for their genetic merit. The cost associated with genetic testing has been shown to be able to be recuperated in the lifetime of the heifer. The high cost of genetic testing in practice is viewed as high barrier for producers but had little effect on net-benefit. (Newton et al., 2018) A study from Denmark values the breakeven price of benefit from the test at $57.00. At the time of the study, this was comparable to the current market price, making it not always the most economically savvy decision to use on every heifer as a standard management practice. (Hjortø et al., 2015) Currently, in the United States between $35 and $50 per heifer. The information and use to the producer can determine if this additional cost is being maximized to the true break even cost. Breeding of replacement dairy heifers has the potential to have an impact on overall heifer raising cost, specifically through protocol cost, age at first calving and number of required female dairy calves. However, the final outcome of a replacement heifer is to be a milking dairy cow, thus the next section will explore the influence of the milking herd on dairy replacement cost.

MILKING HERD INFLUENCES ON REPLACEMENT HEIFER COST

While heifers are commonly viewed as a separate entity from the milking operation, decisions made about the milking herd have a direct impact on heifer raising cost and potential value. Many individual variable costs are heavily integrated into the milking herd and can present a challenge in determining how much of these resources are utilized by heifers. Similar to the previously discussed dynamic programming models, models incorporating heifer development and milking herd expenses are expansive and adoption of such decision-making tools in the dairy industry is not common practice (Bewley, 2010).

Nevertheless, simulation models provide valuable information on the relationship between culling of the milking herd and age at first calving. Figure 1 is a graphical representation of the linear relationship between cull rate, AFC and the number of replacement heifers required on farm (Mohd Nor et al., 2015b). For example, if heifers were calving at 25 months of age and the cull rate of a 100 cow milking herd was 30%, the operation would need to have 73 heifers to maintain the herd size. If a management decision was made to reduce the cull rate of the milking herd to 28% only 63 heifers are needed to maintain the 100 cow herd. If we assumed each heifer was costing $1,700 to raise from birth to weaning, and an operation culled heifer calves to account for the reduced number of replacement required, this farm scenario could reduce total heifer raising cost by $17,000 over a two year period.

Culling is needed when bringing in heifers to control herd size and stocking rates. Culling decisions can be complex with many variables to consider for each individual animal to determine the current status and predictions of future performance (Ahlman et al., 2011). Against common assumption, culling is not always equivalent to an incidence of illness or death. The three main reasons for culling are reproduction, milk production and mastitis (Bascom and Young, 1998, Ahlman et al., 2011). In a survey conducted in 2011 the main reason for culling of conventional herds was low fertility, while organic dairies culled the most for poor udder health (Ahlman et al., 2011). The main reason for culling can be tied to the overall goals of the operation and previous breeding selection decisions. Heifers can have their first calf anywhere between 21 and 25 months, then begin creating a return to the operation (Gabler et al., 2000).

Knowing how many heifers to raise is also reflective on how much value is found in older lactation cows or lower producing females. When it comes to culling heifers, producers usually keep all of their newborn heifers for security of available replacement heifer options (Mohd Nor et al., 2015b). The optimal time for a cow to be replaced was determined finding the intersection of marginal net revenue of the current cow and the economic opportunity of a replacement heifer (Groenendaal et al., 2004). Culling helps improve the genetic lag time between generations. A heifer daughter, who is the result of an AI breeding, is genetically superior to her dam. Continuing to keep this cow in the herd, in comparison to her daughter decreases the potential genetic improvement for the next generation (De Vries, 2017). When distinguishing the optimal time based on retention pay off strategies, the maximum value found in a milking cow was in the fourth lactation and decreased consistently into the 9th lactation (Kalantari and Cabrera, 2012). But in terms of potential genetic improvement, the Council on Dairy Cattle Breeding found, a heifer born in 2015 is expected to be $50.00 more profitable per lactation than those born in the previous years (De Vries, 2017). Evaluating heifers in the whole operation can provide insight on how many heifers are required and when it is most economical to cull milking cows. While modeling has been previously mentioned, a more in-depth description of stochastic modeling is included in this literature review for reference.

MODELING

Many heifer raising papers utilize various economic models to determine the cost to raise heifers, their efficiency, or impact management decisions have on the total cost. The three major components of economic models are: people, products and resources (Mclnerney, 1987). Economic modeling allows for real life situations to be modeled and the effect of small changes to be quantified. Stochastic simulations allow for the model to account for variation in prices and management values. This is referred to as systems simulation in Dijkhuizen et al. (1991), where an animal is moved through a period of time and changing the status based on events and management decisions. Decision trees are commonly used decision analysis (Morris, 1977) and serve as a graphical representation on alternative decisions one can make (Ngategize et al., 1986).

Dynamic programing was developed to attempt to account for more variation and become closer to modeling the complex mind of a human or animal. Using dynamic programming the optimal combination of inputs to create maximum outputs is determined (Bellman, 1966). Each kind of model has a specific outcome or test to determine. Models create to produce the most efficient point of production, even though it may be less than the maximum level of production that can reached, are classified as data envelopment analysis (Stokes et al., 2007). In a survey of 34 Pennsylvania farms only 29% of farms were considered to be meeting their efficiency frontier but no one set of inputs was considered a universal combination for efficiency (Stokes et al., 2007). Simulation modeling was used in to evaluate a more holistic economic situation when adopting precision dairy farming technology(Bewley, 2010). Many layers of decisions have to be considered and using only a single economic measurement can be misleading. Economic models are a method to help create values representing the many decisions that can be made while raising replacement heifers.

CONCLUSION

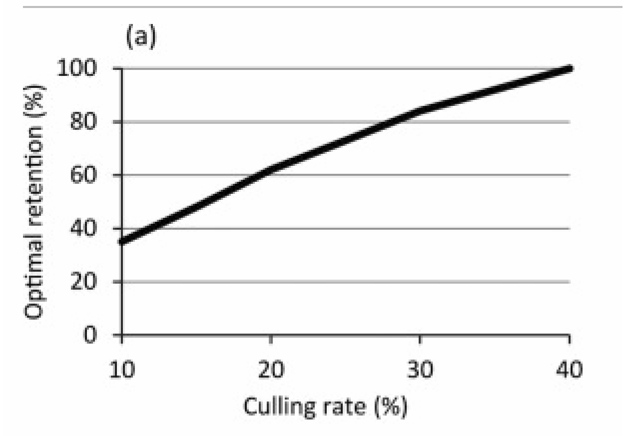
The cost for a dairy operation to raise a replacement heifer is a substantial two-year investment in the future of the dairy enterprise. Individual producers can vary in management decisions on housing, feed, labor utilization, breeding, and health that each present unique benefits and challenges. In addition to the biological impact and daily management routine differences, the cost associated with each decision has a direct impact on the total cost per heifer from birth to calving. Replacement heifer costs on farms vary greatly, but it is still of critical importance to the dairy operation even if producers chose to contract heifer raising to a heifer grower. The growth and quality of care can impact future milk production, cull rates of the milking herd and required replacement heifers are still impacting the dairy operations, whether the heifers are on farm or contract. Heifer raising decisions must be made to balance economic and biological impacts for the operations. This current thesis aims to determine the economic value of housing, feed, labor, health and breeding heifer raising decisions on the total cost per heifer and the influence of each individual variable on the total cost.

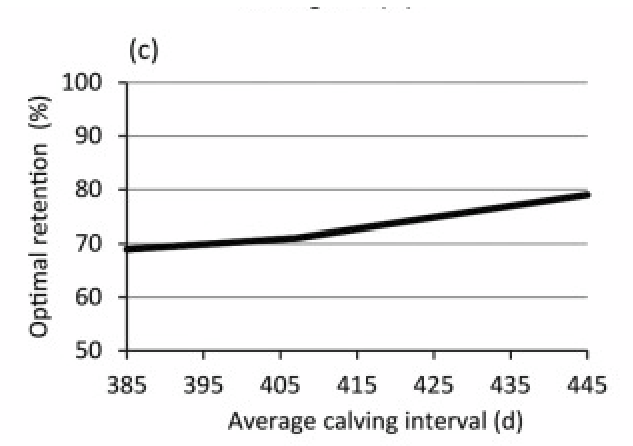
Table 1.1 Summary of replacement heifer raising cost over the past 20 years in published literature, outline average cost with provided SD and, or Minimum and Maximum cost.

	Average Cost	**SD**	**Min**	**Max**
Gabler, 2000	$1,124.06		$896.89	$1,305.03
Karszes, 2007	$1,734		$1,598×	$1,867×
Heinrichs, 2013	$1,808.23	$338.62		
Adkins, 2013	$1,863.19	$553.57	$769.89	$3805.85
Adkins, 2015	$1,730.29	$700.61	$589.12	$5,571.65
Boulton, 2017*	$1,565.63	$408.29		
Tranel, 2019†	$2,241.00			

×Interquartile ranges
*Conducted in United Kingdom
†Extension article, based on Adkins, 2013 data

Figure 1.1 Determining the number of heifers required to maintain herd size with variation in cull rate (a) and age at first calving of heifers (c) presented in (Mohd Nor et al., 2015b).





