COMPARISON OF EARLY (MARCH) AND LATE (JUNE) CALVING SYSTEMS ON COW AND PRE-WEANING CALF PERFORMANCE AND COST OF PRODUCTION ON WESTERN CANADIAN PRAIRIES

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ABSTRACT

A two-year study (2007, 2008) was conducted to evaluate the effects of two calving systems, early (March; Early Calving System (ECS)) vs. late (June; Late Calving System (LCS)) on cow, pre-weaning calf performance and feeding system management and costs. Both early and late calving systems were managed at three locations on the Canadian Prairies: Agriculture and Agri-food Canada (AAFC)-Brandon Research Centre (Brandon, Manitoba); AAFC-Semi arid Prairie Agricultural Research Centre (Swift Current, SK); and Western Beef Development Centre (Lanigan, SK). Four feeding management systems (drylot (DL), pasture (PG), swath-windrow (SG) and bale grazing (BG)) were utilized at all three locations to maximize grazing systems.

Management of animals through the four different feeding systems was found to meet or exceed protein and energy requirements according to NRC (2000). Differences in cow body weight (BW) (P=0.001; location) were observed across locations at pre-calving and weaning periods although there were no obvious patterns when comparing across calving systems. A significant three way interaction was observed for cow BW at breeding (P=0.003), and for cow body condition score (BCS) at breeding (P=0.002). Body condition score at breeding indicated there was a significant (P=0.002) three way interaction, where there were no significant interactions when comparisons across calving system within the same year (Y) and location (L) were performed for Brandon and Lanigan in 2007 and for Lanigan in 2008 also, therefore no improvements in one calving system compared to the other. At Brandon in 2007, ECS cow BCS were similar to LCS cows. In 2007 and 2008, the inverse occurred at SC where LCS cows had greater BCS compared to the ECS. The same two way (Calving System x Location) interaction was significant at pre-calving and weaning for both cow rib (P=0.003; P=0.007) and rump fat (P=0.002; P=0.02) where Lanigan had significantly lower rib and rump fat for the LCS as compared to the ECS. Rib and rump fat measurements did not follow a typical pattern. Fluctuations in body fat reserves varied depending on the calving system and location. Even though differences (P<0.05) occurred in cow BW and fat reserves, there was no significant difference (P>0.05) in reproductive performance between the two calving systems within the management of the current study. Pregnancy rate, calving rate, calving span and weaning rate were similar for both early and late calving systems.

In 2007, calf mortality on average was higher for LCS (5%) vs ECS (1.7%) and the inverse occurred in 2008, where LCS had lower calf mortalities than did ECS, 3.3% and 4%, respectively. Most calf mortalities were born dead or weak. There appeared to be no negative impact on calf mortality with early or late calving systems. A significant two way (Calving System x Year) interaction was observed for calf BW at birth ($P=0.002$) (Table 4.4). Treatment (Calving System) ($P<0.0001$) main effect was significant for ADG (Table 4.4). The average values for calf birth weights for ECS in 2007 and 2008 were 42.1 and 41.2 ± 0.45 kg and for LCS in 2007 and 2008 were 41.4 and 44.1 ± 0.47 kg, respectively. Birth weights in 2007 between ECS and LCS were not different but in 2008 calf birth weight for LCS was heavier ($P<0.05$) than ECS calves. As expected calf birth weights were affected by L ($P<0.0001$). Calf birth weights were 44.8, 40.5 and 41.5 ± 0.8 for BR, SC and LA. Weaning rate was not affected by calving system, location or year. Pre-weaning ADG was 1.13 and 0.96 ±0.01kg d^{-1} for ECS and LCS, respectively. Weaning weights were therefore significantly ($P<0.05$) heavier for ECS as compared to the LCS, 273 and 240 ±1.82 kg, respectively.

The results of cow and calf performance indicate that calving later in the year does not significantly affect cow performance or reproductive efficiency but calf growth rate is significantly affected largely due to the time of year. Labour and feeding system management and costs are typically lower for LCS because of the ability to manage the cow herd on pastures and extended grazing systems which reduces the need for stored feeds during periods of cold weather.

