Economic Feasibility of Incorporating Pea Coproducts in a Manitoba Cow-Calf Operation

By

Courtney Kowk

A Thesis submitted to the Faculty of Graduate Studies

of the University of Manitoba

in partial fulfillment of the requirements of the degree of

MASTER OF SCIENCE

Department of Agribusiness and Agricultural Economics
University of Manitoba
Winnipeg, MB

Abstract

Low-cost feeds that fulfill the nutritional needs of cattle are critical to the profitability of livestock operations. Feed, accounting for 50-60% of total production costs, is the primary expense associated with most livestock operations. Byproducts can be an inexpensive addition to livestock feeds, often possessing nutritional value comparable to the original feed source. The Roquette Pea Protein plant in Portage La Prairie, Manitoba produces 500 tons of pea protein per day, generating three different byproducts with potential for incorporation into cattle diets: pea hulls, pea cream and pea screenings.

This research developed and evaluated six different over-winter cow-calf feeding systems incorporating pea screenings. The objectives of this research were to: (1) compare the quantity of pea screenings or barley needed to meet the energy requirements of a 1300lb cow in the third trimester of pregnancy, feeding grass legume hay, grass, or straw-based diets during the 90 day over-winter period; (2) compare the cost of the three forage-based rations when supplemented with either barley or pea screenings; and (3) determine the price at which rations containing pea screenings are equivalent in cost to (i.e. break-even with) the three conventional barley-based rations.

Price data on the traditional feed ingredients were approximate ten-year averages while pea screenings price was assumed to be 75% of the long-term average price for field peas. All six rations were nutritionally balanced by the Beef Cattle Nutrient Requirements Model 2016 (NRC 2016). Results demonstrate that pea screenings are slightly lower in TDN than barley (80% vs 84%) and can be incorporated as an energy supplement at a slightly higher inclusion rate in Manitoba cow-calf winter rations during the third trimester of pregnancy. Breakeven analysis revealed nine separate pea screening prices where the cost of each alternative ration was comparable with each conventional ration. Findings further suggest that pea screenings price may need to decrease from $176.46/ton to as low as $58.17/ton to incentivize cow-calf producers currently feeding a ration of barley straw supplemented with barley grain to switch to a ration of grass legume hay supplemented with pea screenings.

Acknowledgments

The past two years have gone by in a blink of an eye and with my M.Sc. degree near completion I am left reflecting on those who have helped me along the way. I am so thankful for everything this experience has brought me and I could not have done it without all the support I received along the way.

I would first like to thank my advisor Dr. Jared Carlberg for his ongoing encouragement, guidance, weekly chats, and the laughs shared over the past two years. Thank you Jared for everything you've taught me and for making my experience in the graduate program such a positive one.

I would also like to thank the rest of my committee members, Dr. Jon Biermacher, Dr. Kim Ominski, and Dr. Karin Wittenberg. Dr. Biermacher, you were always a phone call away answering questions, offering advice, and ensuring I stayed on track with my writing, even during your holidays. You have taught me so much about economics and these are skills I know I will use throughout my life. I am so grateful to have been able to work on this project with you. Thank you Dr. Ominski for the time spent working with me on the animal science portion of this research and teaching me skills which fall outside of my degree speciality. You have helped shape me into a well-rounded graduate student. Thank you Dr.Wittenberg, for sharing your wisdom and feedback. Your contributions and input were invaluable to me.

I would also like to thank Genet Mengistu for the help and guidance developing the cattle rations used in this research.

Thank you to my parents Greg and Liane for your love and support throughout my academic endeavors even though each new endeavor I tackle pushes Dad further away from retirement. A special thanks to my mom for proofreading my work for the abundance of grammar errors on car rides home from the lake.

A shout out to my farmer friend Jean Le Heiget (Jeanie) for his practical farm wisdom that a “vegetarian city girl” couldn’t possibly have known on her own.

Lastly, I’d like to thank my faithful furry friends Sully, Arthur, and Phoebe for keeping me from going insane while I spent long hours stuck at home during the COVID 19 isolation periods.

Table of Contents

List of Tables

List of Figures

Chapter 1 Background

1.1 Definition of Food Loss and Food Waste

With its negative environmental, social, and economic consequences, food waste is a global concern with as much as one-third of all edible food across the supply chain wasted (Rezaei 2017). This is equal to 1.3 billion tons of food that is lost/wasted each year; enough to feed more than one billion people (Dou et al. 2018). Food does not reach the consumer's kitchen for a variety of reasons, including unpredictable weather, damage during storage and transportation, processing problems and unstable markets, to name a few. When it reaches the consumer level, waste occurs through overly large portion sizes at restaurants, overbuying at grocery stores, and hesitation about eating foods near or past their "best before" dates (Foodprint 2022).

Wasted food can be conceptualized as consisting of two main types: *food loss* and *food waste*. The term food *loss* is used to describe food that has been spoiled, damaged, or has failed to meet human consumption requirements during the earlier stages of the supply chain and requires disposal before it reaches the retail level (Lipinski 2013). This loss can occur during the production, post-harvest, and processing stages (Ominski et al. 2021) – for example an apple bruised in transport or a potato that is too small to meet the acceptable cosmetic standards. The term food *waste*, by contrast, is typically used to describe food that is available but not consumed at the food service, retail, and consumer levels of the supply chain (Ominski et al. 2021) – e.g., foods that are close to, at or beyond their "best-before" date are often discarded by retailers and consumers.

Food *byproducts* are most commonly associated with food loss but often have market value as the result of an alternative use with economic benefits. They include a wide range of feedstuffs (e.g., grain screenings, cull potatoes, malt barley) and are obtained as a result of processing of the primary commodity (Tiwari and Kwahas 2021). For example, molasses, a syrup commonly used in baking, is a byproduct of sugar refining. Some commodity processing facilities may choose to refer to these alternative-use products as “coproducts” as they are considered to contribute significant economic benefits to the overall enterprise.

1.2 Food Loss and Waste During Production and Consumption

Most food consumers report they are aware that food waste is a global issue, but there still appears to be a disconnect between recognizing the importance of this issue and understanding that there are relatively straightforward ways to mitigate food waste. Households are responsible for the largest portion of all food waste, as approximately 40 to 50 percent of food waste happens at the consumer level (Foodprint 2022). In a 2016 survey of 6,700 adults, 75% of respondents reported that food waste is important or very important to them, yet the data are insufficient to determine whether this concern has influenced any action or whether or not people are actually wasting less food now than in the past (Foodprint 2022). Another study by Moreno and Hoover (2017) found that over half of survey respondents indicated that they regularly engage in strategies to waste less food such as freezing or eating leftovers and agreed that it is important to not overindulge which can lead to food waste. Despite these views, the majority also preferred fruits and vegetables with no blemishes, and nearly half felt less guilty about wasting food that has been in the refrigerator for a long time (Moreno and Hoover 2017). The author also reported that 76% of survey respondents indicated they believe they throw out less food than the average person – which, of course, cannot be true. The studies suggest that while people generally acknowledge that there is a global food waste problem, they do not believe they are the cause of it. Projecting blame onto other consumers, businesses, or farms removes personal responsibility resulting in the perception that control to change their circumstances does not exist.

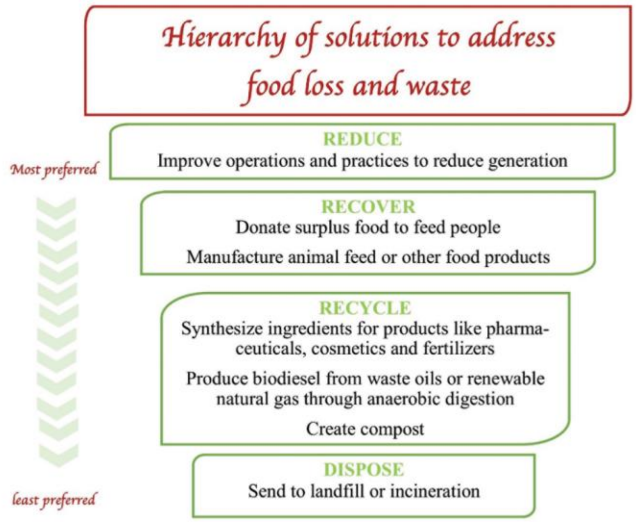
While most *waste* takes place at the consumer and retail level, food *loss* is an issue well before it reaches the consumer's realm. As previously mentioned, food loss occurs in the early stages of the supply chain such as on-farm, at produce packing houses and within processing facilities, and occurs for a variety of reasons. Some types of perishable products (e.g., fruits and vegetables) may not be harvested because of damage by weather, pests, and disease, and market conditions (decreases in prices, market volatility etc.; Foodprint 2022). Therefore, producers may plant more than market demand to hedge against these factors, leaving a surplus if crops are plentiful. One extreme example of unharvested food causing waste is the Bowles Farming Company, which in 2018 left over 100 acres of ripe cantaloupes unharvested and which were then plowed back into the ground, because the company could not justify paying workers to pick the fruit due to the cost of labour, packing, and shipping that would have been more than the price they would receive for the fruit (Wozniacka 2019).

While troubling, it may be necessary for farmers, whose goal is to make a profit, to leave food unharvested in the field. In 2018, a survey from Santa Clara University showed that more than one-third (33.7%) of edible produce (a variety of fruits and vegetables such as watermelon, cabbage, strawberries, and kale) in 123 fields on mid to large size farms in California were left unharvested as market prices were too low to justify harvesting (Wozniacka 2019). Food loss varied depending on the crop and type of produce, with romaine hearts had the highest recorded loss at 113% (Wozniacka 2019).

1.3 Solutions to Address Food Loss and Waste

As previously stated, the global problem of food loss and waste exists throughout all stages of the supply chain. The recovery of food products typically seen as waste to humans and subsequently discarded, has the potential to provide an important source of feed for livestock. Utilizing byproducts and re-directing food loss is listed as the second option to lessen food loss on the “hierarchy of recovery” which prioritizes solutions to address food loss and waste (ECCC 2019; Figure 1.1).

Figure 1.1 Hierarchy of solutions to address food loss and waste



Source: ECCC (2019).

Livestock have the ability to “up-cycle” foods that are inedible by humans or for other reasons no longer wanted into a valuable resource. In other words, they can obtain nutrients from discarded human food and use them in livestock diets to produce animal-based products such as meat and milk. Food loss and waste is used in both monogastrics and ruminants, however, organisms in the rumen of cattle have the unique ability to effectively break down fiber in plant byproducts that is indigestible to humans and convert it to energy (Dou et al 2017). Unlike humans, cattle have the capacity to convert low quality plant proteins into high quality protein. Further, they are also able to utilize some mycotoxin-contaminated feed (i.e., vomitoxin) that monogastrics are sensitive to (Talcott 2013).

Incorporating these human-inedible ingredients into livestock rations simultaneously spares the use of typical feed grains as well as lessen the environmental burden of sending waste to landfill. Scientific and field-based studies have suggested that food waste and byproducts, when partially incorporated into the diet of cattle, have proven to be of high quality and are safe to use for animal feeding (Dou et al 2017). It has been reported that digested food waste may provide nutrients on a dry matter basis that are close to the nutrient content in a typical grain-based diet (BCRC 2020). One example of this is the production of unusable malt barley in Canada; seventy-five percent of malt barley fails to meet the necessary standards for beer-making due to sprouting damage or low protein content (Ribeiro and McAllister 2016). This rejected portion, though not preferred for human consumption, is subsequently used as livestock feed.