CAPTER 2: AN ECONOMIC ANALYSIS OF THE COSTS ASSOCIATED WITH PRE-WEANING MANAGEMENT STRATEGIES FOR DAIRY HEIFERS

INTRODUCTION

Heifer availability is critical for the dairy operation to maintain a consistent herd size and remain economically sustainable in most cases (Zanton and Heinrichs, 2005). Improved fertility and increased use of sexed semen has made replacement heifers more available for dairy operations (De Vries, 2017). Some producers keep all newborn replacement heifers in case more replacements are needed than anticipated, which can create a heavy financial burden for producers when raising excess heifers. Heifer raising expenses are often lumped into broad farm-wide expenses such as feed, labor, and health costs, making it difficult to accurately calculate heifer raising costs (Mohd Nor et al., 2015b). In addition, failing to identify the on-farm cost to raise a replacement heifer can allow for inefficiencies in feed, labor, housing, or health costs to go unnoticed, which accumulate unanticipated replacement female costs.

Previously reported replacement heifer rearing costs are variable and can be explained in part by differences in rearing management systems. For example, the average total cost to raise replacement heifers to weaning only increased by $82.88 per heifer from 2000 to 2015 in recent on-farm surveys but ranges within each study can exceed $350 per heifer (Gabler et al., 2000, Heinrichs et al., 2013, Boulton et al., 2015).

[1]Published as Hawkins, Anna, Kenneth Burdine, Donna Amaral-Phillips, and Joao HC Costa. *"An Economic Analysis of the Costs Associated with Pre-Weaning Management Strategies for Dairy Heifers."* Animals 9, no. 7 (2019): 471.

Heinrichs, 2013 found a range in feed cost on 44 farms of $29.06 to $259.17 per calf; total cost per calf ranged $89.00-$442.78 during the pre-weaning period. In a 2014 survey of 2,545 heifer calves in the United States, individual housing was the dominant form of housing pre-weaned heifers at 86.6% and 13.4% were managed in group housing, yet 8 different housing types were reported (USDA, 2016). Little research has examined the cost between housing types, although the University of Wisconsin has conducted surveys of producers in an automatic and conventional housing scenario. The average cost (min,max) of producers utilizing individual housing was $363.69 ($195.06, $530.76) and those with group housing was $401.58 ($138.39,$585.52), a difference in average cost of $37.89 per calf, but with a difference range of over $300 for individual and $400 for group housing (Akins et al., 2017).

Housing is the first of many decisions a producer makes on how pre-weaned calves will be managed. Utilization of labor and milk source requires additional decisions based on resources and availability. While gaining in popularity, only 1.9% of the calves were fed through an automatic feeder while almost half of the surveyed calves were fed using a bottle or a bucket (Urie et al., 2018). On average, one calf requires 7-12 labor hours during the pre-weaning period, or 7-10 mins per day (Akins et al., 2017). Unpasteurized whole milk was the most common milk source utilized by producers but close to 50% of those also utilized milk replacer (USDA, 2016). More recent surveys show a similar trend, with 40.1% of calves fed whole or waste milk, 34.8% fed milk replacer, and 25.1% fed a combination of the two. Calf starter was provided, starting on average at 5 days old, to all calves surveyed (Urie et al., 2018).

Thus, it is important to understand the costs associated with the myriad of rearing systems for dairy calves in the United States. The objective of this paper was to evaluate the economic impact of different calf raising management decisions, especially housing, liquid diet and allowance, and health expenses on total pre-weaning cost of rearing heifer replacements.

MATERIALS AND METHODS

A cost simulation model was developed at the University of Kentucky Dairy Science program during 2018. This economic model was developed in Excel 2013 (Microsoft, Redmond, WA, USA) utilizing @RISK and PrecisionTree add-ons (Palisade Corporation, Ithaca, NY). The base herd used included 1500 milking cows, 1000 replacement heifers in total and 84 heifer calves in the pre-weaning period, assuming a 30% replacement rate and an average age at first calving of 25 months. Costs were calculated on a per head basis for housing, feed, labor, mortality, and health. All remaining variables are static. Interest was accounted for on infrastructure and mortality as well as the depreciation of assets related to replacement females. Costs associated with herd-wide parameters, such as disease prevalence and mortality rates, were distributed across all remaining calves in the pre-weaning phase. The model required a management decision at 3 points: housing type, milk source, and labor shown in Figure 1. Three main housing types were modeled: individual housing outside (IHO), individual housing inside (IHI), and group housing (GH). Three milk sources were built into the model: whole milk (WM), pasteurized whole milk (PWM), or milk replacer (MR). Four possible liquid feeding plans were modeled: 6, 8, 10, and 12 L of milk per calf per day. Labor was modeled for two categories: conventional, where a person was assigned to feeding and caring for the calves; or automatic, where an automatic calf feeder was utilized in addition to human labor. Totals costs were reported per calf for each management decision, the entire pre-weaning period per calf, and per day per calf. Per day cost was calculated by dividing days of age at weaning by the total cost per calf during the pre-weaning period.

Housing

Housing systems that required a barn (IHI and GH) used values found from Table 1 to determine barn value and monthly payment. Barn cost was derived from the Dairy Calf and Heifer Association Gold Standard recommendation of 3.3 m^2 per calf, with an additional 15% of space to account for walkways and feed areas. Combined, replacement heifers were assumed to require 3.7 M^2 per calf. Construction cost (McCullock et al., 2013) varied based on the infrastructure required for each situation, ranging from $10.00 to $15.50 per M2. Estimated barn value (BV) was then calculated with Equation 1.

$$BV = CC * 3.3\ M2 * \text{number of pre-weaned calves} \qquad \text{Eq. 1}$$

Barn cost per heifer (BC) was calculated using the payment function in excel with 7% interest, 20 years useful life and BV. BC was included in IHI and GH situations. Calves housed in individual housing outside followed the same payment function. Housing calves year round in individual housing with an average occupancy time of 2 months ± rest period would allow 5 calves per hutch per year. Days of age at weaning was used as the length of time a heifer was incurring cost during the pre-weaning period. Housing costs also included utility costs, such as water and electricity. Electricity was only factored for housing systems that included a barn (IHI and GH). The bedding was included at a flat evaluation of $11.00

per calf. For pasture scenarios, a cash value price per acre was used as the value of land to try to account for the opportunity cost of a specific acre being used for other purposes. An additional annual maintenance cost of $31.50 per acre was assumed.

Feed

Milk replacer was mixed at a concentration of 0.11 kg per liter of water. A pasteurizer was depreciated over all calves over the 15 year useful life. The model accounted for four possible feeding milk allotments: 6, 8, 10, and 12 L per calf per day. A 2016 survey of producers in the United States showed over half of the farms were feeding calves between 4-6 L per day (USDA, 2016). Recent studies have shown that increasing milk allotment can increase average daily gain (ADG) pre-weaning, result in larger skeletal measurements at weaning, and decrease vocalizations caused by milk deprivation (Thomas et al., 2001, Kiezebrink et al., 2015). Milk allotments and starter intakes per calf for this model were reflective of experimental data from Rosenberger et al., 2017. In this study, calves were randomly assigned to 6, 8, 10, or 12 L feeding treatments of pasteurized whole milk with *ad libitum* access to calf starter. A step-down weaning program was performed: milk was fed at maximum allotment until weaning at 42 days. Milk allotment was decreased by 50% until day 50, where allotment was decreased daily by 20% until weaned. Calves were assumed to be consuming at least 2.25 kg of calf starter at weaning. An additional 20% was assumed to be fed to account feeding loss per calf. This additional expense was added to daily calf starter cost. Milk and calf starter costs were calculated on a daily basis for the entire pre-weaning period, from day 0 to 65. ADG was determined using the dry matter intake requirements and resulting gain from NRC, 2001. Calf weight was modeled daily to determine appropriate weaning weights based on dry matter intake from milk replacer or whole milk.

The assumed birth weight was 40 kg for each calf. Assumed average daily gains on each feeding plan (6, 8, 10, and 12L) are described in Table 2, following the equation presented in NRC, 2001. The weaning weight was calculated by multiplying ADG by 65 days and adding the weight gain to BW. Feed cost was reported for three variables: total cost during the pre-weaning period, daily feed cost, and feed cost per kg of gain. Total feed cost included milk replacer or whole milk expenses and feeding equipment. Daily feed cost was derived from dividing total feed cost by weaning age (65 days). Daily feed cost was then used to calculate feed cost per kg of gain. Daily cost under each feeding plan was divided by ADG to determine cost per kg of gain.