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LIST OF ABBREVIATIONS

AAFC-BRC	Agriculture and Agri-food Canada – Brandon Research Centre
AAFC-SPARC	Agriculture and Agri-food Canada – Semiarid Prairie Agriculture Research Centre
ADF	Acid detergent fibre
ADG	Average daily gain
BCS	Body condition score
BR	Brandon, Manitoba
BW	Body weight
CP	Crude protein
DM	Dry matter
ECS	Early calving system
h	Hour
LA	Lanigan, Saskatchewan
LCS	Late calving system
mo	Month
MP	Metabolizable protein
N	Nitrogen
NDF	Neutral detergent fibre
P	Probability
SAS	Statistical analysis system
SC	Swift Current, Saskatchewan
SD	Standard deviation
SE	Standard error
%	Percentage
WBDC	Western Beef Development Centre

1 GENERAL INTRODUCTION

In the last 50 years, the calving period in western Canada has been gradually moved into late winter, early spring. With the feedlot market needing calves in the fall, the reason for producers to calve earlier in the year was to raise a bigger marketable calf. Early calving systems were also preferred because of more favourable labour distribution to decrease confliction with spring farming practices. The calving period can affect how the remainder of the production year is managed. Feed and labour resources are either purchased or produced to help manage the cow herd. Producers use several feeding management systems to ensure cow performance is optimal at critical time during the year: calving, breeding and weaning. The cost of these management systems will vary greatly from year to year because of precipitation and temperature conditions. Cow-calf producers have looked to reduce costs through extending the grazing season and managing the cow-herd in low-cost winter feeding systems. Level of utilization of these feeding systems can change because the nutritional requirements of the beef cow will vary with physiological status, such as during gestation and lactation. Moreover, as temperatures are above or below the thermal neutral zone, maintenance needs of the cow change and nutrient utilization can vary drastically.

Calving earlier in the calendar year can change management practices: increased use of harvested forages, use of machinery to feed the animals, increased fuel and labor needs were important to manage a cow-herd that was calving in colder weather. Infrastructure and facility can also change. Shelter from the consistently changing environment in late winter, early spring was needed. Permanent calving barns or shelters were established to alleviate the effect of the unstable climate. These changes in management were implemented with an added cost to raising a calf to weaning. The costs incurred by the cow herd are the costs that must be recovered by the sale of the calf.

In 2003, export markets were changed drastically in Canada because of finding bovine spongiform encephalopathy (BSE) in Canadian cattle. Today, Canada still remains heavily dependable on the export of live animals for slaughter to the United States of America (U.S.A). The closure of the border strongly affected the price of the weaned calf because of the lack of availability to slaughter finished cattle. The beef cattle herd in Canada hit a peak in 2005 at 16,900,000 head but has fallen 4.9 percent to 14,000,000 in 2010 (Statistics Canada 2010). To remain competitive within the beef industry and with other meat industries, cow-calf producers are forced to look at alternative management practices for ways to reduce costs. By delaying the calving period, it has been found in other studies in Canada (Pang et al. 1998; Stonehouse et al. 2003) and United States (Adams et al. 1996; Carriker et al. 2001; Grings et al. 2003) that labour and feed costs to maintain the beef cow herd can be reduced without significantly affecting cow performance (Pang et al. 1999). Even though this research is applicable, it is out of date because of the change in cattle markets, fuel prices and labour costs. Studies done in the United States are more current but the assumption that the environmental and market conditions are similar to the western Canadian provinces may not always be accurate.

The objectives of this literature review are to provide an overview of all corresponding factors that influence beef cow-calf production based on two types of calving systems (March (early) versus June (late)), to review:

- cow and calf performance differences as influenced by various feeding systems and nutrient availability;
- the various grazing periods and their use in different production systems;
- the effect of the environment on the outcome of the various feeding and calving systems; and
- the differences in cost of feeding system.