Considering a solution to reducing food waste has become increasingly relevant due in part to the effects of Covid-19 which have upset food supply chains, disrupted shipping, and resulted in an increased number of sick employees, who are critical in keeping the supply chain in motion (OECD 2020). At the same time, feed prices have been rising due to adverse weather and low yields leading to shrinking world harvests, along with the impact of China (the biggest buyer of commodities), which is now acquiring large amounts of feed to meet the needs of its expanding hog numbers (Bloomberg 2021). Cattle farmers, as well as those raising pigs and poultry, have experienced the highest corn and soybean prices in seven years in the U.S, which has increased the cost of feeding herds by 30% or more (Durisin et al 2022).

1.4 Potential Use of Pea Coproducts in Livestock Diets

Recently, the world's largest pea manufacturing plant (Roquette Pea Protein, Inc., hereafter referred to as "Roquette") was built in Portage La Prairie, Manitoba (-98.291170, 49.974390). The plant has the ability to supply pea protein products nationally and internationally (when operating at full capacity, it can produce 500 tons of pea protein per day) by processing yellow peas (*Lathyrus aphaca*) into powdered fibres, protein, and starch products which have applications in pharmaceutical, human nutrition, and food manufacturing industries (Verdict Media Limited 2022). Through this production process, a number of coproducts, are also produced, including pea screenings, pea hulls, and liquid pea cream. Though they are not used in the production of food products for human consumption, pea "screenings" (made up of broken kernels, hulls, chaff, and other residue) can be fed to cattle in the form of pellets, or alternatively loose screenings added to a feed ration. These pea coproducts may be a new feedstuff that can be used while potentially reducing costs associated with winter feed rations for their livestock.

Pea protein is created by separating different constituents of the pea by simple processes such as washing, drying, grinding, and sieving. One of the reasons for this is to remove a type of carbohydrate called oligosaccharides which is present in the seeds of peas. Although difficult for humans to digest, swine and cattle are not as sensitive to oligosaccharides (Roquette 2022) so a liquid coproduct "pea cream" which contains this carbohydrate, was developed to serve as a liquid animal feed. Due to Canada's cold winter climate, pea cream requires holding tanks in an insulated storage facility to guard against freezing, which is an investment many producers will need to make if they plan to incorporate pea cream into their diet ration. Roquette operates 24 hours per day, 7 days a week year-round making dairy, feedlot, and swine producers the preferred customers of pea cream since they are able to utilize this coproduct on a year-round basis.

Cow-calf operations are less likely to utilize pea coproducts on a year-round basis as cows typically graze perennial forage during the summer months, with no supplement provided. All pea coproducts may be utilized in the backgrounding and finishing phases of the beef industry where significant levels of energy are required. In these settings, pea coproducts could offer an economic advantage compared to conventional rations comprised of grain and oilseed meals (Delporte 2022). For cow-calf producers wishing to supplement winter rations with pea byproducts, use of pea cream may be more limited than screenings or hulls as it is typically fed in a total mixed ration (TMR). This is an effective strategy to ensure that all diet ingredients are consumed in the formulated proportions. Though effective, indoor or heated facilities are required in order to properly store the pea cream, which can be costly to build. Delporte (2022) asserts that combining a home-grown fibre product and mixing it with pea cream to make a silage would be ideal for these producers, but for many Manitoban cow-calf producers, they do not possess the infrastructure necessary for silage-based rations and therefore opt for a hay-based diet. An alternative for producers who do not have the necessary infrastructure to make silage or to store pea cream, would be to use the pea screenings which are a good source of protein, (CP = 22.7%) and energy (TDN= 80% DM basis; Roquette 2021). Pea screenings can be fed to cattle on the ground, from a raised trough or bunk in the form of pellets or alternatively, producers who have the proper infrastructure can mix loose screenings into a feed ration. Delporte (2022) believes using locally produced pea screenings on Manitoba cow-calf farms has the potential to offset the use of feed barley, freeing up land to be used for other commodities. Feed companies will likely be the primary buyer of pea screenings (Delporte 2022) from Roquette and therefore the primary supplier of pea screenings and pellets to cow-calf producers.

Research conducted in the mid-1990s at the University of Saskatchewan on grain screenings showed that in order to realize full feeding value, the refuse screenings needed to be processed (ground and pelleted) prior to feeding (McKinnon 2015). This is due to a significant amount of the energy in grain screening pellets that is derived from the oil content of weed seeds, which, if not processed, simply passes through the animal undigested (McKinnon 2015). However, processing the pellets prior to distribution may increase the cost of this and other byproducts including pea screenings. Pea screenings tend to be comprised of broken peas with a considerable amount of “pea powder” and therefore pelleting may improve palatability but may also increase cost. From the perspective of a cow-calf operator, screening pellets are a good fit for wintering beef cows as they will help meet energy and protein requirements when fed with a medium-to good-quality forage. In some cases, additional supplements are added to the pellets ensure a guaranteed minimum concentrations of nutrients. This approach serves to mitigate some of the inherent nutrient variability (Lardy et al 2018) that is associated with by-product feedstuffs.

Chapter 2 Literature Review

This chapter explores an array of studies detailing how byproducts and food waste have historically been incorporated to animal diets. Though the current research focuses on pea screenings fed to beef cattle in Manitoba, this literature review starts by exploring Sugiura et al (2009), who provide a global geographical perspective of how food waste is incorporated into cattle diets in other parts of the world. The review focuses on North America where some pertinent information can be found in Westendorf (2000) with the focus being on the seventh chapter "The Economics of Feeding Processed Food Waste to Swine" and the tenth chapter "Sweetpotatoes and Associated Byproducts as Feeds for Beef Cattle." In addition, several studies (Dou et al. 2018, Soto-Navarro et al. 2012 and Anderson 2002) address the feasibility and palatability of feeding field peas to beef cattle. They also highlight some of the limitations and challenges that are associated with this feed type.

Japan is one of several Asian countries that has successfully used food waste to produce "Ecofeed", an animal feed made from recycled food waste (Sugiura et al 2009). In Canada, inclusion of byproducts and food waste in animal diets is limited by regulatory policies as feedstuffs must be included in the Feeds Act governed by the Canadian Food Inspection Agency (CFIA) (Ominski et al 2021). Sugiura et al (2009) note the livestock industry is one of the most important agricultural sectors in Japan, representing 28.5% of total agricultural output. In Japan, a large amount of food waste is produced in the food processing and catering industries, most of which was incinerated or buried without being recycled. To promote the production of feed manufactured from recycled waste, a group comprised of participants from government, agricultural organizations and scientists set a goal to improve self-sufficiency of compound feed (a mixture of raw materials and supplements fed to the livestock, sourced from either plant, animal, organic or inorganic substances, or industrial processing) and to lower livestock production costs. As a result, Ecofeed was developed, which is made from byproducts from the food processing industry, surplus food which was not used during processing, and cooking waste, scraps, and leftovers from catering industry or households (Sugiura et al 2009). Whether or not this food waste can be used as raw materials for Ecofeed depends on the stability of supply, quality, and nutritional values; otherwise, the food waste is ensiled or dried to enhance preservation before being used as feed.

Although Ecofeed has the ability to lower feed costs, the shelf life of Ecofeed is quite short due to the high moisture and quick deterioration. Another issue associated with Ecofeed is the unpredictability of the available food waste used as feed materials, leading to inconsistency in the nutritional value of the feed produced. Nevertheless, it is evident that some countries are addressing the food waste challenge using creative ideas such as Ecofeed, and they have successfully recycled food waste for feed at relatively low cost (Sugiura et al 2009).

Spinelli and Corso (2000) have considered the multiple factors that affect the feeding of processed food waste (PFW) to swine in the United States which are highlighted in Figure 2.1.

Figure 2.1 Factors affecting processed food waste (PFW) feeding to swine in the United States

Farm-level Demand	Farm-level Supply
Lower relative feeding efficiency	Inadequate availability of PFW
Lengthens time on feed/in bldgs	Seasonally
Requires add'l feed additives	Regionally
Producer reluctance	Quality inconsistency
Feed handling	Nutritional value/food safety
Farm prod. practices, i.e. cropping patterns	Concerns for the potential of animal disease/public health disease
Price discounts	
Penalty on price of fat hogs	
Affecting Both Demand and Supply of PFW	
Restrictive federal and state regulations affect both farm-level demand and supply of PFW	
High boiling temperatures/times may discourage innovation.	

Source: Spinelli and Corso (2000)

The analysis showed that while current feeding operations differ in the cost of acquiring and using food waste (leaving them with limited but positive profitability), most of the net benefits accrue to society. This apparently small net gain to producers as a result of lower feed costs, plus its current inconveniences such as collection and/or processing, help explain its limited interest in most areas of the United States (Spinelli and Corso 2000). Today, as the society strives to sustainably feed the growing population while mitigating environmental damages, there is a renewed interest in reinvigorating the practice (Dou et al 2018). For example, food waste repurposing to animal feed is identified as one of the food waste recycling solutions in the U.S. (ReFED, 2016). Back in 2000, Spinelli and Corso (2000) predicted that the emergence of mega-scale food processors, along with advances in new food-waste processing technologies such as a dehydrated PFW product with increased storage capacity, would increase interest in feeding food waste.

The handling of processed food waste often requires the movement of slurry-like and semi-solid food material from their source(s) to livestock operations. Special equipment such as metal containers for hauling, storing and feeding is required, as is additional equipment for cooking in some cases. Several large-scale swine operations have fairly sophisticated equipment, ranging from specially outfitted cement mixer-type vehicles for pickup, mixing, and cooking. This equipment must be considered specific to the PFW-feeding operation and its cost should be compared to conventional feeding apparatus (Spinelli and Corso 2000). However, much of the same equipment, particularly the transport equipment, would be in service if this same food waste is collected and sent to a landfill. The authors claim that many processed food waste operators travel further and have high pick-up costs, but at the time of this study, no data could be found to support this. Since this study was published in 2000, some of the methods and techniques are perhaps outdated. In a more recent study, Dou et al (2018) stated that food waste collection from diffuse sources at the consumption stage would be similar whether it is for feed-making or composting or anaerobic digestion. An example of this is Rutgers University who pays a pig farmer $30/ton of food waste hauled from the campus dining services instead of the $60 landfill fee the university would have to pay otherwise (Dou et al 2018). GIS-based digital mapping, coupled with the application of advanced logistics tools, can help develop optimal scenarios for food waste collection, transport, and handling (Dou et al 2018).

Another inefficiency discussed by Spinelli and Corso (2000) is the revenue foregone by the producer by housing food waste-fed hogs longer than necessary. The authors discovered most relevant research found that feeding processed food waste requires hogs to be on feed for an additional two months compared to hogs fed a conventional feed ration. The same literature showed that most processed food waste must be priced at least one-half the cost of conventional feed to remain competitive on a feeding value basis (Spinelli and Corso 2000). More recently, a review by Dou et al. (2018) has demonstrated that when fed formulated rations, livestock fed diets containing food loss and waste can achieve comparable gains to those conventional diets.