Labor

Labor to care for calves and the number of employees working were adapted from published surveys of producers employing individual and group housing (Table 1). Because of the lack of data on group housing without automatic feeder labor time requirements, we assumed the median of an automatic feeder and individually housed heifers (5.5 mins/calf/day). Management labor was calculated separately to represent additional labor required from owners, managers, and/or family. Management followed the trend of 10% of the paid labor, creating the assumption of 0.55 mins/calf/day for group housing without an automatic feeder. Minutes per calf could be input directly or total time per all pre-weaned calves could be used to calculate total labor cost using Equation 2.

$$((\text{Daily Paid Labor Hours}/\text{Number of Calves})*\text{Hourly Paid Labor})+((\text{Daily Management Labor Hours}/\text{Number of Calves})*\text{Hourly Management Pay}) \quad \text{Eq. 2}$$

The expenses related to buying and using an automatic calf feeder were included in the labor section. Justified by the change in labor demands, the use of an automatic calf feeder can be viewed as an additional autonomous employee. The cost of the feeder was assumed at $15,000 value, 10 years useful life and $200.00 annual maintenance. These values were assumed based on market prices and a routine maintenance program. Eq. 3 represents the calculation of daily feeder cost per calf using the payment (PMT) function in excel.

$$(-\text{PMT (interest rate, 120, initial value))/number of pre-weaned calves} \quad (3)$$

Mortality and Health

The cost of each calf was calculated daily and therefore monthly cost to raise one calf in each management style was determined. All calves were assumed to die at the end of the first month of life, accruing the additional monthly cost plus interest. This additional cost is divided over the remaining number of calves. Equation 4 explains how calf mortality was added as an additional cost to each remaining calf.

$$\text{(((Value of Newborn Calf + (Cost up to death*((Interest Rate/365)*60)) *Mortality Rate)/(Remaining Calves)} \quad \text{Eq. 4}$$

Health costs are reflective of a standard vaccination protocol including fly control, respiratory vaccine, vitamin A, D, and E, selenium, and a vaccine for rotavirus and coronavirus scours, and E. Coli. Labor costs related to health tasks were compiled into a “working heifer” labor expense. The total health cost was figured at $9.22 per calf. Fair market prices were assumed on all vaccine and health related equipment through averaging online prices obtained in January 2019.

The prevalence of respiratory illness and diarrhea was determined by the 2014 Heifer Raiser Survey conducted by the USDA, 18% for respiratory illness and 25% for diarrhea on average. Because of the variation in this measure from farm to farm it was made stochastic to account for variation between farms. The minimum incidence was 16% for respiratory illness with a maximum of 19%. The minimum of diarrhea was 22% and maximum of 28%. Based on the selected prevalence, there was a direct relationship to the additional treatment cost for each calf. We modeled a protocol that would include electrolytes and 3 days of antibiotics. We assumed an 85.6% improvement rate and culled the remaining heifers at the end of that week.

Stochastic Simulation

A simulation model was developed in Excel 2013 (Microsoft, Redmond, WA, USA) utilizing @RISK and PrecisionTree add-ons (Palisade Corporation, Ithaca, NY) to evaluate the cost of raising an individual heifer from birth to weaning under different management styles and systems. 10,000 simulations of the model were performed for each of the situations. Stochastic simulations allowed for variation of inputs values which are reflected in ranges of potential outcomes, unlike a static model which will always produce the same outcome. Modeling variables stochastically, such as weaning age, mortality rates and disease prevalence, we can simulate different outcomes. All variables were modeled following a Pert distribution set with minimum, most likely, and maximum value. Assumptions were made based on published literature, surveys and market assumptions were also used to calculate the total cost (Table 1). A month in the cost spreadsheet was considered 30 days.

RESULTS AND DISCUSSION

Housing

Total cost to house calves in individual housing outside, individual housing inside and group housing were $21.12, $70.52, $94.30, respectively. All of these costs were within 1 SD of the average found in published literature. For housing that included a barn, the barn payment per heifer was the largest contributor to cost, while bedding was the largest contributing cost per calf for individual housing outside (see Table 3).

Feed

Feed cost was heavily dependent upon the amount of milk allotted per day. Table 4 shows the total cost of each milk source with 6, 8, 10, and 12 L allotments. As milk allotment per calf increased, the cost of milk increased.

The cost of pasteurizing whole milk ranged from 10-18% of the total cost of feeding calves in applicable scenarios. This model assumed the same nutritional value and gain from milk replacer and whole milk, creating a limitation in the model. However, calves fed pasteurized or unpasteurized whole milk have been shown to increase model-produced ADG by at least 0.03 kg/day with the potential to be over 0.25 kg/day of gain in comparison to milk replacer (Shivley et al., 2018). The additional cost to feed whole milk has the potential to be offset by an increase in weight gain.

The estimated cost per kg of gain decreased as milk allowance increased, and with increasing ADG, shown in Table 6. For example, group housed calves on milk replacer with an automatic feeder fed 6 L will cost $3.50 per kg of gain. When these same calves are increased to 12 L the cost decreases to $2.67 per kg of gain. The minimum decrease in cost was from feeding 10 L of milk replacer to 12 L of milk replacer at $0.01 difference per kg of gain, and the maximum savings per kg of gain was $0.41 increasing from 10 to 12 L of pasteurized whole milk. If birth weights were 44 kg with a goal of weaning calves at 100 kg, we could assume a minimum of $0.56 to $22.96 in feed efficiency savings per calf alone. Modeling cost per kg of gain following experimental data presented in the (NRC, 2001) equations indicates that feeding calves a higher allowance of milk decreases the cost of kg of gain. The cost of milk and calf starter, with our current assumptions in inputs and ADG, decrease cost per kg of gain.

Labor

Labor decisions depended on the housing system selected. Hourly wages for management are higher than those for paid employees as shown in Table 1. Employees contributed more to the total cost than management in conventional and automatic systems even though their hourly rate is lower. Labor costs associated with the automatic calf feeder were responsible for 23% of the total labor cost. Labor cost of individual housing and group housing contributed 33% and 26%, respectively. The minutes and total cost per hourly laborer was decreased from inside individual housing to group housing by 36% per calf for a value of 2.4 minutes or $0.50 per calf per day. This shows a reduction in overall labor cost but an increased demand in fixed and variable expenses. These include the paying for the feeder, annual maintenance and a barn to house calves.

This breakdown of cost follows the same trends of Wisconsin surveys of conventional and automatic calf raisers. Paid labor cost alone was reduced by 39% for farms utilizing an automatic calf feeder, and paid management decreased by 14%. The total pre-weaning cost decreased 6% from conventional to automatic labor, the cost difference was recovered in an additional fixed variable cost of the automatic calf feeders.

Health

Mortality rate and prevalence of diarrhea or respiratory illness, which were included in variable costs, impacted the total cost. The average cost, including the risk of each calf being healthy or experiencing diarrhea, totaled (mean ± SD) \$5.39 ± 14.42 per calf. The average cost per BRD case was \$0.70 ± 7.33 per calf. Preventative health costs added an additional \$9.22 to each calf.

The change in total cost per calf accounting for additional expenses with fewer calves, as mortality rate increases (2%, 8%, 10%, and 15%) are reported in Table 6. As mortality rate increased, the cost of infrastructure and higher cost management systems showed a larger increase in the dollar amount added for each calf. Across management styles, decreasing mortality rate from 15% to 2% reduced overall cost from \$39.47 to \$36.84 per calf. For a farm raising 500 pre-weaned calves annually, potential savings by decreasing mortality 10% alone could be over \$18,000.

It has been found that management practices specific to a housing type can change illness prevalence. For example, calves housed in groups of 12-18 had a higher incidence of respiratory illness and lower daily gains than calves housed in groups of 6-9 (Urie et al., 2018). We assume a constant square footage per calf, therefore the barn square footage increases as number of calves increase and this may not always be reflective of true management practices. A limitation to the model is the same probabilities in averages and ranges in mortality for all management pathways for calculated cost.

Total Cost of Management Scenarios

All possible combinations of management decisions (each combination of housing type, milk source and labor type) and for each of the 4 milk allotments were analyzed for total cost, daily cost, and percentage of feed, labor, fixed and variable costs (Table 8). Fixed costs included barn and housing infrastructure, depreciation of assets, and interest. Variable costs included health-related expenses, mortality, and utilities for electricity and water. Feed represented the largest factor in all management scenarios, followed by labor, then variable and fixed costs. This follows the same results found in previously published models where 57% of total cost were due to feed costs (Heinrichs et al., 2013).

Using the assumptions in Table 1, on average, the most expensive management style was utilizing group housing, feeding pasteurized whole milk with conventional labor. The least expensive management pathway was individual housing outside, fed whole milk and using conventional labor. The main difference in cost can be attributed to the larger infrastructure needs for group housing and the additional cost of a pasteurizer. Total and daily cost for all management scenarios with 6, 8, 10, and 12L allotments is shown in Table 3.

The mean for total cost ranged between $258.67 to $582.98 per calf across all management pathways. As seen in previous literature the mean cost in each milk allotment has less variation than when looking at the range of projected costs per management scenario. This can be attributed to variation in health and mortality rates. Increasing the mortality rate and disease prevalence increased the cost for the remaining calves by spreading infrastructure cost, the loss of the calf and incurred expenses, and additional illness treatments over fewer calves. Variation in costs is not always related to efficiency on-farm, but instead related to trade-offs in management styles.