2 LITERATURE REVIEW

2.1 Calving Systems in Western Canada

Timing or season of calving can affect the synchrony between the nutrient dynamics in forage and nutrient requirements of beef cows, producing large effects on inputs and outputs from a rangeland-based cow-calf production system (Adams et al. 1994a; 1996). In nature, foraging animals would give birth to their newborns in synchrony with warm weather, the summer months, to give the young a chance during a period of increased susceptibility to disease and adverse environmental conditions. Calves born in the summer months, does not allow for a long growth period before weaning in the fall, therefore the calving date has been moved earlier in the calendar year to increase calf weaning weights and to reduce the interference with spring farming practices (Sprott et al. 2001). Therefore, changing the calving date is feasible, but managing the cow herd should be focused on matching cow nutrient requirements with available feedstuffs. The use of mechanically harvested forages is required when the calving season does not coincide with available feed resources that meet the nutrient demands of a pregnant or lactating beef cow.

2.1.1 Winter and Spring Calving

Late winter and early spring calving has typically been the system of choice to decrease interference with other spring farming practices. Calves born in spring (March to April) have lighter weaning weights in the fall (Pang et al. 1999; NRC 2000) and costs are low relative to winter born calves (January to February), but spring born calves are typically heavier than summer born calves (Julien and Tess 2002; Stonehouse et al. 2003; Grings et al. 2005; Renquist et al. 2006). Cost savings usually come from feeding less harvested feeds needed to maintain the cow herd throughout the winter months. Calves born in the spring are generally not exposed to extreme cold weather although late spring snow storms can happen on the prairies. However, in a Montana study, Grings et al. (2005) found February calves gained 0.12 kg d^{-1} less from birth to the beginning of the breeding season (approximately 69 d of age) than April or June borne calves. Once forage quality improved throughout the summer, average daily gain (ADG) improved from 69 d to weaning for the early born calves.

2.1.2 Summer Calving

Directly following parturition, a beef cow's nutrient requirements are highest because of the onset of lactation. A summer calving cow's nutrient requirements can mainly be met by perennial forages during the summer months but nutritional challenges coincide with declining forage quality in late summer (Reisenauer Leesburg et al. 2007b). Calves born in summer normally are not exposed to extreme cold weather. Calves born late May or early June, face favourable weather conditions during the summer period but may be exposed to extreme hot or dry weather conditions in late summer. These conditions may be unfavourable due to the possibility of dehydration and lack of available forage in the growing season. Calf growth rates may be impacted because of lower quality forages available in the fall or early winter (Stockton et al. 2007). Neonatal calves from an early age of 1 to 4 m typically depend solely on the dam's milk (NRC 2000). The lactating dam may be affected by warm summer weather when dry matter (DM) and water intake may decrease, affecting total milk production (Sprott et al. 2001). For these reasons, the high temperatures in late summer can affect total nutrient supply for the calf and consequently, the calves may have a lower pre-weaning growth rate (Sprott et al. 2001; Stockton et al. 2007). Summer born calves are typically weaned in early January and have lighter weights than a late winter or early spring born calf (Reisenauer et al. 2001; Stonehouse et al. 2003). Backgrounding of the summer born calf post-weaning is often done to increase calf weight prior to marketing (Stonehouse et al. 2003; Reisenauer Leesburg et al. 2007a).

2.1.3 Fall Calving

Fall calving is seen as being more favourable economically than spring or summer calving, but a disadvantage is that pasture forage quality declines into the fall. Higher quality forages are needed than what is available on fall pasture since cows are lactating during the fall and winter months (Curtis et al. 2008). Cows calving in the fall (September to November) will consume more hay than cows calving from January to March (Bagley et al. 1987; Reisenauer Leesburg et al. 2007b). Feed quality can be of concern at this point to maintain high conception rates during environmental conditions that require increased nutrient demands along with higher feed costs (Brees and Horner 2007; Curtis et al. 2008). According to Curtis et al. (2008) fall calving is gaining popularity in the Midwestern United States, as a result of the higher conception rates, lower calf loss at or near parturition and greater market prices for fall born calves (Bagley et al.