Though challenges exist, the literature reveals there are cases where it makes good economic sense to feed processed food waste to livestock. There are many current situations where swine that are fed processed food waste are well cared for, receive nutritionally sound diets comparable to conventional hog feeds, and produce a safe pork product while reducing the amount of food waste being sent to local landfills (Spinelli and Corso 2000). Dou et al (2018) further confirms that consumption-stage food waste is rich in major nutrients for nourishing swine and other livestock animals. Contemporary treatment technologies can convert food waste materials into feed products that are easy to handle and safe to use for animal feeding. Such feeds derived from food waste can replace some of the grains in conventional diets with potential benefits of resource conservation (Dou et al 2018). This success implies that processed food waste-feeding operations can be profitable while conforming to good agricultural production practices.

Poore et al (2000) has described a scenario in which cull sweet potatoes and their related byproducts are used as an alternative feedstuffs for beef cattle to assist producers in lowering feed costs. Like many other commodities, disposal of cull sweetpotatoes does not present a problem until the supply greatly exceeds the demand, making disposal expensive and difficult (Poore et al. 2000). Large quantities of sweetpotatoes are disposed of in three major ways including dumping in landfills, spreading on cropland, or recycling as livestock feed which may provide an economic return at minimal cost.

Sweetpotato processing waste takes various forms such as peel waste, cull sweetpotatoes, screen waste, and several others, all of which are acceptable to mix into a cattle diet. Sweetpotatoes contain large amounts of starch and sugars and are used mainly as energy supplements in livestock feeds. The average DM content of sweetpotatoes is 31% (Bath et al. 1998), however these sweetpotato byproducts vary greatly in water content depending upon the portion of the plant (vines or roots) that they came from. Dried sweetpotatoes may comprise a high proportion of the carbohydrate in diets, but wet products will generally be limited to 15 to 25% of diet DM as moisture content of feedstuff has the greatest impact upon feed consumption and thus nutrient intake by cows (Poore et al. 2000). Sweetpotatoes and their associated byproducts are a good source of readily degradable carbohydrate (energy; TDN 80%) but are marginal sources for protein (CP 6.08%) and minerals. This study shows that wet sweetpotato byproducts can be successfully utilized as a partial substitute for corn. High-quality dehydrated sweetpotato meal used as the carbohydrate feed in a balanced ration was worth 90 to 95% as much as corn for finishing calves based on the TDN content. The study also proved that animal performance was comparable between corn and sweetpotatoes, however, the high moisture content may limit the rate of inclusion of sweet potatoes in the diet. The authors referenced Briggs et al. (1947), who found that dried sweetpotatoes (3632g) were highly palatable to steers and no refusals occurred when included in a balanced ration. They found dried sweetpotatoes had 92.3% the TDN value of No. 3 corn (a mix of white and yellow corn).

In summary, sweetpotoates can contribute to a nutritious low-cost diet for beef cattle. If a producer is going to use sweetpotato byproducts in their cattle ration, chopping whole cull sweetpotatoes into smaller pieces and allowing them to soften before feeding to reduce choking is recommended (Poore et al. 2000). Feeding smaller amounts (sweetpotato byproducts can generally be utilized in growing cattle rations at levels up to 20% of diet dry matter) but more frequently to help control spoilage and possible freezing in cold temperatures is also recommended. The high moisture rations spoil very readily, especially in the heat of summer, and are prone to freeze solid in the bunk in colder weather – drastic climate fluctuations which are very familiar to Manitoba. The best time to begin feeding in areas of hot temperatures is very early morning and again at dusk, when temperatures are lowest (Poole et al. 2000). The authors also recommended to adequately mix the ration to ensure consistency throughout. The authors concluded that feeding cattle sweetpotato byproducts not only contributes to a nutritious diet but is economically viable for producers who live in close proximity to the source of the products.

A study by Soto-Navarro et al. (2012) illustrates that peas can successfully be fed as a protein source for cattle. Much of the research on field peas in cattle diets has been conducted in dairy cows or finishing beef steers whereas little work has been conducted on the use of field peas as an energy or protein supplement for forage-based diets common in cow-calf operations. Therefore, Soto-Navarro et al. (2012 evaluated intake and performance of field peas as a source of CP in crossbred beef cows fed medium-quality grass hay diets. Cows were offered grass hay ad libitum twice daily and allotted randomly to one of five treatments where increasing amounts of whole field peas were supplemented thirty minutes before first feeding in individual electronic headgates. The study also compared the field pea supplements to one supplemental treatment of 1360 g of 74% barley and 26% canola. These authors found that forage intake (kg/d) of cows tended to decrease linearly with increasing field pea supplementation amount, however total intake (forage + supplement) increased linearly with increasing field pea amounts. Forage intake for 1360g treatment of field peas and 1360g treatment of barley and canola were similar. Overall, results of the study suggested that field pea grain is an acceptable alternative to traditional cereal grains and protein sources when incorporated into beef cattle diets (Soto-Navarro et al. 2012). Although this study was based on field peas and not field pea screenings, the nutrient compositions are very similar. Compared to field pea grain, pea screenings have slightly lower CP (22.7% vs 25.17% DM basis) and slightly higher TDN (80% vs 75.8% DM basis; Cowbytes 2011 and Roquette 2021). Soto-Navarro et al. (2012) also indicated that due to variability in protein composition across cultivars of field pea, nutrient analysis and animal requirements should be considered when field peas are incorporated into beef cattle diets.

In a publication by the University of North Dakota, Anderson (2002) explains that field peas not only posses many positive attributes for cattle nutrition, but they are also very palatable. Anderson (2002) found that feed intake has generally increased for diets with peas compared to diets without peas in several North Dakota State University trials. Palatability, animal performance, and net return are the ultimate tests of the desirability of a feed. In a feedlot finishing experiment (Anderson, 1999), peas were fed at 76% of the diet dry matter (76%) to determine if there were any palatability or anti-nutritional concerns. Intake was numerically greater for the pea treatment, suggesting no inhibitory factors were present. Palatability is not the only benefit to feeding field peas, as similarly discussed in the study by Soto-Navarro et al. (2012), field peas are an energy, and protein-dense feedstuff that can replace energy and protein provided by other nutrients (Anderson 2002). Energy content is comparable to barley and corn, and as a protein source, peas are comparable to wheat middlings, canola meal, and sunflower meal.

This study suggested that peas can be included in creep feeds, growing and finishing diets, beef cow rations, and is a very palatable feedstuff for all classes of beef cattle. Similar to Soto-Navarro et al (2012), Anderson (2002) found that peas have not been widely used in beef diets in the U.S. because of availability and, to some extent, competitive prices, however, it is practiced widely where peas are grown.

Chapter 3 Introduction

With 60,000 beef farms and feedlots, the Canadian cattle industry is a key economic driver of the Canadian agri-food sector, contributing $21.8 billion to the country's gross domestic product at market prices (CCA 2022). The base of Canada's national herd is built upon traditional breeds of British origin, primarily Angus and Hereford, but there are currently twenty-six breeds of beef cattle recognized under the Animal Pedigree Act (APA) administered by Agriculture and Agri-Food Canada (CBBC 2022). The production of high-quality beef begins the way it has for more than a century in Canada – in cow-calf operations. Cow-calf operations are one of three general stages in the Canadian beef production system. In cow-calf operations, calves are raised alongside their dams on predominantly naturalized grasslands (i.e., red fescue, quack grass) until they are sold as weaned calves, with a small percentage kept as herd replacements (Kime et al 2020). Weaned calves that are sold are then moved to the backgrounding phase which is the second type of production system in Canada. In this phase of production, additional weight is added using pasture forage in the summer and fall and hay or silage in the winter and spring. In the final stage, backgrounded calves are transported to the finishing sector where they are fed TMR grain diets designed to encourage ideal carcass quality traits (i.e., yield grade and quality grade) prior to slaughter.

Manitoba is the third largest beef producing province in Canada accounting for roughly 12% of the national beef herd (Government of Manitoba 2022a). Approximately 98% of beef operations are cow-calf operations (Government of Manitoba 2022a). Economic success for each cow-calf producer is related to the ability of the producer to maximize calving rate which is weaning approximately one healthy calf per cow each year (Government of Manitoba 2022b). The goal of cow-calf producers is to maximize their net returns using their scarce land, labor, and access to financial capital. Since nutrition is often the most important factor influencing reproductive performance, economical management of feed resources to consistently achieve high reproductive and calving rates will help ensure the greatest profitability possible for beef cattle operations.

The gestation period for cattle lasts approximately nine months (~283 days) over three trimesters (Table. 3.1). Cattle have different nutritional needs at different stages of gestation. In order to meet the herd's energy and protein requirements, producers will often modify their feeding strategies as bred cows move through pregnancy. Typically, in Manitoba, cows are bred in the early months of summer, usually June, while still nursing a calf. Their nutritional requirements in early gestation are not much different from their typical maintenance plus lactation requirements, and therefore the cow's needs can be met by grazing Manitoba's lush natural grasslands. As the fetus grows and the cow moves into late gestation, cattle require a 20 percent increase in crude protein (CP) intake and a 16 percent increase in total digestible nutrient (TDN, an index of energy content) intake (BCRC 2022). This need for additional nutrients is magnified when the cow calves in spring (February – April) and must produce milk for a calf.

By the end of November, cold weather has set in in Manitoba and typically remains until the definitive arrival of spring in April. During this period, the nutritional requirements of cow-calf herds are met by using a winter feed ration, and the requirements for nutrients will once again change as cows reach their calving date. As the cold winter months set in and the ambient temperature drops to -20ºC (or even lower; Table. 3.2), the energy component of the ration needs to be increased by approximately 15-20% (Manitoba Agriculture 2018). During this period, the cow is in her last trimester of pregnancy and adequate amounts of TDN, CP, minerals and vitamins in this crucial period are needed to ensure good reproductive performance. In order to achieve this, producers will enhance the diet with higher quality (i.e., greater sources of CP and

TDN) feed such as alfalfa hay and barley. Mature cows with a good body condition score (BCS; a rating given to cows based upon the amount of fat they are carrying) ranging from 3.0 to 4.0, generally require average quality forage (TDN ~ 57%, CP ~ 10%) supplemented with grain (e.g., barley grain, TDN 84%, CP 13.5%) or screening pellets, minerals, fortified salt, and vitamins to meet these nutritional needs (BCRC 2020). Cows should be fed to calve in a BCS of 3.0 to 3.5 and heifers a BCS of 3.5. Pregnant cows should be fed 55-60-65% for TDN and 7 to 8%, 9 to 10%, 11 to 12% for CP for mid, late, and lactation stages of pregnancy (NRC 2016). With some variation (depending on breeding dates; also, there are a few producers who choose to have their herds calve in the fall), Manitoba's calving season occurs in February to March (Government of Manitoba 2022b). Calving during this period allows for calves to be weaned off grass in September and make them available as 650lb feedlot replacements. It also gives producers the opportunity to garner a higher gross revenue at time of sale as calves can be finished before April to take advantage of stronger markets (Government of Manitoba 2022b).

Table 3.1 Stage of production and feeding strategy for a typical cow-calf operation in Manitoba

Production cycle*	Month	Trimester	Feed Strategy**
Breeding	May	1	Winter Feeding / Pasture Grazing
Breeding	June	1	Pasture Grazing
	July	1	Pasture Grazing
	August	2	Pasture Grazing
Weaning	September	2	Pasture Grazing/ Extended Grazing
	October	2	Extended Grazing
	November	3	Winter Feeding
	December	3	Winter Feeding
	January	3	Winter Feeding
Calving	February	Open	Winter Feeding
Calving	March	Open	Winter Feeding
	April	Open	Winter Feeding

*Assume a 60-day breeding period (May 1-June 30), average weaning date in late September, and a 60-day calving season from mid February though mid April.