The least expensive pathways were the 3 combinations for individual housing outside. In these scenarios, housing cost contributed 7-8% of the total cost compared to other management pathways utilizing more infrastructure, where housing accounted for 21-30% of total cost. The addition of barns with individual housing inside and in group housing was the contribution of the additional 14-23% of housing cost.

When costs were broken down by day, assuming a 65 day weaning age, cost ranged from $3.83 to $6.19 per calf per day. The average daily charge for a contract raiser from birth to weaning was $1.88/day (Wolf, 2003). Based on our calculated total cost for rearing pre-weaning calves, this would create a significant loss for the contract raiser. But in the Wisconsin heifer raising survey the cost per day of fixed and variable costs, which most closely matches our model, $2.05-$8.73 for minimum and maximum daily cost (Akins et al., 2017). This simulation model can be compared to surveys to validate the results are reflective of on-farm total values.

CONCLUSIONS

Raising calves from birth to weaning contributes to a major portion of the total heifer raising cost. Milk and calf starter contributed over half the cost to raise a calf from birth to weaning. Costs calculated by this model are based on currently available data, it is likely some of our assumptions will under or overestimate total and specific costs of calf raising practices across the US. More data are needed to improve accurate assumptions for farms. However, no model will be able to accurately describe all situations of calf rearing in various locations. Calculating pre-weaning cost for each individual farm is critical in making management decisions and remaining sustainable.

Figure 2.1 Decision tree of possible management decisions for housing, milk source, and labor for pre-weaned calves.

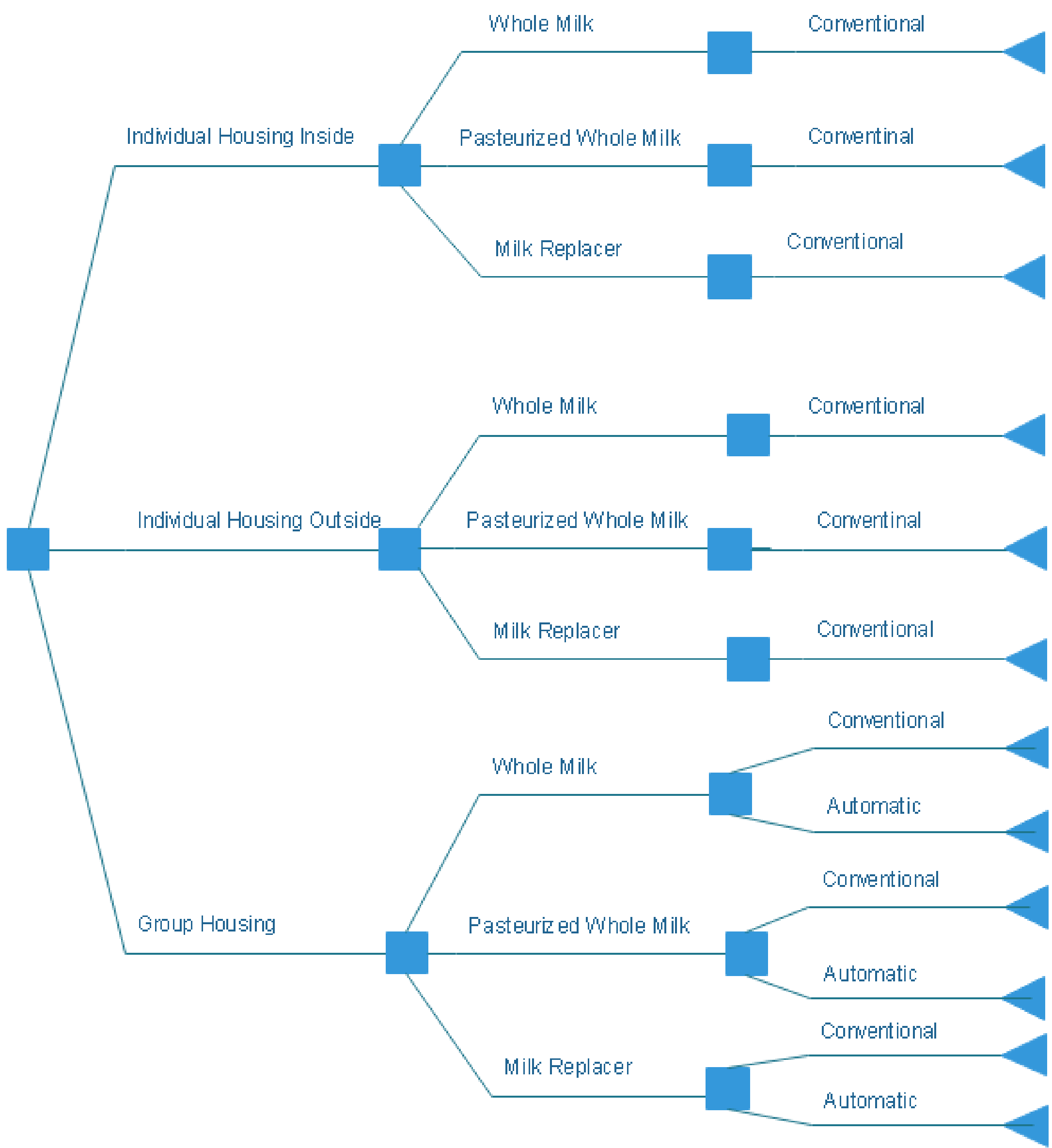


Table 2.1 -Model inputs for the economic model. Inputs were adapted from published literature, the latest USDA reports and heifer raising surveys.

Variable		Value	Source
Number of pre-weaned calves in 2 months		84	Based on rearing 500 heifers annually
Employee Labor (/hr)		$14.00	Based on National Dairy Labor Survey, 2014
Management Labor (/hr)		$22.00	Based on National Dairy Labor Survey, 2014
Interest Rate		7%	
Barn construction per M^2 Frame		$10.00	(Adkins, 2017)
Barn construction per M^2 Frame and Group Pens		$15.50	(Adkins, 2017)
Individual hutch		$300.00	Based on average market price
Value of newborn calf		$100.00	Based on USDA market reports
Whole milk value (cwt)		$15.00	Based on USDA, 2016
Milk replacer value (22.7 kg)		$65.00	Based on average market price
Calf Starter (mt)		$550.00	Based on average market price
Automatic calf feeder value		$20,000	Based on (Adkins, 2017)
Pasteurizer value		$10,000	Based on average market price
Diarrhea prevalence		21.4%	(Urie,2018)
Respiratory illness prevalence		12.7%	(Urie, 2018)
Pre-weaning mortality rate		5%	(NAHMS, 2011)
Water cost per calf pre-weaning		$0.50	Based on water price Jan. 2019
Electrical cost per calf pre-weaning		$0.50	Based on electrical price Jan. 2019
Bedding per calf pre-weaning		$11.00	Heinrichs, 2013
Weaning Age		65 days	(Adkins, 2017)

Table 2.2: Birth weight and weaning weight were a result of milk allotted and calf starter intake per calf following experimental data from Rosenberger et al, 2017. ADG followed the equation presented in NRC, 2001.

Milk Allotment (L/day)	Starter Intake (kg)	ADG (kg)	BW* (kg)	WW* (kg)
6	64	0.3	40	77.4
8	63.7	0.3-0.6	40	87.6
10	63.4	0.6-0.9	40	98.4
12	60.3	0.9-1.2	40	108.3

*Birth weight (BW) was assumed at 40 kg, weaning weight (WW) was calculated based on ADG for 65 day weaning age.

Table 2.3 Percentage breakdown of hutch/barn infrastructure, bedding and, water and electric on total housing cost per housing management decision.

Housing System	Individual housing outside	Individual housing inside	Group Housing
Hutch or Barn*	32%	83%	87%
Bedding	52%	16%	12%
Water & Electric	2%	1%	1%

*includes interest and depreciation of infrastructure

Table 2.4 Cost of milk replacer, whole milk, and pasteurized whole milk as a milk source for calves with 6,8,10, and 12 L milk allowances.

Milk Source	Milk Allotment (L)			
	6	8	10	12
Milk Replacer	$81.52	$107.02	$132.53	$158.04
Whole Milk	$81.41	$108.38	$135.36	$162.33
Pasteurized Whole Milk	$99.79	$126.76	$153.73	$180.71

Table 2.5 Feed cost per kg of gain of pre-weaned calves fed milk replacer, pasteurized whole milk and whole milk.

	Milk Allotment (L)			
	6	8	10	12
ADG (kg)	0.3	0.3-0.6	0.6-0.9	0.9-1.2
Milk Replacer	$3.50	$2.75	$2.68	$2.67
Pasteurized Whole Milk	$3.60	$3.45	$3.31	$2.90
Whole Milk	$2.98	$2.96	$2.92	$2.60

Table 2.6 Total cost under each management pathway per calf when mortality rate is set at 2, 8, 10, and 15%.