1987; Kreft et al. 1998; Sprott et al. 2001). Market prices are typically high in early summer when fall born calves are ready to be sold. This is just before cool season forage production declines in mid-summer which is one advantage that fall calving has over spring and summer calving (Kreft et al. 1998).

2.2 Nutritional Management of the Beef Cow

Managing the beef cow throughout the year can be a challenge as nutrient requirements change not only because of physiological status but also by climate. About 70% of the energetic cost for a cow production year is attributable to maintaining the non-pregnant, non-lactating cow (Jenkins and Ferrell 1983). There are many factors that impact energy maintenance of a cow not including lactation and gestation, which are: (1) physical activity; (2) ambient temperature above or below thermal neutral zone; (3) protein intake above necessary requirements; (4) decreasing metabolizable dietary energy; (5) physiological degree of maturity and (6) body composition can impact the maintenance requirements of an animal (Reid et al. 1980). When primarily utilizing forages throughout the year, beef cows generally cannot meet all requirements for maintenance, gestation or milk production. Thus, supplementation with higher quality forage, energy or protein supplements is needed. Conversely, Stonehouse et al. (2003) and Adams (1996; 2001) found that when delaying the calving season, the lactating cow's nutrient requirements can primarily be met through foraging of available pasture perennials. Sprott (1999) and Sprott et al. (2001) are in agreement, where they found nutritional requirements of the cow will vary seasonally and can depend on calving season, weaning date, breeding season, replacement heifer needs, and animal size. Klosterman et al. (1968) reported that Charolais and Hereford cows may have similar requirements but body condition has a large role on the energy requirements needed. Malnutrition can delay the onset of puberty, increase the duration of postpartum estrus, cause decreased conception rates, increase embryonic mortality, affect prenatal development and cause abnormal sexual behaviour of the cow (Bratton et al. 1959; Wiltbank et al. 1964; Corah et al. 1975; Richards et al. 1986; Houghton et al. 1990a). Guo et al. (2007) found failure to meet energy requirements of the cow prior to calving and into the transition period can have detrimental effects, not only on the cow but the calf's performance is also affected because of lowered milk production. This study was performed on Holstein cows therefore the importance of an energy dense diet with the onset of lactation is critical to cow health and maintenance of milk production. Lowered milk production was also associated with the lack in change of an energy dense transition diet therefore greater need of mobilizing of adipose tissue and greater exposure to ketone bodies significantly affected the cow's health for a longer period (Guo et al. 2007). These authors found that if the density of the diet coincided with parturition, the negative effects of the onset of lactation as well as a decrease in dry matter intake were lessened (Guo et al. 2007). This is also relevant to beef cows as the physiological change pre- and post-partum is equivalent to that of a Holstein dairy cow (Bratton et al. 1959; Monty and Wolff 1974; Fisher and Williams 1978).

Since the pre- and post-calving periods are the most stressful time on the beef cow, it may be ideal to manage the beef cow in a production system that is also less demanding, such as a summer calving system. A milder environment during the calving season and therefore during the pre- and post-calving season, has been proven to improve reproductive efficiency of the cow and ameliorate body condition at breeding (Stonehouse et al. 2003).

2.2.1 Nutritional Requirements of the Beef Cow during Gestation

Meeting the nutrient requirements of the beef cow during gestation is imperative for proper foetal growth and the subsequent lactation following parturition. For growing heifers (2 and 3 years of age), maintenance and body growth are also important to consider in addition to the growth of the fetus, thus extra energy must be considered when feeding pregnant heifers (Ferrell et al. 1976b). All factors are central to ensuring the cow is rebred within 80 d post calving. Wiltbank et al. (1964) found the interval from calving to first estrus ranged from 49 to 82 days. The shortest post-partum interval (PPI) was found with the treatment group that had adequate energy requirements pre-calving, according to NRC (2000), therefore feeding level of energy had a large impact on PPI. Wiltbank et al. (1962) performed a study with 4 treatment groups, 2 pre-calving energy levels (High, 9.13 lb per d; Low, 4.54 lb per d) and 2 post-calving energy levels (High, 15.99 lb per d; Low, 7.91 lb per d). The occurrence of estrus after calving was significantly influenced by feeding level. Even though, both the pre- and post-calving energy levels influenced onset of estrus, the level of energy provided before calving appeared to be relatively more important. A higher proportion of cows had cycled by 90 d post-calving, and estrus was exhibited sooner after calving in the cows receiving the high energy ration prior to calving (Wiltbank et al. 1962). The majority of cows that were fed a continuous low energy plane failed to show estrus, while most of the cows (85%) on the low-high regime had cycled by 90 days post-partum (Wiltbank et al. 1962).