**Extending grazing involves leaving herds on pasture long into the fall by feeding perennial pastures held in reserve, annual crops, crop residues and bales left in the field (Manitoba Agriculture, 2008)

Table 3.2 Climate data averaged for Winnipeg Manitoba (2017-2021)

Month	Mean Temp (ºC)	Min Temp (ºC)	Max Temp (ºC)	Precipitation (mm)
Jan	-13.7	-18.1	-9.2	18.7
Feb	-15.5	-20.6	-10.4	12.4
Mar	-5.0	-10.4	0.4	27.5
Apr	2.9	-3.6	9.2	29.0
May	11.3	3.8	18.9	71.1
Jun	18.5	11.6	25.4	98.4
Jul	20.5	13.7	27.3	67.7
Aug	18.7	11.4	25.9	56.0
Sep	13.2	7.0	19.4	34.1
Oct	4.7	-0.3	9.7	31.7
Nov	-5.2	-9.8	-0.6	19.7
Dec	-12.2	-16.9	-7.5	22.0
Total	38.2	-32.1	108.6	488.2

Feed costs represent the highest cash operating expense associated with cow-calf production contributing to 60% or more of production costs (Greenwood 2021). The conventional rations used in winter cow-calf diets are made up of a wide variety of different feedstuffs (e.g., grass hay, alfalfa hay, corn silage, and barley) to ensure that CP, TDN, mineral and vitamin requirements are met. To help reduce this expense, producers have also utilized alternative byproduct feeds such as grain screenings, wet corn gluten, dried distillers' grain, or soybean hulls to replace commonly used feedstuffs. These alternative byproducts have been incorporated into diets in a multitude of ways. One study in South Dakota by Mueller et al (2011) evaluated the effect of replacing dry rolled corn with soybean hulls on performance, mineral, and blood metabolite status of 155 steers. This study concluded that the use of soybean hulls in receiving diets can support body weight as effectively as dry rolled corn and identified it as a potential replacement in oat silage-based diets. A study by Rush (2005) sought to determine the cost effectiveness of using corn gluten feed compared to hay and a conventional protein supplement fed to heifers in Nebraska. No differences were noted in the heifers gain or breeding performance; however, heifers fed corn gluten feed resulted in a cost saving of $6.71/head during the 60-day feeding period.

Drought in summer of 2021 led to increased feed prices. In addition, an extremely cold winter coupled with a late spring led to increased winter-feeding costs from fall 2021 to spring 2022. The 2021 prices for alfalfa hay (a common feed ingredient in Manitoba cow-calf diets) were up 109.5 percent year over year in North Dakota with similar increases seen in Canada (Peel 2021). Most other protein and energy feedstuff prices increased when comparing prices in 2020 and 2021, with the amount of increase varying by ingredient type and source (Peel 2021). Potential exists for Roquette's pea coproducts to supply an economical and sustainable feed source for cattle producers. As mentioned above, Roquette produces three main pea coproducts by taking the parts of pea that are not considered suitable for human consumption and developing animal feeds. Together, these three coproducts embody one-third of the pea with pea cream representing 25%, while screenings and hulls represent approximately 5% each (Delporte 2022). The incorporation of these coproducts into cattle rations might allow for reduced feed costs as these coproducts do not need to be grown or imported (Delporte 2022). Producers will be in the position to spend their efforts on land management and producing cash crops (where regionally appropriate) instead of continuing to focus on the growth or storage of feed (Delporte 2022).

As indicated above, cows calving in February-March calving period are typically bred in June, with first trimester on pasture where no additional energy supplements are required unless forage yield and quality are compromised due to drought or other climate-related factors. The second trimester (mid gestation) occurs in the fall where the temperature in Manitoba on average ranges from 4.7ºC to 18.7ºC (Table 3.2) and forage quality is typically sufficient to meet energy requirements, therefore, supplementation of either barley or pea screenings is not required. In late gestation, energy requirements often exceed energy supplied by the forage due to increased fetal growth (Caton et al. 2007) and average ambient temperatures ranging from -13.7ºC to -5.2ºC (Table 3.2). Therefore, addition of a high-energy feedstuff such as barley or pea screenings in the diet is necessary to meet energy requirements. Replacing traditional winter feed ingredients in Manitoba beef cow diets such as barley with pea screenings to meet nutrient requirements could result in a more economical winter-feeding program for Manitoba cow-calf producers. Therefore, the objectives of this research were to: (1) compare the quantity of pea screenings or barley needed to meet the energy requirements of a 1300lb cow in the third trimester of pregnancy, feeding grass legume hay, grass, or straw-based diets during the 90 day over-winter period; (2) compare the cost of the three forage-based rations when supplemented with either barley or pea screenings; and (3) determine the price at which rations containing pea screenings are equivalent in cost to (i.e. break-even with) the three conventional barley-based rations.

Chapter 4 Methodology

Three conventional barley-based and three alternative pea screening-based rations were developed, and the cost of each were determined to show the economic competitiveness between them. A breakeven analysis was then conducted to determine the price at which pea screenings are equivalent to barley in order to help producers decide whether to include them in cattle diets.

4.1 Ration Development and Balancing

A total of six forage-based (legume hay, grass hay, or barley straw) overwintering rations were used in the analysis, including three conventional diets supplemented with barley, a commonly used energy source by cow-calf producers in the region, and three alternative rations using pea screenings. All rations were formulated using the Beef Cattle Nutrients Requirement Program (NRC 2016) for a mature, 1300-pound cow in good body condition in the third trimester of pregnancy with an average outdoor temperature of -15.5ºC (Table 3.2).

The feed ingredients and their respective nutrient profiles used in the six balanced cow-calf feed rations evaluated in this study are reported in Table 4.1.

Table. 4.1 Nutrient profile of feed ingredients used to formulate overwintering diets for a 1300 lb beef cow in the third trimester of pregnancy

Ingredients	DM %	CP %DM	NDF %DM	TDN %DM	Ca %DM	P %DM	Mg %DM	K %DM
Barley grain*	89.7	12.8	18.3	84.1	0.1	0.4	0.1	0.5
Pea screenings**	88.1	22.7	23	80	0.2	0.5	0.2	1.1
Barley straw*	85.1	6.1	71.6	48.3	0.5	0.2	0.2	2.3
Grass hay***	89.9	10.7	62.8	57.7	0.5	0.2	0.2	1.3
Grass-legume hay***	87.2	12.5	60	58	0.8	0.2	0.2	1.6
Mineral 2:1***	99	0	0	0	19.19	9.09	0	0
Mineral 1:1***	99	0	0	0	18.18	18.18	0	0
Limestone*	100	0	0	0	34	0	2.06	0
Salt*	100	0	0	0	0	0	0	0

*NRC
**Roquette
*** Cowbytes

The first of the three conventional diets is a grass legume hay and barley diet (LH+B). It consists of 25.36 lbs of grass legume hay, 7.25 lbs barley grain, 0.04 lbs 1:1 mineral and 0.04 lbs salt. The second conventional ration is a grass hay and barley diet (GH+B). It is comprised of 24.81 lbs of grass hay, 7.20 lbs barley grain, 0.24 lbs 2:1 mineral, and 0.04 lbs salt. The third conventional ration is a barley straw-based diet with barley grain (BS+B). It includes 18.80 lbs of barley straw, 14.04 lbs barley grain, 0.27 lbs 2:1 mineral, 0.001 lbs salt[1], and 0.08 lbs limestone. All values are reported on a "as-fed" basis. These three rations were then compared on a nutritional basis (Table 5.1) to three alternative rations where pea screenings were included in the diet instead of barley. The first of three alternative rations is grass legume hay and pea screenings (LH+PS) with 24.66 lbs grass legume hay, 8.26 lbs pea screenings, 0.16 lbs 1:1 mineral, and 0.04 lbs salt. The second ration is based on grass hay and pea screenings (GH+PS) with 23.92 lbs grass hay, 8.35 lbs pea screenings, 0.35 lbs 2:1 mineral, and 0.04 lbs salt. The third alternative ration is straw based with added pea screenings (BS+PS) consisting of 18.21 lbs barley straw, 15.37 lbs pea screenings, 0.43 lbs 2:1 mineral, 0.001 lbs salt and 0.09 lbs limestone. With the balanced rations total quantities (lbs/head/day) of each feed ration were calculated by summing the amount (lbs) of each feed ingredient used. This value was multiplied by the total number of winter-feeding days in the late gestation period (90) to get the total quantity fed during this period (lbs/head).

When cattle producers purchase feed, they are usually deciding to purchase a source of either protein or energy. Mineral requirements typically can be met with a less expensive free

[1] The amount of salt in the barley straw ration is very small due to the increased amounts of Na and Cl contained in the straw compared to the other rations.

choice salt/mineral program, so most nutritional supplementation and feeding focuses on the CP and TDN needs of cattle. Both measurements (CP and TDN) were evaluated on a “dry-matter” (DM; 0% moisture) basis whereas feedstuffs are priced “as-is”, meaning that a portion of the weight of the feedstuff is moisture (water). This DM evaluation is critical as it allows producers to compare nutrient concentrations of feeds with varying moisture content as cattle do not require a certain amount of *dry* feed but rather require a certain amount of *digestible* feed**.** DM values of TDN and CP can be seen in Table 4.2.

Feeds can not be compared fairly solely on a on price per ton basis as the lowest-price feed may not be the most economical feed. As stated above, nutritionists can express cattle’s requirement for specific nutrients in pounds of energy or protein, as CP and TDN are the primary nutrients needed to balance a ration. Choosing an economical protein or energy supplement is simplified when comparing products on a per pound of actual nutrient basis. If cattle require energy, which is common in late gestation, producers may look to calculate and compare the costs per unit of TDN and then consider the value of other nutrients the feed contains. As cattle move into the lactation stage the need for protein increases thus price per pound of CP is a good method to determine the best buy. The challenge for the cow-calf operator is to develop a feeding program that meets these requirements in an economic manner. Cattle that are fed good quality grass (i.e., alfalfa) in the mid-gestation period may only require an increase in the quantity of forage to meet late-gestation needs, whereas cattle fed poorer-quality forage such as cereal straw may need to increase the quantity as well as quality (McKinnon 2021). This typically involves providing supplemental energy and protein, which was done in this research by providing either barley in the conventional rations, or pea screenings in the alternative rations.

Table 4.2. Cost of feed ingredients (per ton and per unit of TDN and CP) used to formulate overwintering rations for 1300 lb beef cows in the third trimester of pregnancy

Feed Type	$/ton	Cost per lb of TDN (As Fed Basis)	Cost per lb of CP (As Fed Basis)
Grass Hay	96.00	$0.10	$0.56
Grass Legume Hay	112.08	$0.13	$0.59
Barley Grain	177.30	$0.13	$0.86
Barley Straw	33.36	$0.05	$0.38
Pea Screenings	176.46	$0.14	$0.50

4.2 Economic Methods for Base Case Costs

Costs associated with each of the six feed rations were calculated. Prices for each type of feed, except pea screenings, were based on long term averages collected from multiple sources to help avoid major current fluctuations in the market.