	Mortality Rate			
	2%	8%	10%	15%
Individual Housing Outside				
Milk Replacer-Conventional	$283.03	$298.74	$304.44	$319.87
Pasteurized Whole Milk-Conventional	$291.27	$307.26	$313.06	$328.75
Whole Milk-Conventional	$287.98	$303.85	$309.61	$325.20
Individual Housing Inside				
Milk Replacer-Conventional	$303.03	$319.40	$325.34	$341.42
Pasteurized Whole Milk-Conventional	$311.28	$327.92	$333.96	$350.30
Whole Milk-Conventional	$307.98	$324.51	$330.51	$346.75
Group Housing				
Milk Replacer-Conventional	$312.06	$328.73	$334.78	$351.15
Pasteurized Whole Milk- Conventional	$320.31	$337.24	$343.39	$360.03
Whole Milk-Conventional	$317.01	$333.84	$339.95	$356.48
Milk Replacer-Automatic	$293.10	$309.15	$314.97	$330.72
Pasteurized Whole Milk-Automatic	$301.35	$317.66	$323.58	$339.60
Whole Milk-Automatic	$298.05	$314.25	$320.14	$336.05

Table 2.7 Total cost mean, SD, min and max of each management pathway under 6, 8, 10, 12 L milk allotments.

Management Scenario	Milk Allotment (L)															
	6				8				10				12			
	Mean	SD	Min	Max	Mean	SD	Min	Max	Mean	SD	Min	Max	Mean	SD	Min	Max
Individual Hutches Outside																
Milk Replacer-Conventional	$276.03	$16.77	$259.92	$407.56	$301.71	$16.82	$285.07	$433.73	$327.39	$16.87	$310.22	$459.90	$353.07	$16.93	$335.37	$486.08
Pasteurized Whole Milk-Conventional	$295.55	$16.81	$279.04	$427.45	$323.38	$16.86	$306.30	$455.82	$351.22	$16.92	$333.56	$484.19	$379.06	$16.99	$360.82	$512.57
Whole Milk-Conventional	$274.63	$16.77	$258.56	$406.13	$302.47	$16.82	$285.82	$434.51	$330.30	$16.88	$313.08	$462.88	$358.14	$16.94	$340.34	$491.25
Individual Housing Inside																
Milk Replacer-Conventional	$301.11	$16.82	$284.49	$433.12	$326.79	$16.87	$309.63	$459.29	$352.47	$16.93	$334.78	$485.47	$378.15	$16.98	$359.93	$511.64
Pasteurized Whole Milk-Conventional	$320.63	$16.86	$303.60	$453.01	$348.46	$16.92	$330.86	$481.39	$376.30	$16.98	$358.12	$509.76	$404.13	$17.04	$385.39	$538.13
Whole Milk-Conventional	$299.71	$16.81	$283.12	$431.70	$327.55	$16.87	$310.38	$460.07	$355.38	$16.93	$337.64	$488.44	$383.22	$16.99	$364.90	$516.81
Group Housing																
Milk Replacer-Conventional	$345.11	$16.91	$327.58	$477.97	$370.79	$16.97	$352.73	$504.14	$396.47	$17.03	$377.88	$530.32	$422.15	$17.09	$403.03	$556.49
Pasteurized Whole Milk-Conventional	$364.63	$19.95	$346.70	$497.87	$392.47	$17.02	$373.96	$526.24	$420.30	$17.08	$401.22	$554.61	$448.14	$17.15	$428.48	$582.98
Whole Milk-Conventional	$343.72	$19.91	$326.21	$476.55	$371.55	$16.97	$353.48	$504.92	$399.39	$17.03	$380.74	$533.29	$427.22	$17.10	$408.00	$561.66
Milk Replacer-Automatic	$339.97	$16.90	$322.54	$472.73	$365.65	$16.95	$347.69	$498.90	$391.33	$17.01	$372.84	$525.07	$417.01	$17.08	$397.99	$551.25
Pasteurized Whole Milk-Automatic	$359.49	$16.94	$341.66	$492.62	$387.32	$17.00	$368.92	$520.99	$415.16	$17.07	$396.18	$549.36	$442.99	$17.14	$423.44	$577.74
Whole Milk-Automatic	$338.57	$16.89	$321.18	$471.30	$366.41	$16.96	$348.44	$499.68	$394.24	$17.02	$375.70	$528.05	$422.08	$17.09	$402.96	$556.42

CHAPTER 3: SIMULATION MODEL OF REPLACEMENT DAIRY HEIFER COST FROM BIRTH TO CALVING: EFFECTS OF DIFFERENT MANAGEMENT PRACTICES

INRODUCTION

Replacement heifers are the second largest annual operating expense on the farm, below feed cost (Tozer and Heinrichs, 2001). The cost of raising a replacement heifer is increasing and plays an important role in dairy enterprise economics (Gabler et al., 2000, Heinrichs et al., 2013). In the Netherlands, the difference in actual and perceived cost of heifer retention averaged $898.19 (Mohd Nor et al., 2015a). The difference in cost is accounted for in the operation, however it is normally misallocated to another area of dairy expenses. Therefore, determining the true cost on farm of raising replacement heifers is the first step in better managing these costs.

Analyzing replacement heifer raising costs can uncover additional information about resources utilized on the farm and assist in evaluating the efficiency of an operation. Feed costs are the primary expense, accounting for 60 to 73% of all expenses during the rearing period (Gabler et al., 2000, Heinrichs et al., 2013). Labor utilization, the second largest contributor to cost, has been found as a clear distinction on efficient and inefficient farms, through a 2013 survey of Pennsylvania producers. Farms labeled as efficient were allocated on average $140 in labor resources for each replacement heifer (Heinrichs et al., 2013). Currently, the most common housing system for post-weaned heifers is group housing, followed by open dry-lots (USDA, 2014). There are multiple options for how to raise replacement heifers on farm, with each decision presenting a unique cost.

Additionally, biological management decisions can also influence the total cost of raising a replacement heifer. By changing management to raising replacement heifers to be bred to calve at 24 versus 25 months, has the potential to save considerable amounts for the dairy enterprise (Tozer and Heinrichs, 2001). Decreasing cull rates of the milking herd has a direct influence on the cost of the entire heifer raising enterprise, by lowering the required number of heifers to be raised (Tozer and Heinrichs, 2001, Mohd Nor et al, 2015). Many current investment decisions made on dairy operations are based on tradition or intuition, providing an opportunity for more objective methods of investment analysis (Bewley, 2010).

The objective of this study is to develop an economic model to determine the cost of raising a replacement heifer managed in confinement, dry-lots and pasture-based scenarios post-weaning. Furthermore, account for additional variation in feed, labor and health inputs and quantify the impact of these individual variables on the total cost.

MATERIALS AND METHODS

A heifer cost simulation model was created in Excel 2013 (Microsoft, Redmond, WA, USA) utilizing @RISK add-ons (Palisade Corporation, Ithaca, NY) at the University of Kentucky Dairy Science program. This model serves as the extension to a pre-weaning model described in Chapter 2. The pre-weaning period is an intensive time for raising replacement heifers and therefore, described separately in the previous chapter. All heifer calves are assumed to follow the growth and cost patterns seen from heifers raised on an automatic calf feeder in group housing, fed milk replacer and allotted 8L of milk per day.

The total cost (± SD) is \$352.40 ± \$16.70 for the preweaning period. This accounts for variation in diarrhea and respiratory illness, mortality rate and weaning age.

Replacement heifer costs were separated into month sections (3-6, 7-10, 11-14, 15-60 days pre-calving) postweaning, representing common biological changes, such as weaning; and management changes, such as changing in housing, like housing heifer on pasture after breeding. Each month section was developed in a new sheet within the model. Management decisions were required for 3 main factors: housing type, ration composition, and labor utilization. The cost associated with each decision was calculated by day, therefore, within each month section a producer could allocate how many days heifers were utilizing specific resources. This structure allows for more flexibility to account for differences from one farm to the next. Housing could be one of three options: confinement, dry-lot or pasture. Rations were utilizing corn silage or pasture supplemented with grain. A visual representation of post-weaning management decision pathways for housing, feed, and labor are outlined in Figure 3.1. Based on previous decisions, only one possible option may be available. For example, if pasture is used within the heifer rearing system then the only labor option would be time assumed required to care for a heifer out on pasture.

Breeding and health related costs were calculated separately. Health costs per age group were combined with the corresponding month totals, while totals for breeding were incorporated into the final overall cost calculation. All calculated total costs per age group and management style was presented in an overview spreadsheet.

Variables related to health incidence, commodity prices, and on-farm management variables were made stochastic with @RISK simulation. Pert distributions were made with parameters set from published literature or sample farm data. A convenience sample of 12 dairy farms located in the states of Ohio and Indiana provided annual financial data to aid in the creation of assumptions. Table 3.1 outlines the key assumptions made by authors for the calculation of cost of replacement heifers from weaning to calving.