Underfeeding of protein can also reduce cow and calf performance such as: reduced birth weight, weak labor, decreased milk production, increased dystocia and poor rebreeding performance (Bellows and Short 1978; Kroker and Cummins 1979). Patterson et al. (2003) compared metabolizable protein (MP) requirements on primiparous beef heifers and its effects on pregnancy. Two treatments were evaluated with 2 diets where one was formulated to meet MP requirements and the other crude protein requirements. The body condition score of the heifers played a large role in the effect of the treatments. When heifer body condition at calving was lower, pregnancy rates were reduced and the response to MP treatment was greater. Pregnant heifers may respond to supplementation to meet MP requirements, especially if they are losing body condition during the winter.

2.2.2 Nutritional Requirements during Lactation

The breeding season for the beef cow occurs during the lactation period, approximately 45 to 60 d post-calving, therefore adequate nutrition is crucial to maintain milk production as well as optimize reproductive performance. As previously mentioned, nutritional requirements greatly impact the post-partum interval. High energy diets (≥ 2.45 Mcal ME/kg; NRC 2000) are needed to meet the requirements of the lactating cow however if the diet is low in energy, body condition, body weight and reproductive efficiency of the cow will be compromised (Buskirk et al. 1992). It is crucial to maintain good body condition throughout the lactation period for successful reproductive performance of the cow and sustained calf growth rate. Lactating cows will most likely lose body weight in the first 30 to 60 d of lactation, but should be able to regain body condition and body weight during the remainder of the lactation period provided the cow's nutritional requirements are met (Buskirk et al. 1992; Loy et al. 2002).

Milk production in beef cows is very difficult to assess and even more so in crossbred cows (Grings et al. 1996; Short et al. 1996; NRC 2000). Energy and protein supplements are often used to meet the requirements of the lactating beef cow on pasture, typically during late summer when forage quality and digestibility is low. Creep feeding supplements can also be used to meet the calf`s nutrient requirements and reduce the dependency on the cow later in the lactation period (Loy et al. 2002).

Increased calf growth rates can significantly affect the nutritional requirements of the cow because of increased consumption of milk (Grings et al. 1996). Therefore, cows that have increased milk production to meet the increased demand of the calf also have increased dry matter intake (DMI) and consequently increased body condition and body weight fluctuations.

2.2.3 Nutritional Requirements of the Cow Post-Weaning

Following weaning the beef cow's nutrient requirements decrease significantly because of cessation of the lactation period (NRC 2000). The beef cow is usually pregnant at this point but nutrient requirements are not significantly affected by the foetus of a mature cow in good body condition until late gestation (Hess et al. 2005). Following weaning of the calf, the cow's energy and protein requirements will decrease. This is a period of time where lower quality feed can be fed to meet maintenance requirements.

2.3 Grazing Management

Beef cattle in western Canada are managed under various summer and winter grazing systems to meet nutrient requirements while considering varying environmental factors. Meeting nutrient requirements can be difficult when genotype of the animal, environmental conditions, physiological status, and feed resources can all influence the nutrient demand of the animal (NRC 2000). The efficient utilization of pasture forages by beef cows and calves is necessary to optimize production. Nutritional management of the beef cow throughout the year in western Canada can be a challenge. Range and pasture land in western Canada will vary in providing available high quality forage. The growing season can start in early May and may provide quality forage well into the fall depending on temperature and total amount of precipitation. A large percentage of annual moisture on the western prairies comes from snow accumulation during the winter months and this will affect the quantity and quality of pasture forage the following spring. Snow fall and spring rain will also impact pasture production for the growing season. As temperatures increase and precipitation decreases in late summer, pasture forage can often be adequate to maintain a cow-calf pair because of varying nutritional requirements of the cow (Adams et al. 1996; Hersom 2009). Physiological status of the cow influences nutritional requirements and are highest during late gestation (i.e. third trimester) and early lactation (NRC 2000).