Table 4.3. Price of each feed ingredient ($/lb)

Feed Type	$/lb
Grass Hay [A]	0.048
Barley Straw [C]	0.018
Grass Legume Hay [A]	0.056
Barley Grain [B]	0.089
Pea Screenings	0.088
2:1 Mineral [D]	0.436
1:1 Mineral [D]	0.527
Salt [D]	0.222
Limestone [D]	0.073

[A] Data collected from Agricultural Services Corporation 2012-2022
[B] Data collected from Manitoba Markets 2012-2022
[C] Data collected from the Government of Manitoba Beef Cow-Calf production costs reports 2013-2021
[D] Data collected from Cowbytes 2011

Grass legume hay, field peas, and grass hay data were gathered from Manitoba Agricultural Services Corporation (F. Price, personal communication, May 5, 2022) and were based on data ranging between 2012-2022. Barley grain prices were also based on an 11-year average from 2012 – 2022 with data collected from Manitoba Markets (Government of Manitoba 2022c). Barley straw prices were collected from the years 2013-2021 from the Government of Manitoba, Beef Cow-Calf Production costs reports (Government of Manitoba 2022e). The prices for minerals, salt, and limestone were taken from Cowbytes 2011. Since there are no historical data for pea screenings, prices are assumed to be 75% of the long-term market price for field peas collected from Agricultural Services Corporation (Delporte 2022). The cost of each feed ingredient used in the economic analysis is given in Table 4.3.

Total cost ($/head/day) for each feed system was calculated by multiplying the amount (lbs) of each feed type by the long-term average price. Next, the total feed cost was converted to a $/head by multiplying the daily total by 90 late gestation winter feeding days out of the total 195 winter feeding days. The relative difference in cost ($/head) between systems was then calculated to understand the comparative economics between the feed systems. The ration that had the lowest total cost was used as the base to which the other the other five systems were compared to give direct insight into the true scale of difference. The calculation was completed by holding total cost of the base system constant and then subtracting it from the total cost of the other five feed systems.

4.3 Breakeven Analysis

A key objective of this research is to provide economical information about the price of pea screenings to the industry in order to facilitate an understanding about how much producers can afford to pay for the pea screening coproduct. From an economic perspective, cow-calf producers should respond to financial incentive in making the decision to switch from barley to pea screenings. Holding all other production costs constant, and assuming no change in uncertainty, producers would, theoretically, switch to an alternative feedstuff so long as it reduces the total feed cost. To determine whether this would be likely to occur given the set of assumptions made for this research, the relative breakeven price of pea screenings was calculated between rations to determine the price pea screenings must be to make producers incentivised in their decision to include pea screenings in the diet rather than barley. Previous studies have utilized a breakeven analysis strategy to evaluate purchase and sale decisions. Peterson et al.

(1989) used a breakeven analysis to determine whether preconditioning beef calves was a profitable practice for cow-calf producers. Break-even prices were estimated for preconditioned calves and calves not preconditioned, relative to calves in a control group, for cow-calf producers and cattle feeders. These break-even prices represented the required minimum sale price for cow-calf producers and the maximum affordable purchase price for cattle feeders that gave the same returns to cow-calf producers and cattle feeders as did animals in the control group (Peterson et al. 1989).

The relative breakeven price of pea screenings for each pea screening feed ration (i.e., BS+PS, GH+PS, LH+PS) relative to each corresponding conventional system (i.e., BS+B, GH+B, and LH+B) will help communicate essential price information to supply chain members – both on the production side (cow-calf producers, backgrounders, cattle feeders) and the input side (Roquette and other prospective suppliers of coproducts with potential use as animal feed).

The breakeven values were calculated by solving for the breakeven price of pea screenings. The breakeven cost is represented mathematically as:

$$TC_B = TC_{PS}$$

$$TC_A = \Sigma(TC_{GH} + TC_{BS} + TC_{LH} + TC_B + TC_M + TC_S)$$

$$TC_{PS} = P_{PS} \times Q_{PS}$$

$$TC_B = TC_A + TC_{PS}$$

$$\frac{(TC_B - TC_A)}{Q_{PS}} = P_{PS}$$

where TC_B = total cost of conventional ration of interest ($/head/day), TC_{PS} = total cost of alternative ration of interest ($/head/day), TC_A = total sum of all costs in alternative ration excluding pea screenings ($/head/day), P_{PS} = price of pea screenings ($/lb), and Q_{PS}= quantity of pea screenings (lbs/head/day).

This breakeven value was then multiplied by 2000 lbs to convert prices from $/lb to $/ton. These results demonstrate the price pea screenings must reach to be competitive with the current feeding system and highlights the point at which producers would consider switching from the conventional rations to one of the three pea screening rations.

In addition to the breakeven price of pea screening, the breakeven prices of barley grain and was also calculated. This calculation was done to demonstrate the point at which barley prices become so high that pea screenings become the more desirable choice.

Chapter 5 Results and Discussion

5.1 Ration Formulations

The quantities of individual ingredients and the nutrient (DM basis) composition for each of the six alternative rations are reported in Table 5.1.

When comparing each conventional ration to its alternative counterpart (e.g., LH+B compared to LH+PS) it is observed that the alternative diets require a higher quantity of pea screenings in the alternative rations than the quantity of barley needed in the conventional rations (Table 5.1). These quantity differences indicate that the two energy sources are not a one-to-one substitution due to the differing TDN levels of barley grain and pea screenings as seen in Table. 4.1. Pea screenings have a lower TDN than barley (80% compared to 84% DM basis) thus a marginally larger quantity is needed in the diets to reach adequate energy amounts of 60% in late gestation (NRC 2016).

Forage levels also differ across the six rations. The proportion of forages in the conventional rations are all slightly higher than in the alternative rations. This is due to the increased level of pea screenings as well as the dry matter intake (DMI). The rations were formulated to achieve a consistent DMI on a percentage of body weight across all rations (conventional and alternative) with values ranging from 2.21% to 2.27% which fall in the acceptable range of 2.2 – 2.5% for a dry cow (NRC 2016). While maintaining these comparable intake levels, energy requirements also need to be met. With the additional pea screenings in the diets, the proportion of forages in the alternative rations was lowered.

Table 5.1 also highlights the increased amount of supplemented energy (barley grain or pea screenings) in rations which contain a lower quality (energy density) forage such as barley straw. The amount of barley grain in the BS+B ration is double (14.04 lbs/hd/day) the amounts in the GH+B ration (7.20 lbs/hd/day) and the LH+B ration (7.25 lbs/hd/day). The same can be said for the alternative rations. The quantity of pea screenings in the BS+PS ration is much greater (15.37 lbs/hd/day) than it is in the GH+PS ration (8.35 lbs/hd/day) and the LH+PS ration (8.26 lbs/hd/day). This is due to the poorer quality of the barley straw (48.3% TDN, 6.1% CP) compared to the grass hay (57.7% TDN, 10.7% CP) and the grass legume hay (58% TDN, 12.5% CP) which naturally supply more energy and protein in the diets. When evaluating CP levels of each ration, the BS+B ration had the lowest dietary CP with a value of 8.9% compared to the other two conventional rations, GH+B and LH+B, which reported values of 11.1% and 12.5% respectively (Table 5.1). Though all three of these conventional rations met CP requirements for cows in the late gestation period of pregnancy, (9-10%; NRC 2016) the BS+B ration is only marginally adequate due to the low quality of the barley straw the BS+B ration. All three alternative pea screening rations exceed the necessary amounts of CP to satisfy the requirements for cows in late gestation as well as cows in the lactation stage of pregnancy which require 11-12% CP (NRC 2016). At this stage, cows fed the BS+B ration would be deficient in CP as this diet does supply adequate amounts of CP to meet the needs of lactating cows. This demonstrates that pea screenings are better able to meet CP requirements than barley when the forage quality is poor and physiological status of the cow demands more protein.

In all six rations either a 2:1 or a 1:1 mineral package was incorporated to ensure that the diets were balanced for both macro and micro nutrients. These mineral packages are designed by feed companies to ensure sufficient amounts of all macro and trace minerals. Since legumes are naturally high in calcium, as mentioned above, both LH+B and LH+PS rations were able to meet their mineral requirements by feeding a 1:1 mineral package. The other four rations which naturally contain lower amounts of calcium were given a 2:1 mineral package. These mineral packages generally cover the requirements of trace minerals such as zinc, copper, manganese, and selenium. Supplemental salt is also provided at 1 to 2 ounces per day to maintain osmotic pressure in the body, regulate water intake, and increase palatability of the feed (NRM 2017).

Though the quantities of each feed ingredient differ, the total quantities (lbs/hd/day) across all rations are fairly similar reporting values in lbs/head/day of 32.28 (GH+B), 33.19 (BS+B), 32.29 (LH+B), 32.66 (GH+PS), 34.11 (BS+PS), and 33.12 (LH+PS). When multiplied by the 90 late gestation winter feeding days the range of total quantities appears more drastic with a low of 2905.59 lbs/hd in the GH+B ration to a high of 3069.73 lbs/hd in the BS+PS ration. This produces a difference of 164.14 lbs/hd between the lowest and highest ration.

Table 5.1. Diet (as fed) and nutrient (DM basis) composition of three conventional barley-supplemented and three alternative pea screening-supplemented diets formulated to meet nutrient requirements of 1300 lb beef cows during the third trimester of pregnancy

		Feed Ration					
Feed Type	**lbs/unit**	**GH+B**	**BS+B**	**LH+B**	**GH+PS**	**BS+PS**	**LH+PS**
		(lbs, as-fed/head/day)*					
Grass Hay	2205	24.81	0.00	0.00	23.92	0.00	0.00
Barley Straw	2000	0.00	18.80	0.00	0.00	18.21	0.00
Grass Legume	2205	0.00	0.00	25.36	0.00	0.00	24.66
Barley	2205	7.20	14.04	7.25	0.00	0.00	0.00
Pea Screenings	2205	0.00	0.00	0.00	8.35	15.37	8.26
2:1 Mineral	55	0.24	0.27	0.00	0.35	0.43	0.00
1:1 Mineral	55	0.00	0.00	0.04	0.00	0.00	0.16
Salt	44	0.04	0.001	0.04	0.04	0.001	0.04
Limestone	55	0.00	0.08	0.00	0.00	0.09	0.00
Total quantity (lbs/hd/day)	-	32.28	33.19	32.69	32.66	34.11	33.12
Total quantity (lbs/hd)	-	2905.59	2987.17	2942.10	2939.72	3069.73	2980.37
Intake (as % Body weight)		2.48	2.55	2.51	2.51	2.62	2.55
		Nutrient composition (% DM)					
DM (%)		89.9	87.2	87.8	89.6	86.7	87.5
CP (%)		11.1	8.9	12.5	13.6	13.6	15.0
Fat (%)		0.5	1.5	0.5	0.3	1.0	0.3
NDF (%)		52.3	47.5	50.4	52.0	48.0	50.3
TDN (%)		63.0	63.2	63.7	62.5	61.9	63.1
CP:TDN		0.18	0.14	0.20	0.22	0.22	0.24
Calcium (%)		0.58	0.59	0.66	0.67	0.52	0.74
Phosphorus (%)		0.29	0.37	0.23	0.36	0.33	0.34
Calcium:Phosphorus		2.01	1.63	2.84	1.86	1.58	2.16
Potassium (%)		1.13	1.49	1.33	1.25	1.10	1.44
Magnesium (%)		0.16	0.16	0.17	0.18	0.19	0.18

* GH+B is a balanced feed ration comprised of grass hay and barley grain, BS+B is a feed ration comprised of barley straw and barley grain, LH+B is a ration comprised of a grass legume hay and barley grain, GH+PS is a ration comprised of grass hay and pea screenings, BS+PS is a ration comprised of barley straw and pea screenings, and LH+PS is a balanced ration comprised of a grass legume hay and pea screenings. All rations include mineral and salt.
DM, Dry Matter; CP, Crude Protein; NDF, Neutral Detergent Fiber; TDN, Total Digestible Nutrients.