Housing

Housing costs were calculated separately for three management decisions, confinement, dry-lot and pasture. For the confinement housing scenario, a barn cost per replacement heifer was calculated. Required square meter of barn space was calculated based on the age group and number of animals from the input page. Square meter requirements per replacement heifer began at 2.8m^2 at 3-6 months and increased 0.93m^2 with each age group (Graves, 2016). The total required m^2 was multiplied by the construction cost per m^2 to calculate the barn value. Barn payments were calculated, including interest and depreciation, then broken down by total number of heifers utilizing the barn. Housing scenario dry-lot and pasture both incorporated land value as the base of housing cost. Pasture as a housing system was calculated separately than the nutritional content gained by using pasture as a feedstuff. Average acre rental rate in Kentucky was used as the assumption to value the land (Halich, 2018). Annual pasture maintained per acre was assumed at $31.50, accounting for seed, equipment, upkeep and labor. Based on the University of Massachusetts recommendation, 0.5 acres are required per 227 kg of animal and was used to determine the number of replacement heifer per acre. Daily pasture price per animal was calculated using equation 3.1. in dry-lot, 55.7 m^2 was required per replacement heifer and used to calculated required spacing. Additionally, dry-lot calculated the investment of 3.71 m^2 shade per replacement heifer, valued at \$0.13 per m^2 (Lardy et al., 2017). All housing options accounted for water consumption with water valued at \$0.00285 per gallon.

$$((\text{Annual Rental Rate per Acre} + \text{Annual Pasture Maintenance per Acre})/365 \text{ days}) / \text{Number of Animals per Acre} \quad \text{Eq.3.1}$$

Feed

Feed costs were calculated following the nutritional requirement of Holstein dairy heifers in each stage of growth following the NRC, 2001. Heifers requirements are shown in Table 2. Options for diet formulation included 2 diet types: R1, comprised of silage, forage, corn, soybean meal, and distillers grain. R2: included the utilization of pasture into the diet while supplemented with forage and corn. All rations included a mineral pre-mix and assumed heifers would consume 2.2% of their body weight in dry matter. Feed cost was calculated as the average of USDA agriculture commodity market reports from Jan 2014 to November 2018. Feed cost and rations are both inputs into the model. Therefore, in the available economic model the user can alter the model to be reflective of their farm or condition.

The three commodities outlined in Table 3.2 were made stochastic by assuming a 15% increase or decrease to create a minimum and maximum price. Distribution of the commodity prices are shown in Table 3.4 for corn, corn silage and soybeans as a result of the stochastic simulation model. Most values used for feed cost calculations were within 2 standard deviations from the mean. The mean remained the same average value set from USDA published market reports. Shrink of forage and concentrates was accounted for in the daily cost of the feed using equation 3.2. An assumption of shrink percentages was made at 10% for silage and forage feedstuff, and 3% for concentrates.

$$\text{Total Daily Cost of Individual Feedstuff} / (1 - \%\ \text{shrink}) \qquad \text{Eq. 3.2}$$

Projected body weight of replacement heifers in each month section was based off a weaning weight of 88 kg and 0.8 kg average daily gain of heifers post-weaning to follow results found in Chapter 2 of this thesis.

Labor

Labor hours required varied from confinement housing to a pasture-based system. Published surveys of producer reported time required per heifer were used in the calculation of labor cost. Equation 3.3 explains how the total labor hours (TLH) were used to determine how many minutes of labor are required per replacement heifer.

$$\text{Labor Required per replacement heifer} = \text{TLH} / \text{Total Number of days the replacement heifer was in the rearing program} \qquad \text{Eq. 3.3}$$

To determine the labor cost within each month section, the total number of days within each month period is multiplied by labor requirement (LR). The resulting variable is the total number of minutes of labor required per heifer within each month section (TLR). Equation 3.4 represents the final step in calculating the cost of labor per heifer (Lowe et al., 2016). Hourly cost associated with more than one employee working on heifers at a time was calculated into the cost.

$$LC = TLR * \text{Number of Employees} * \text{Employee Hourly Wage} \qquad \text{Eq. 3.4}$$

Pasture based scenarios followed the same labor calculations outlined above. An assumption was made based on lack of published literature for TLH required per heifer in a pasture-based scenario. 1:02 minutes was assumed for labor required per heifer, this is broken down from the 3 hours of labor requirements per day to care for 175 heifers. The model allows for labor to be provided minutes per replacement heifer or total labor hours per day and then divide it down to get a per replacement heifer cost.

Health

An external sheet is included in the model to calculate health costs by age group. A standard vaccine protocol was used as the assumed costs. Health related expenses for pre-weaned calves was included in the assumed pre-weaned replacement heifer cost used in all scenarios. Table 3.5 outlines the vaccines and treatments provided to each age group and subsequently included in the overall cost. Labor requirement for working replacement heifers to provide these injections and treatments through working facilities was accounted for by an additional $0.20 per dose (Lima et al., 2010). The sum of these expenses resulted in a health cost per age group.

Breeding

Variation of synch protocols, visual heat detection or a combination of both, were incorporated to account for difference preferences in breeding protocols. After 6 possible breeding cycles, 7% percent of heifers were assumed to be culled because of unsuccessful breeding. In this situation, Equation 3.5 was used to determine the additional cost incurred by the remaining heifers on the operation. This accounts for the cost of raising heifers that did not complete the heifer raising program.

$$\text{(Value of Newborn Heifer + (Total Cost at 13 months – Springer Heifer Value) * \% Culled)/ Remaining Heifers} \qquad \text{Eq. 3.5}$$

Heat detection and conception rate were used to determine the number of heifers culled because of breeding performance. In the model 176 heifers were in the age group to be bred and considered “at risk”. The number inseminated was a function of how many heifers at risk were detected to be in heat. The number of pregnant heifers was a result of inseminated heifers multiplied by the conception rate. The difference in at risk and pregnant heifers were considered open. This open population would become the “at risk” heifers in the following cycles. Our model allowed for a heifer to complete 6 cycles before she was culled. Services per pregnancy was the sum of all inseminations, divided by the total number of pregnancies. The number of heifers within each group was dependent on how many heifers were culled in the breeding tab.

RESULTS

The mean total cost (min,max) for a producer to raise a replacement heifer from birth to calving, assuming the same pre-weaning strategy of group housing with an automatic calf feeder, was found to be $1,919.02 ($1,777.25, $2,100.57), $1,593.57 ($1,490.30, $1,737.26) and $1,335.84 ($1,266.69, $1,423.94) for confinement, dry-lots and pasture, respectively. These averages follow the trend of previously published literature, resulting in average values within 1 standard deviation of presented averages (Karszes, 2008, Heinrichs et al., 2013, Akins et al., 2017, Boulton et al., 2017a). Contribution of feed, labor, housing, and fixed and variable costs are reported in Figure 3.2. The two largest contributing variables to the total cost was feed and labor expenses in all management situations, always representing at least 60% of the total cost.

Housing

Total housing cost per replacement heifer was $423.05, $117.96, and $207.96 for confinement, dry-lot and pasture management systems. When compared to total cost, housing contributed 21% for confinement, 7% for dry-lot, and 15% for pasture. When the sum of variables reported in published surveys is calculated to match the variables presented in our housing section, the average producer reported housing costs at $280. This represented 18% of total allocated cost (Akins et al., 2017). Most published surveys are not shown divided by housing management system, which may explain the largest cost represented in confinement. Housing cost was the highest for confinement housing because of the additional cost of barn infrastructure. Monthly barn payments per replacement heifer, accounting for interest and depreciation, was $4.81. This model assumes the payments on the barn, therefore calculated costs may be higher than seen on expended at the farm. The main contributor for the pasture-based scenario was the value of the land the replacement heifers were occupying and the associated opportunity cost. With current assumptions replacement heifers were costing producers $0.06 per day or $1.80 per month for the land as a housing system, excluding additional value of land as a feed source. Because of the nature of dry-lot housing, more heifers could occupy the same acre in comparison to pasture, reducing the land cost per replacement heifer.

Feed

Feed cost is dependent on input for price per ton and allotment of feed. Total feed cost, under current assumptions, was $932.14, $932.14, and $702.17 for confinement, dry-lot, and pasture. Confinement and dry-lot scenarios have the same feed cost because both situations are reliant on delivered feed including a silage ration. As a percentage of the total cost, feed cost contributed 47%, 57%, and 51% for confinement, dry-lot and pasture scenarios respectively. Feed cost is consistently the largest expense on farm in published replacement heifer raising cost, ranging from 51 to over 70% (Karszes, 2008, Heinrichs et al., 2013). Percentage of feed cost is higher for dry-lots and pastures partly due to the lower total cost and reduced emphasis on infrastructure found in the housing cost of confinement. This relationship is important when analyzing replacement heifer costs on farm, because we can assume when comparing percentages of the total cost, confinement will have a lower total percentage of cost in comparison to a pasture setting.