Utilization of perennial pastures and harvested forages are strongly related to the timing of the calving season (Adams et al. 1996). Cow-calf production depends heavily on forage systems with as high as 90% of total diet being forage based (Barnes and Nelson 2003). Grazing systems must satisfy many objectives such as providing appropriate quality and quantity of forage for the breeding herd, ensuring the sustainability of the forage resources, promoting healthy, vigorous plant growth and maintaining the desired botanical composition (Hersom 2009).

2.3.1 Summer Grazing Management

The growing season in western Canada is relatively short, averaging only 120 to 150 d from April to August and changes depending on the total and timing of precipitation. Efficient utilization of available pasture forages in this time period is essential for reducing feed costs. Cool and warm season grasses are the foundation of the grazing period and should be grazed according to their growth pattern (Figure 2.1). Cool season grasses are identified by the C_3 photosynthetic pathway. Warm season grasses have C_4 photosynthetic pathways. Both photosynthetic pathways are important for the varying temperature during the growing season in western Canada. Both C_3 and C_4 are adapted to different optimal temperatures, which is mainly due to photorespiration and total precipitation. Palatability and nutritive value is greatly affected by ideal growing conditions for each species (Wilson and Hattersley 1989; Volenec and Nelson 2007). Generally, C_3 plants have higher dry matter digestibility than C_4 species (Larcher 2003). However, warm season (C_4) plants are unique in such a way that growth can occur under drier and hotter conditions than C_3 plants (Holechek et al. 2004). In addition to this advantage, C_4 plants have enhanced photosynthetic ability in arid climates and improved water, N and light use efficiency (Kocacinar and Sage 2003). Furthermore, when CO_2 concentrations are low within the leaves, warm season plants are still capable of photosynthesis (Ehleringer and Monson 1993).

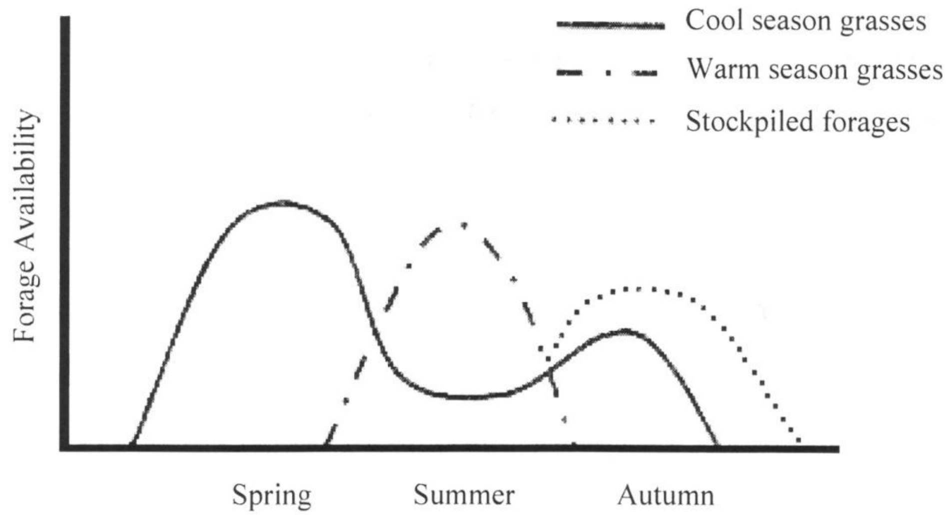

Figure 2.1 The typical availability of different forages throughout the growing season (adapted from Cherney and Kallenbach (2007)).