5.2 Costs of Feed Rations

Table 4.2 listed above can be used to communicate to producers the most cost-effective feedstuff by calculating the cost per unit of nutrient supplied. As feed prices and their relationships to each other are constantly changing, the 11-year average price of barely grain was used resulting in a price of $177.30/ton. The assumed price of pea screenings was extrapolated from the 11-year price of field peas ($235.24/ton) resulting in a price of $176.46/ton. When compared on a price per pound of TDN basis the two are relatively equal, with barley grain reporting $0.13/lb TDN and pea screenings reporting $0.14/lb TDN (Table 4.2). This implies that while barley has a slightly higher TDN percentage, when evaluating on a cost per TDN basis, pea screenings is a near equivalent alternative.

Despite being slightly lower in TDN, pea screenings are a much greater source of protein (Table. 4.1) and offer additional nutrients for producers who are feeding a lower quality hay or straw. Pea screenings report CP values of 22.7% while barley grain reports CP values nearing half as much with a value of 12.8%. This additional protein in pea screenings makes it a more economical source of protein with a cost of $0.50 per pound of CP compared to $0.86 per pound for the same amount of barley. Producers who choose to feed a cheaper but poorer quality forage would benefit from taking advantage of this high-quality protein source to meet cattle's nutritional requirements in an economical way. Although the high amounts of protein may not be as relevant to a cow-calf producer who mainly looks to fill the energy component of the ration at this stage of gestation, however, it may be relevant during lactation when protein requirements are increased and therefore the more economical choice may be pea screenings.

While measuring feedstuff on a cost per unit of nutrient basis is simple and easy to calculate, results should be interpreted with caution. Feeds should be evaluated based on their most valuable nutrient or on what the feed was purchased for. Feeds of similar nature should be compared: i.e., protein sources should be compared with protein sources, and energy sources with energy sources.

Costs for individual ingredients and total cost ($/hd) for the six cow-calf winter feed rations are reported in Table 5.2. The results indicate that the three conventional rations are less costly than the corresponding alternative rations where pea screenings are used to meet energy requirements of the diet as a substitute for barley. Among the six systems, the most cost-effective ration is the BS+B system that realized a total cost of $154.26/hd. This ration is $15.50/hd cheaper than its pea screening counterpart the BS+PS ration, which realized a cost of $169.76/hd. Similarly, the BS+B ration is $20.46/hd cheaper than the GH+B ration, $29.90/hd cheaper than the GH+PS ration, $34.01/hd cheaper than the LH+B ration, and $43.96/hd cheaper than the LH+PS ration.

This BS+B ration is most appealing to cow-calf producers due to the relatively low cost of the barley straw ($36.67/ton) compared to the other two forages: grass hay ($96.00/ton) and grass legume hay ($112.08/ton). Though the cost of each ration varies slightly, each producer will choose the feed system that makes the most economical sense based on their location, ease of feed access, and individual supply of own crop variety as this will vary from producer to producer. These variables will ultimately influence the producer’s choice of what feedstuff to include in their cattle diets. For producers who choose to feed one of the two other conventional rations (i.e., GH+B and LH+B) options, the most economical system between them is the GH+B ration because it is $13.55/hd less than the LH+B system. If producers were to substitute pea screenings into the GH+B diet instead of barley grain while feeding this grass hay, the cost would increase by $9.45/hd reaching a total cost of $184.16/hd for the GH+PS ration over the 90-day winter feeding period. Both the conventional and alternative grass hay rations are more cost-effective than feeding a grass legume hay, based on the nutrient analysis and forage prices used in the study. The GH+B ration is $13.55/hd less expensive than the LH+B and $23.50/hd less expensive than feeding the LH+PS ration. The legume hay rations (LH+B and LH+PS) have higher TDN and CP concentrations and therefore require less barley grain or pea screenings. Even though lower quantities of supplements are needed in these rations, they are still the two most expensive options to feed due to the overall higher historical price of legume hay compared to grass hay and barley straw.

On a larger scale, assuming a 150 head cow herd, producers who feed the BS+B ration, the most economical ration overall, would see a savings of $2325.46 during the 90 days on late gestation winter feed compared to feeding the BS+PS ration as the total costs for these two rations come to $23,138.39 and $25,463.85 respectively. Similarly, these producers would save increasing amounts if they chose to feed the BS+B ration compared to the four other rations. Producers would see a savings of $3068.54 if they were to feed BS+B instead of the GH+B ration, $4485.18 instead of the GH+PS ration, a savings of $5101.36 instead of the LH+B ration, and $6593.82 instead of the LH+PS ration. Although most cost effective, there are challenges when feeding a poorer quality forage ration like the BS+B system. For example, large amount of high energy supplements offered on a free choice basis can lead to digestive issues as not all cows are eating an equivalent amount. Further, during periods of extreme cold, increased DMI of a low quality forage including straw can lead to impaction.

Table 5.2 Historical prices for feed ingredients and average costs for six winter feed rations for a representative 1300 lb cow winter fed for 90 days in Manitoba

		Feed Rations ($/head/day)					
Feed Type	**Price ($/lb)**	**GH+B**	**BS+B**	**LH+B**	**GH+PS**	**BS+PS**	**LH+PS**
Grass Hay	0.048	1.19	0.00	0.00	1.15	0.00	0.00
Barley Straw	0.018	0.00	0.34	0.00	0.00	0.33	0.00
Grass Legume Hay	0.056	0.00	0.00	1.42	0.00	0.00	1.38
Barley	0.089	0.64	1.24	0.64	0.00	0.00	0.00
Pea Screenings	0.088	0.00	0.00	0.00	0.74	1.36	0.73
2:1 Mineral	0.436	0.11	0.12	0.00	0.15	0.19	0.00
1:1 Mineral	0.527	0.00	0.00	0.02	0.00	0.00	0.09
Salt	0.170	0.01	0.00*	0.01	0.01	0.00*	0.01
Limestone	0.073	0.00	0.01	0.00	0.00	0.01	0.00
Total cost ($/hd/day)	-	1.94	1.71	2.09	2.05	1.89	2.20
Total cost ($/hd)	-	174.71	154.26	188.26	184.16	169.76	198.21
Relative different in cost ($/hd)		20.46	0.00	34.01	29.90	15.50	43.96
Total cost assuming 150 hd herd		26206.93	23138.39	28239.75	27623.57	25463.85	29732.21

GH+B is a ration comprised of grass hay and barley grain, BS+B is a ration comprised of barley straw and barley grain, LH+B is a ration comprised of a grass legume hay and barley grain, GH+PS is a ration comprised of grass hay and pea screenings, BS+PS is a ration comprised of barley straw and pea screenings, and LH+PS is a balanced ration comprised of a grass legume hay and pea screenings.

* Cost of salt was >$0.01/hd/day thus rounded to $0.00/head/day

5.3 Break-Even Analysis

Table 5.3 reports relative breakeven prices ($/ton) of pea screenings and barley grain by ration. Initially, a sensitivity analysis was conducted to determine how sensitive the relative results were to incremental changes in prices for pea screenings. Once it was clear that the barley straw and barley grain (BS+B) ration was the most economical (based on the historical prices), it was unnecessary to test hypothetical increases in the price of pea screenings and the sensitivity analysis was removed from the research and replaced by a breakeven analysis.

Nine breakeven prices for pea screenings were calculated in order to compare the economic viability of each of the three alternative systems (GH+PS, BS+PS, LH+PS) with each of the three conventional systems (GH+B, BS+B, LH+B). The nine breakeven prices were calculated in groups of three, first comparing the three pea screening rations (GH+PS, BS+PS, and LH+PS) with the GH+B feed system, then the three pea screening rations with the BS+B system, and lastly the three pea screening rations with the LH+B system. The set of nine breakeven prices of pea screenings demonstrate in which situations barley rations would be the more economical option. If the breakeven price of pea screenings is lower than the current price of pea screenings ($176.46/ton) then it would make more economic sense to choose a ration containing barley. Conversely, if the breakeven price of pea screenings is higher than $176.46/ton compared to the conventional rations, then the alternative pea screenings rations are the most economical choice. For producers currently feeding the GH+B ration to their cattle, the price of pea screenings would need to decrease by $25.12/ton (14.23%) from the base case price of $176.46/ton to a new price of $151.34/ton for cow-calf producers to incorporate pea screenings into their feeding strategy. As seen above in Table. 4.3 the prices of barley and pea screenings in $/ton are near equivalent ($177.30 vs $176.46 respectively) but the GH+PS system requires 16.09% more pea screenings than the quantity of barley required in the GH+B system, therefore increasing the cost of the entire ration. The GH+PS system does require slightly less grass hay (23.92 lbs/hd/day) compared to the GH+B system (24.81 lbs/hd/day), this is due to the varying TDN levels discussed previously, but the price of grass hay is not enough to offset the cost of the additional pea screenings.

In order for the LH+PS system to break even with the GH+B system the price of pea screenings would need to decrease by $63.24/ton (35.84%) to a new (and much lower) price of $113.22/ton. The LH+PS system requires 14.75% more pea screenings than the quantity of barley required in the GH+B ration and requires approximately equal amounts of legume hay (24.66 lbs/hd/day) compared to the quantity of grass hay needed (24.81 lbs/hd/day) in the GH+B system. The major difference in these two rations is the cost of grass hay compared to grass legume hay (which is 16.75% more expensive), though incorporated at approximately equal quantities, legume hay costs $112.08/ton whereas grass hay is $96.00/ton. Unlike the GH+PS and the LH+PS rations, in order for the BS+PS ration to breakeven with the GH+B ration the price of pea screenings would have to rise by only $7.17/ton (4.06%) to a price of $183.63/ton due to the low-cost of barley straw. Even though the BS+PS requires more than double (113.57% more) the quantity of pea screenings than the quantity of barley required in the GH+B system, the cost per ton of barley straw is so low it offsets this increase in quantity of pea screenings.