Labor

Labor was broken down by paid hourly employees and hourly management employees, but labor is reported as the sum of these two expenses. The mean labor expense for confinement, dry-lot, and pasture was $932.14, $932.14, $702.17, respectively. As observed in feed cost, the labor for confinement and dry-lot scenarios are considered the same due to similar time and skill requirements. Labor accounted for 20, 24, and 19% of the total cost in confinement, dry-lot, and pasture housing scenarios. Labor accounted on average 18.2% of the total cost of Wisconsin producers, just below our calculated percentages (Akins, 2016).

A perceived challenge with this input, is determining the time strictly used for caring for replacement heifers. Especially on farms where labor is not hired specifically for the post weaning replacement heifer period. Laborer's may split time between feeding and care of replacement heifers and the milking herd. In addition, creating a true assumption for the relationship of hourly paid employees and management requirements. We have assumed 10% of the hourly labor was equivalent to the management labor required. In some situations, management may be varied from this assumption.

Breeding

Heat detection varied based on management decisions and set reproductive performance. Cost to sync one replacement heifer, utilizing CIDR technology, for breeding was an investment of $19.60 per heifer. Incorporating visual observation into the breeding protocol added an additional cost of $4.68 per replacement heifer. Therefore, heat detection programs utilizing both visual observation and a sync program totaled $24.28.

The assumed base reproductive performance was 65% heat detection rate and 55% conception rate. Following the herd model of 1000 heifers annually, 84 replacement heifers would be in the initial "at risk" group of pregnancy. Under our base assumptions after 6 cycles, 7% of the replacement heifers, or 6 heifers, would be culled based on reproductive reasons. The cost accrued before breeding for confinement, dry-lot, and pasture management decisions is $1,197.85, $1,063.32, and $927.77. When distributed over the remaining heifers, an additional $8.38, $6.65, $5.13 per replacement heifer for confinement, dry-lot and pasture housing systems.

Total cost for breeding with a sync protocol and visual heat detection, accounting for additional expenses due to reproductive culls, was $66.95. This accounted for 3.4, 4.2, and 5.0% for confinement, dry-lot and pasture based management scenarios. If only visual heat detection was utilized, percentage of the total cost decreased to 2.2, 2.6, and 3.2% of each management scenario.

Total Cost

Total replacement heifer raising cost ranges from $1,266 to $2,100 per head. The lowest cost was a result of pasture management decisions, with total cost increasing as infrastructure increased. This model assumed average daily gain constant between management scenarios causing age at first calving to also remain consistent. Average daily gain in pasture-based scenarios may experience slower gains of heifers, increasing the rearing period and increasing the presented total costs.

When analyzing replacement heifer cost as an enterprise on the dairy operation on an annual basis, the number of replacement heifers raised can have a large impact on total cost. When the current assumption of the number of replacement heifers raised on farm was reduced by 5%, (500 heifers annually reduced to 475 replacement heifers), the cost per replacement heifer increased by $85.54, $67.75, $61.89 per heifer for confinement, dry-lot and pasture. Even though the cost per heifer increased the total annual investment in replacement heifers decreased by $7,109, $5,873, and $1,078 annually for each of the respective management scenarios. These results are larger in variation than the conclusions made by (Tozer and Heinrichs, 2001), valuing a 1% decrease in cull rate of the milking herd having the potential to decrease overall replacement heifer cost by $1,000 to $1,500. In addition, out results follow a similar trend found in (Mohd Nor et al., 2015b) where a 5% decrease in cull rate has the potential to decrease replacement heifers costs by $6,500 annually. While heifer raising is often considered a separate enterprise from the dairy herd, management decisions have a large influence on the entire operation.

CONCLUSIONS

Upon analysis of all scenarios, utilizing pasture to raise heifers resulted in a lower overall cost when compared to confinement housing options. Percentage breakdowns of feed, labor, housing, fixed and variable cost provided more information on efficiency rather than total cost. As with all research, the model and results presented are dependent of inputs and assumptions made by the authors. Actual costs calculated may result in higher or lower totals when individual farms utilize the program. The authors determined the model to be highly effective in calculating the cost of raising heifers on an individual farm.

This cost analysis is critical to assist farms in making decisions in utilization of their resources to raise or purchase replacement dairy heifers.

Figure 3.1 Possible management decision options for producers to raise heifers post-weaning.

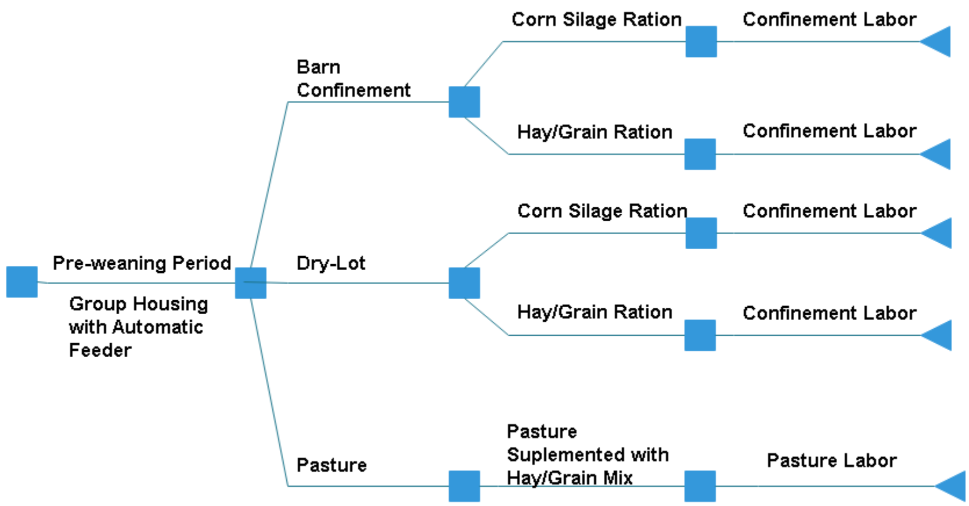


Table 3.1 Key assumptions presented in the model to determine the cost to raise a replacement dairy heifer from weaning to calving. Values were found in published literature, extension surveys, and USDA market reports.

Variable	**Value**	**Source**
Number of Heifers Raised Annually	1000	
Hourly Employee Labor	\$14.00	Based on National Dairy Labor Survey, 2014
Hourly Management Labor	\$22.00	Based on National Dairy Labor Survey, 2014
Interest Rate	7%	
Construction per M^2 Frame	\$13.00	(Adkins, 2017)
Weaning Age	65 days	(Adkins, 2017)
Value of newborn calf	\$100.00	Based on USDA market reports
Whole milk value (cwt)	\$15.00	Based on (USDA, 2017)
Milk replacer value (22.7 kg)	\$65.00	Based on average market price
Manure Management (\$/head/month)	\$0.90	(Adkins, 2017)
Pasture Rental Rate (Improved Pasture)	\$40.00	(Halich, 2018)

Table 3.2 Assumed commodity prices based on USDA monthly reports from January 2014 to November 2018 for corn and soybeans. Corn silage was valued based on corn commodity price.

Variable	**Value**	**Source**
Corn Silage ($/ton)	$36.26	10x Average USDA Corn Price ’14-’18
Corn ($/ton)	$130.00	USDA Market Averages ’14-’18
Soybean Meal ($/ton)	$333.00	USDA Market Averages ’14-’18

Table 3.3 Projected weight and nutritional requirements for dairy heifers.

Month Age Groups	Projected Wt.* (kg)	DMI (kg/d)	ME (Mcal/d)	CP %
3-6	148	4.2	9.6	15.9
7-10	245	6.2	14.1	13.1
11-14	340	7.9	18.2	11.7
15-Calving	544	12.2	27.5	13.3

*Diets were balanced for NRC provided weight requirements which most closely matched projected weights. 150, 250, 350 kg respectively.

Table 3.4 The distribution, mean, SD, minimum and maximum of commodity prices per ton used to calculate feed cost of dairy heifers post-calving. Values were developed using the @RISK.

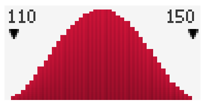
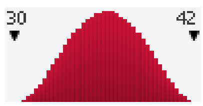
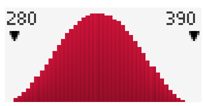
	Distribution	Mean	SD	Minimum	Maximum
Corn		$130.00	$7.37	$111.35	$148.91
Corn Silage		$36.26	$2.06	$30.96	$41.54
Soybean Meal		$333.00	$18.88	$284.80	$381.85

Table 3.5: Outline of the health protocol followed by the authors to create health related expenses for each age group of heifers.