Producers who are currently feeding the BS+B ration would require the price of pea screenings to decrease by $22.41/ton (12.70%) to a price of $154.05/ton in order to consider switching to the BS+PS system. The BS+PS and the BS+B rations contain approximately the same amount of barley straw in lbs/hd/day (18.21 compared to 18.80 respectively) but the BS+PS ration requires 9.5% more pea screenings than the BS+B ration needs barley making pea screenings an unlikely addition to their current feed at these prices. Both the GH+PS ration and the LH+PS ration share a similar conclusion. In order for the cost of the GH+PS system to breakeven with the BS+B system the price of pea screenings would need to decrease by $79.53/ton (45.07%) to a new price of $96.93/ton. Although the GH+PS ration requires 40.48% less pea screenings than the amount of barley required in the BS+B ration, the price of the grass hay ($96.00/ton) is 2.62 times more expensive than the price of barley straw ($36.67/ton) and still requires the price of pea screenings to be reduced if producers are to consider this option. At greater prices for pea screenings, the relative economics becomes even less viable as convincing producers to consider feeding a ration of grass legume hay and pea screenings seems unlikely. For the LH+PS system to breakeven with the BS+B system the price of pea screenings would need to drop exponentially by $118.29/ton (67.04%) to a new price of only $58.17/ton. While the LH+PS ration requires 41.17% less pea screenings than the BS+B system requires barley, the high quantity of expensive grass legume hay required in LH+PS (24.66 lbs/hd/day) makes this the most expensive ration out of the six systems ($198.21/hd).

With a similar cost to the LH+PS system, the LH+B system is the most expensive conventional ration with a total cost of $188.26/hd. In order for both the GH+PS system and the BS+PS systems to breakeven with the LH+B system, the price of pea screenings would have to increase by $10.93/ton (6.19%) and $26.76/ton (15.16%) resulting in pea screening prices of $187.39/ton and $203.22/ton respectively. As mentioned above, the price of grass legume hay is more costly than both grass hay and barley straw, so even though both of these alternative rations contain more pea screenings (15.23% and 111.98%) than the quantity of barley, the LH+B ration still requires a lower price of pea screenings to breakeven. As aforementioned, due to the high prices of grass legume hay, the LH+B ration and the LH+PS ration are the two most expensive options for Manitoban cow-calf producers. For the LH+PS ration to breakeven with the LH+B ration the price of pea screenings must decrease by $26.77/ton (15.17%) to a new price of $149.69/ton. This partially due to the fact that LH+PS has 13.90% more pea screenings required than barley in LH+B even though the quantities of grass legume hay are so similar (24.66 lbs/hd/day compared to 25.36 lbs/head/day).

Breakeven prices for barley are also reported in Table 5.3. The set of nine breakeven prices of barley demonstrate in which situations pea screenings rations would be the more economical option. If the breakeven price of barley is lower than the current price of barley ($177.30/ton) then it would make more economic sense to choose a ration containing pea screenings. Conversely, if the breakeven price of barley is higher than $177.30 compared to the alternative rations, then the conventional barley rations remain the most economical choice. This is most clearly shown when considering a situation where producers were hypothetically feeding the LH+PS ration. In order for the cost of the GH+B, BS+B, and LH+B systems to breakeven with the LS+PS system the prices of barley grain would need to increase to $249.88/ton, $246.90/ton, and $207.80/ton respectively. These results are expected as the LH+PS system is the most expensive overall causing the barley price to have to increase in order to be equal.

Table 5.3. Breakeven prices ($/ton) of pea screenings and barley when included in forage-based rations formulated to meet the nutrient requirements of a 1300 lb cow winter fed for a 90-day period during late gestation in Manitoba

	Feed Ration*					
Price scenario	**GH+B**	**BS+B**	**LH+B**	**GH+PS**	**BS+PS**	**LH+PS**
Breakeven price of pea screenings ($/ton)	151.34	96.93	187.39	base	-	-
	183.63	154.05	203.22	-	base	-
	113.22	58.17	149.69	-	-	base
Breakeven price of barley grain ($/ton)	base	-	-	206.46	162.00	249.88
	-	base	-	224.64	201.85	246.90
	-	-	base	164.71	120.58	207.80

GH+B is a balanced feed ration comprised of grass hay and barley grain, BS+B is a feed ration comprised of barley straw and barley grain, LH+B is a ration comprised of grass legume hay and barley grain, GH+PS is a ration comprised of grass hay and pea screenings, BS+PS is a ration comprised of barley straw and pea screenings, and LH+PS is a balanced ration comprised of grass legume hay and pea screenings. All rations include mineral and salt.

Chapter 6 Conclusions, Limitations and Suggestions for Future Research

6.1 Conclusion

The purpose of this study was to determine the relative economic value of incorporating pea screenings into three conventional Manitoban cow-calf feed rations over the late gestation winter-feeding period of 90 days. Sample rations collected from the Government of Manitoba (2022d) were used as guidelines to build and incorporate pea screenings into three alternative rations and were then balanced using NRC (2016).

The quantities of individual ingredients for each of the six alternative feed rations all balanced successfully using the NRC program. Results demonstrate that pea screenings are nutritionally comparable to barley grain when used as an energy supplement in Manitoban cow-calf winter diet rations but contain much higher amounts of protein which is beneficial when low quality forage is fed.

Results indicate that the least cost ration favored the conventional practice of feeding barley straw plus barley feed grain and the alternative feed ration that provides barley straw plus pea screenings was 10.05% more costly compared to the conventional ration. Economic analysis revealed that the long-term pricing estimate for pea screenings is too high at this time to convince producers that the use of pea screenings would be economically beneficial. If feed manufacturers like Roquette wish to entice cow-calf producers, they will need to price their coproducts in a manner that makes them competitive with conventional products and feeding practices.

Results of the breakeven analysis provide adequate data to allow for price adjustments of pea screenings in order for the alternative rations to be competitive with the conventional rations. The findings suggest that the price of pea screenings may need to decrease to as low as

$58.17/ton in order for cow-calf producers currently feeding a ration of grass legume hay supplemented with barley grain to consider switching to the most economical pea screening ration consisting of barley straw and barley grain.

Realistically, producers may be unlikely to change their current practices for a near zero or minimal cost savings, especially if switching to a pea coproduct requires them to switch to a new feed supplier. Producers often place economic and social value on existing relationships where trust has been established as the result of reliable performance. Accordingly, any reduction in feed costs may need to be substantial for producers to assume the risk involved with a new feed type and/or source. A superior solution may be for existing feed supply dealers to purchase pea products directly from the pea plant and sell them to existing customers, who are more likely to trust the supplier, at an economically attractive price.

6.2 Limitations and Suggestions for Future Research

There are several limitations to this study, particularly with respect to the lack of data on pea screenings and other pea coproducts. Long term studies on pricing strategy as well as animal response data on feeding pea screenings are not yet available. Additional data will allow future research to determine how competitive pea screenings will be given fluctuating markets compared to conventional feed grains such as barley. Possession of a longer-term data set will decrease risk and give producers more confidence when considering incorporating these coproducts into their rations. This study also assumed long-term year average prices for most other feed ingredients, but the most economical ration may vary year-to-year depending on a variety of conditions (i.e., supply and demand, weather, disease outbreak, war, palatability when offered on a free-choice basis).

This research makes a variety of assumptions in order to simplify the realisation of forage diversity and feed choice for livestock throughout Manitoba. The feed options selected in this research were chosen to represent what is common in Manitoba, but in reality, producers grow different types of crops on their farm and tend to have their own opinions on what is best to feed their cattle. It is also assumed that there is no change in cost associated with transportation or methods used to feed pea screenings and that they would be locally available. Relaxation of these assumptions would make this research more realistic, but also far more complex, and it may not be the case that refining assumptions would change key results pertaining to the feasibility of incorporating pea screenings into cattle rations.

This research has demonstrated that there are potential for large-scale pea processing facilities to market a significant proportion of their coproducts, and that at least one of those coproducts (pea screenings) can be substituted for traditionally- used feed grains to meet the nutrient requirements of overwintering beef cows in the third trimester of pregnancy. Future researchers may wish to extend this study into use in lactating cow diets or feedlots, which may also be able to employ these coproducts in an economically viable way. Lactating cows have increased energy and protein requirements and feedlot cattle are fed predominantly high-quality forage diets early in their growth periods and high-energy cereal grain diets during the finishing periods. Roquette has expressed interest in feedlots as protein requirements of light weight calves are greater than cows creating an opportunity where pea screenings could offer an economic advantage compared to classical grain or meal (Delporte 2022).

The current research examined potential to supplement forage-based diets with pea screenings. Future research may explore the benefits and costs for cow-calf producers who utilize a silage-based feeding system, as it is not an uncommon practice in Manitoba. The largest market for Manitoba corn is livestock feed, more than half of the corn designated for silage was on specialized dairy farms, followed by 26.9% of area on beef cattle farms (Hamel and Dorff 2015). Corn silage is low in protein therefore the addition of high protein pea coproducts would be a good nutritional balance to this feed. Producers feeding silage would also benefit from the opportunity to utilize pea cream as well as pea screenings in their rations. Due to the liquid consistency of the pea cream, producers who have a liquid storage system would have the advantage of incorporating pea cream as a supplement to their TMR. For producers who do not currently have the ensiling infrastructure or liquid storage facilities, however, costs would be very significant and therefore pea cream may not be economically viable for them.

Ultimately, findings of this study would be of interest to Roquette and other prospective suppliers of pea coproducts as well as Manitoba cow-calf producers. The research demonstrates that pea screenings can be successfully substituted for traditionally used feed grain in an over-winter diet to meet the nutritional standards of a cow in the late gestation period of pregnancy. Though plausible, the price of pea screenings must be competitive with conventional products and practice in order to appeal to cow-calf producers.

References

Anderson, V., R. Harrold, D. Landblom, G. Lardy, B. Schatz, and J.W. Schroeder. 2002. A guide to feeding field peas to livestock: nutrient content and feeding recommendations for beef, dairy, sheep, swine and poultry. Extension Bulletin AS-1224, North Dakota State University Extension Service. Fargo, ND.

Anderson, V.L. 1999. Field peas in diets for growing and finishing steer calves. NDSU Carrington Research Extension Center Beef and Bison Field Day Proceedings. Vol. 22. Pp 9-15.

Bath, D., J. Dunbar, J. King, S. Berry, R. Leonard and S. Olbrich. (1998). By-products and Unusual Feedstuffs. Feedstuffs Vol 70, No 30, pp. 32-38

Beef Cattle Research Council. 2020. BCRC. (2020a, January 22). *Alternative Feeds*. https://www.beefresearch.ca/topics/alternative-feeds/

Beef Cattle Research Council. 2020. BCRC. (2020b, February 26). *Silage Cost of Production*. https://www.beefresearch.ca/blog/silage-cost-of-production/

Beef Cattle Research Council. 2022. BCRC. (2022, March 23). *Beef Cattle Research Council - Nutrition in Beef Cattle*. https://www.beefresearch.ca/topics/nutrition-in-beef-cattle/

Bloomberg. (2021, February 23). Meat prices poised to rise as feed costs squeeze producers. Arkansas Democrat-Gazette, Inc.

Briggs, G., W. D. Gallup, V. G. Heller, A. E. Darlow, and F. B. Cross. (1947). The Digestibility of Dried Sweet Potatoes by Steers and Lambs. Stillwater, OK, Oklahoma Agricultural Experiment Station, Oklahoma Agricultural and Mechanical College, Technical Bulletin No. T-28.

Caton, J.S., Grazul-Bilska, A.T., Vonnahme, K.A., Luther, J.S., Lardy, G.P., Hammer, C.J., Redmer, D.A., and Reynolds. L.P., 2007, January. Nutritional Management during Gestation: Impacts on Lifelong Performance. Center for Nutrition and Pregnancy, Animal and Range Science Department North Dakota State University, Fargo, ND

C-Lock Inc. (2022). SmartFeed Pro. Product Overview. Rapid City, South Dakota. https://www.c-lockinc.com/researchers/products/smartfeed-pro

Cowbytes 5 (2011). Alberta Agriculture and Rural Development. 5.3.1 Demo Version

Crawford, G. (2007, April 5). Avoiding Mineral Toxicity in Cattle. American Cattlemen, products and services for American Cattlemen. University of Minnesota Beef Center. https://www.americancattlemen.com/articles/avoiding-mineral-toxicity-cattle

Dahlen, C. (2016, February 2). Good Nutrition Vital for Pregnant Cows. North Dakota State University Extension and Ag Research News https://www.ag.ndsu.edu/news/newsreleases/2016/feb-1-2016/good-nutrition-vital-for-pregnant-cows

(Delporte, C. (2022, April 21) Personal email and phone communication

Dou, Z., Toth, J. D., & Westendorf, M. L. (2018). Food waste for livestock feeding: Feasibility, safety, and sustainability implications. In *Global Food Security* (Vol. 17, pp. 154–161). Elsevier B.V. https://doi.org/10.1016/j.gfs.2017.12.003

Durisin, M., Skerritt, J., Hirtzer, M., (2022, May 19) It Costs too Much for Ranchers to Satisfy World's Meat Demand. Bloomberg Business https://www.bloomberg.com/news/articles/2022-05-20/that-bacon-chicken-and-beef-won-t-get-cheaper-anytime-soon

ECCC. 2019. Taking stock: reducing food loss and waste in Canada. Waste reduction and management division. Quebec (Canada): Environment and Climate Change Canada. Available from https://www.canada.ca/content/ dam/eccc/food-loss-and-waste/Taking%20Stock%20Report%20EN%20 Final.pdf

Foodprint. (2022, March 15 updated) (published 2018, October 8). The Problem of Food Waste. Almost half of our food is wasted in the United States. How does this happen? What can we do to solve our enormous food waste problem? GRACE Communications Foundation. https://foodprint.org/issues/the-problem-of-food-waste/

Government of Manitoba. (2022a). Agriculture Beef. https://www.gov.mb.ca/agriculture/livestock/beef/print,index.html

Government of Manitoba. (2022b). Manitoba Markets and Statistics. Agriculture https://www.gov.mb.ca/agriculture/markets-and-statistics/index.html

Government of Manitoba. (2022c). When Should I Calve My Cows? Agriculture, Livestock, Beef. Https://Www.Gov.Mb.ca/Agriculture/Livestock/Beef/When-Should-i-Calve-My-Cows.Html#:~:Text=Spring%20calving%20herds%20usually%20calve,Third%20trimester%20and%20lactation%20periods. https://www.gov.mb.ca/agriculture/livestock/beef/when-should-i-calve-my-cows.html#:~:text=Spring%20calving%20herds%20usually%20calve,third%20trimester%20and%20lactation%20periods

Government of Manitoba. (2022d) Dupchak, K. Winter Rations for Beef Cows. Agriculture. https://www.gov.mb.ca/agriculture/livestock/beef/winter-rations-for-beef-cows.html (Date accessed 2022).

Government of Manitoba. (2022e) Cost of Production Guides & Calculators. Manitoba Agriculture https://www.gov.mb.ca/agriculture/farm-management/production-economics/cost-of-production.html

Hamel, M.-A., & Dorff, E. (2015, November 30). Corn: Canada's third most valuable crop. Statistics Canada. https://www150.statcan.gc.ca/n1/pub/96-325-x/2014001/article/11913-eng.htm

Lardy, G., Anderson, V., Dahlen, C. (2018, October) Alternative Feed for Ruminants. General Concepts and Recommendations for Using Alternative Feeds. North Dakota Sate University Extension Service https://www.ndsu.edu/agriculture/sites/default/files/2022-03/as1182_0.pdf

Lipinski, B. (2013, June 5). By the Numbers: Reducing Food Loss and Waste. World Resources Institute Washington DC. https://www.wri.org/insights/numbers-reducing-food-loss-and-waste

Manitoba Agriculture. (2008 February). A Quick Guide to Extended Grazing. Manitoba Agriculture, Food and Rural Initiatives • Agriculture and Agri-Food Canada • Manitoba Forage Council. https://www.gov.mb.ca/agriculture/crops/crop-management/forages/pubs/quick_guide_extended_grazing.pdf

Manitoba Agriculture. (2018, August 9). Ration planning to stretch hay supplies for cows and feeder calves. Manitoba Agriculture, Food and Rural Initiatives. https://www.beefproducer.ca/ration-planning-to-stretch-hay-supplies-for-cows-and-feeder-calves/

McKinnon, J. (2015, December 2). The facts on grain screening pellets. Nutrition with John McKinnon, beef cattle nutritionist Canadian Cattlemen. The Beef Magazine. https://www.canadiancattlemen.ca/nutrition/the-facts-on-grain-screening-pellets/

McKinnon, J. (2021, February 19). Late gestation rations for cows. Nutrition with John McKinnon, beef cattle nutritionist Canadian Cattlemen. The Beef Magazine. https://www.canadiancattlemen.ca/nutrition/late-gestation-rations-for-cows/

Montanholi, Y. Dahlen, C.R. Redden, R.R (2019 December). Comparing Value of Feedstuffs. North Dakota State University. https://www.ag.ndsu.edu/publications/livestock/comparing-value-of-feedstuffs

Moreno, L. Hoover, D (2017). ESTIMATING QUANTITIES AND TYPES OF FOOD WASTE AT THE CITY LEVEL ACKNOWLEDGMENTS The Natural Resources Defense Council. https://www.nrdc.org/sites/default/files/food-waste-city-level-report.pdf

NRC (National Research Council) Beef Cattle Nutrient Requirements Model 2016. EXE. 8th Revised edition. Microsoft® Excel® 2016 (version 16) National Academies of Sciences, Engineering, and Medicine

NRM. (2017, November 6). Added Sodium Essential To Keep Cows Healthy. Northern Roller Mills – Feed to Suceed. https://nrm.co.nz/2017/11/06/added-sodium-essential-keep-cows-healthy/#:~:text=The%20element%20sodium%20(Na)%20is,as%20well%20as%20water%20regulation.

OECD (Organisation for Economic Co-operation and Development (2020, June 2). Food Supply Chains and COVID 19: Impacts and Policy Lessons. OECD Policy Responses to Coronavirus (COVID-19) https://read.oecd-ilibrary.org/view/?ref=134_134305-ybqvdf0kg9&title=Food-Supply-Chains-and-COVID-19-Impacts-and-policy-lessons

Ominski, K., Mcallister, T., Stanford, K., Mengistu, G., Kebebe, E. G., Omonijo, F., Cordeiro, M., Legesse, G., & Wittenberg, K. (2021). Utilization of by-products and food waste in livestock production systems: A Canadian perspective. *Animal Frontiers*, *11*(2), 55–63. https://doi.org/10.1093/af/vfab004

Parish, J. (2007, February). Feedstuff Comparisons – As Fed versus Dry Matter. “Stocker Cents” article. Cattle Business in Mississippi. https://extension.msstate.edu/sites/default/files/topic-files/cattle-business-mississippi-articles/cattle-business-mississippi-articles-landing-page/stocker_feb2007.pdf

Peel, D. (2021, October 19). Higher Feed Prices this Winter. *FEED-LOT Magazine Inc*.Oklahoma State University Extension Livestock Marketing Specialist. https://www.feedlotmagazine.com/news/higher-feed-prices-this-winter/article_64889226-3041-11ec-8ebe-2b9e03af9d1e.html

Peterson, E.B., Strohbehn, D.R., Ladd, G.W., and Willham, R.L. (1989) The Economic Viability of Preconditioning For Cow-Calf Producers. Iowa State University, Ames 50011. (Date accessed: August 5, 2022)

Poore, M., Rogers, G., Ferko-Cotten, B., & Schultheis, J. (2000). *Sweetpotatoes and Associated By-products as Feeds for Beef Cattle* (M. Westendorf, Ed.; 1st ed). Iowa State University Press.

Purina. (2022). Ration Balancing : New Advances in Dairy Research.

Rezaei, M. (2017). *Feature Articles FOOD LOSS AND WASTE IN THE FOOD SUPPLY CHAIN*. http://theplate.nationalgeographic.com/2016/01/22/kenyan-farmers--ght-food-loss-by-drying-selling-mangoes/.

Rethink Food Waste through Economics and Data (ReFED), 2016. A Roadmap to Reduce U.S. Food Waste by 20 Percent. ⟨https://www.refed.com/downloads/ExecutiveSummary.pdf⟩

Ribeiro, G., and T. McAllister. (2016). Can the beef value of beer barley be rated with just one test? Available from https://www.country-guide.ca/crops/cereals/barley/can-the-beef-value-of-beer-barley-be-rated-with-just-one-test/

Roquette. (2022). Better Business, Stronger Planet: How Plant and Animal Protein Industries Work Together for a Better Result. Roquette Frères. https://www.roquette.com/plant-protein/the-standard/better-business-stronger-planet-how-plant-and-animal-protein-industries-work-together-for-a-better-result

Rush, I. G. (2005, December 7). Distillers Grains for Range Cattle. University of Nebraska-Scotssbluff. Angus Productions Inc. Range Beef Cow Symposium Animal Science Department

Soto-Navarro, S. A., Encinias, A. M., Bauer, M. L., Lardy, G. P., & Caton, J. S. (2012). Feeding value of field pea as a protein source in forage-based diets fed to beef cattle. *Journal of Animal Science*, *90*(2), 585–591. https://doi.org/10.2527/jas.2011-4098

Spinelli, F., & Corso, B. (2000). *The Economics of Feeding Processed Food Waste to Swine* (M. Westendorf, Ed.; 1st ed). Iowa State University Press.

Stewart, L. (2017). Mineral Supplements for Beef Cattle. University of Georgia Extension. https://secure.caes.uga.edu/extension/publications/files/pdf/B%20895_4.PDF

Sugiura, K., Onodera, T., Yamatani, S., & Watahara, M. (2009). Ecofeed, animal feed produced from recycled food waste. In *Veterinaria Italiana* (Vol. 45, Issue 3). www.izs.it/vet_italiana

Talcott, P. (2013) Mycotoxins. Vomitoxin (Deoxynivalenol) In Small Animal Toxicology (Third Edition) Science Direct https://www.sciencedirect.com/topics/agricultural-and-biological-sciences/vomitoxin/pdf

Task Force on Commodity Costs, A., & Buland data steward, D. (2000). *Commodity Costs and Returns Estimation Handbook A Report of the AAEA Task Force on Commodity Costs and Returns*.

Tiwari, A., & Khawas, R. (2021, June 14). *Food Waste and Agro By-Products: A Step towards Food Sustainability*.

Weiss, P., and F. Raymond. (1989). Utilisation du pois par les taurillons. Atout Pois. ITCF Eds./Paris. 1989

Westendorf, M. (2000). Food Waste to Animal Feed. Iowa State University Press. First edition, Library of Congress Cataloging-in-Publication Data. Edited by Michael L. Westendorf, includes bibliographical references

Wozniacka, G. (2019, August 20). Study Finds Farm-Level Food Waste is Much Worse Than We Thought. Civil Eats California. https://civileats.com/2019/08/20/study-finds-farm-level-food-waste-is-much-worse-than-we-thought/