	Age Group			
Health Description	3-6 Months	7-10 Months	11-14 Months	15-Calving
Dewormer	X	X	X	X
Fly Treatment	X	X	X	X
Respiratory Vaccine	X			X
Leptospirosis Vaccine	X	X	X	
7-Way Vaccine	X	X	X	X
E. Coli Vaccine				X
Brucellosis Vaccine	X			
Staphylococcus Aureus Vaccine				X
Vitamin A&D				X
Total Cost	$11.60	$6.03	$6.37	$8.10

Table 3.6 Three main housing scenarios were evaluated incorporating the variation represented through stochastic variables. The distribution of total cost, mean, SD, minimum and maximum are shown for each of the housing types selected.

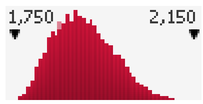
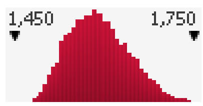
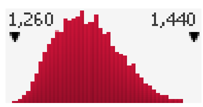
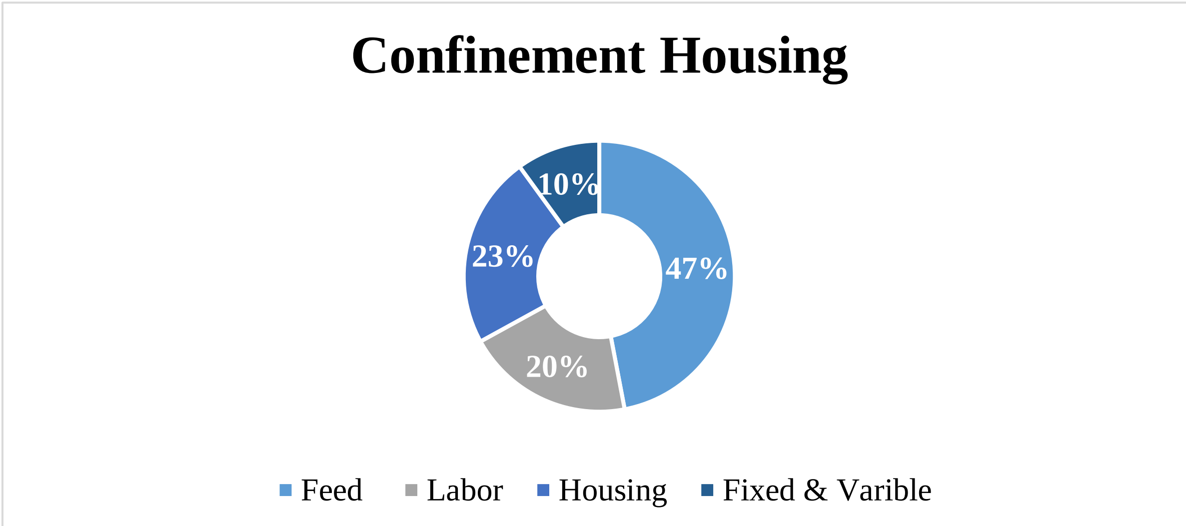
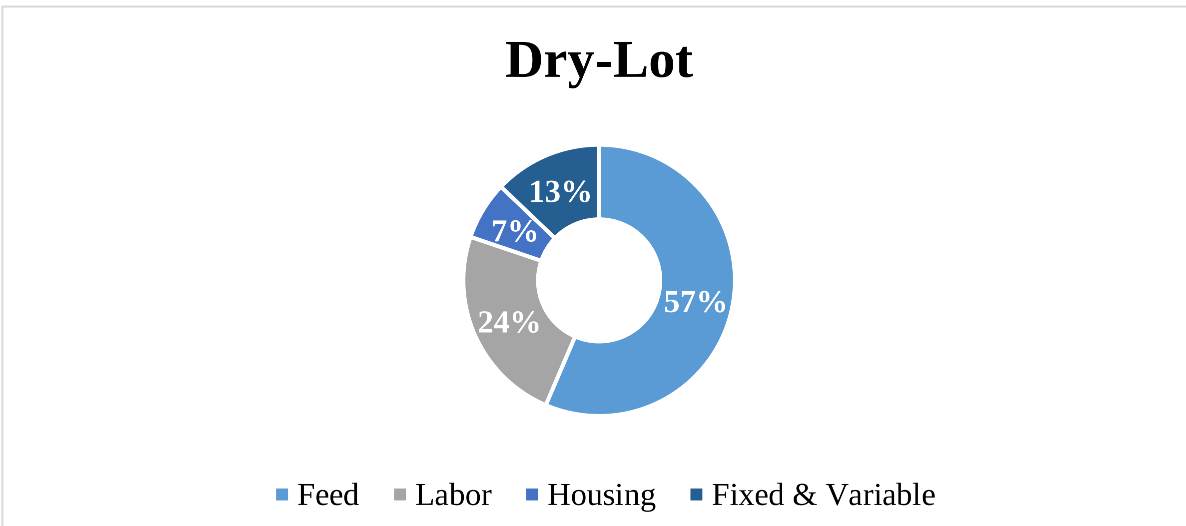
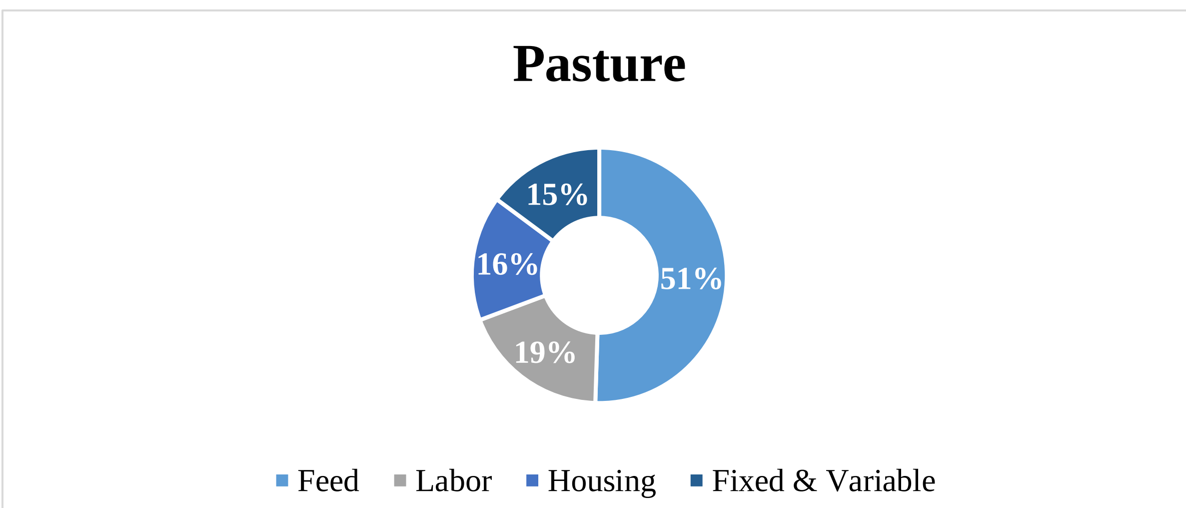
	Distribution	Mean	SD	Minimum	Maximum
Confinement		$1,910.02	$58.78	$1,777.25	$2,100.57
Dry-Lot		$1,593.57	$44.09	$1,490.30	$1,737.26
Pasture		$1,335.84	$28.78	$1,266.69	$1,423.94

Figure 3.2 Percentage breakdown of the contribution of housing, feed, labor, and fixed and variable costs in the total replacement heifer rearing period for confinement, dry-lots and pasture.







CHAPTER 4: OVERALL RESULTS AND CONCLUSIONS

SUMMARY OF RESULTS

The cost to raise replacement heifers vary greatly and is heavily dependent on feed, housing, labor and health management decisions. Pre-weaned and weaned replacement heifers can be the two broad categories to categorize costs and management scenarios. Pre-weaning replacement heifer raising cost ranged in cost from $268 to $409. Milk source and allotment has a large impact on overall cost. An intensified feeding system can increase daily feeding cost, but cost per kg of gain had a negative relationship with ADG. Cost for the total replacement heifer cost per head ranged from $1,266 to $2,100 under our current assumptions. Feed was the largest contributor to overall cost, followed by labor then housing. The utilization of quality pasture can decrease overall cost as well as decreasing the number of replacement heifers raised and cull rates of the milking herd.

Models are a product of their inputs and therefore our results are dependent on assumptions made based on published literature, surveys and industry knowledge. Heifer raising cost is a measure made with variables that are likely to change from one operation to the next, making it imperative that producers individually calculate cost. A input sheet was constructed to allow for ease in changing key variables throughout the model. With the intention of this model to be used as a resource for producers to calculate their own replacement heifer cost on-farm.

FUTURE RESEACH

Future research should be developed to determine economic links from management decisions pre-calving, specifically in the pre-weaning period, to economic benefit when heifers enter the milking herd. The pre-weaning period represents the largest economic investment per day, therefore increasing the importance of return on investment.

While large surveys require a large number of resources to conduct and buy in from producers to collect large amounts of on farm data, the information provided from such surveys are critical in creating economic models. They provide valuable insight to trends in productions from one survey to the next and a better understanding of what is happening on farm. Many surveys presented in this thesis are representative of a small area of region, which may not always be an accurate representation of the whole industry.

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