Warm season grasses' optimal growth temperatures are usually 30 to 35 degrees Celsius (^{o}C) and growth slows considerably below 15 ^{o}C. Cool season grasses achieve peak production early in the growing season, as early as May and as late as early October. Ideal growing temperature for C_3 forages is usually 20 to 25 ^{o}C and growth has sustained when temperatures drop as low as 1-2 ^{o}C (Baron and Bélanger 2007). Warm and cool season forages differ in their photosynthetic pathways where the biochemical processes that use the electrons from the light reactions to reduce CO_2 to the carbohydrate level. C_3 photosynthesis occurs with a key enzyme, ribulose-bisphosphate carboxylase/oxygenase, which fixes CO_2 directly using CO_2 concentration near the enzyme active site and is so named because of the first product of CO_2 fixation is a 3-carbon acid, 3-phosphoglyceric acid (Volenec and Nelson 2007**).** Warm season species' photosynthesis occurs through a specialized CO_2 concentrating process in the mesophyll cells that use the enzyme phosphoenolpyruvate carboxylase (PEPc), which uses carbonic acid instead of CO_2 or O_2 directly (Volenec and Nelson 2007). This section does not attempt to review the many characteristics of warm and cool season forages. Excellent descriptions of both types of forages available on the Canadian prairies have been published (Bruynooghe 1996; Kusler 2009; Ward 2009).

Various grazing systems have been used to efficiently graze or harvest forages during optimal growth stage to maximize palatability and nutrient quality. By grazing at the right stage of maturity for each forage species total grazing days can be extended and decrease the use of mechanically harvested forages. In a study conducted by Janovich et al. (2004) total amount of hay required by August or April calving cows did not vary significantly, 1,061 and 1,096 kg DM cow^{-1}, respectively, when managed in a year round grazing system. An increased amount of dry matter intake (DMI) was found when cows in the April-calving system were managed using harvested forages (2,409 kg DM cow^{-1}), which resulted in a difference of 1,313 kg DM cow^{-1} (Janovick et al. 2004).

A study by Fisher et al. (1996) studied two grazing systems, continuous and rotational grazing. Different stocking densities for both grazing systems were used throughout the summer management period. Body weight and condition for summer calving cows was not different between grazing systems. This would suggest there are various ways to manage cows on summer pastures without a negative impact on cow performance or reproductive efficiency. Utilizing different grazing systems within a summer or late winter/early spring calving system would be possible as long as nutrient requirements were met at all times.

2.3.2 Extended Grazing Systems

Incorporation of extended grazing systems and alternative forages introduces different ways to meet the pregnant cow's nutrient requirements during critical periods and efficient utilization of various annual crops and perennial forages that are available (Olson 2005). By extending the grazing season into the fall and winter, decreased amounts of days are spent in drylot pens feeding mechanically harvested forages (Adams et al. 1994b; 1996; 2001) and subsequently can decrease the cost of managing a cow-calf herd (Stonehouse et al. 2003).

In late summer, forage quality declines and continues to decline through the fall and winter, creating a long period when nutritional quality of pastures may limit maximal beef production (Adams 1987). This period is a critical time to include grazing alternatives to meet nutrient demands of the cow and calf. One disadvantage of extended grazing systems on the Canadian prairies is the total accumulation of snow during the winter months. Snow depth can limit the accessibility to the forage and may increase energy requirements needed to access the feed. NRC (2000) states that an increase of 10 to 20% in maintenance energy requirements for foraging animals as compared to penned animals. McCartney et al. (2004) found that cows grazing swaths required at least 18 to 21 percent extra energy, which may have been because of the extra energy needed for walking, foraging and maintaining body temperature during winter.

In addition to increasing total cow grazing days, extended grazing systems also improve nutrient cycling on perennial and annual cropland. The nutrients deposited by the animals directly on the pastures and cropland are then available for next year`s crop (Lux et al. 1999). Traditionally in Canada, management of beef cows in the fall and winter occurs in a drylot pens. However, with increased costs associated with winter feeding other management practices are being utilized to decrease costs and labour needs.

2.3.2.1 Perennial Stockpiled Forages

Stockpiling of forages is a grazing method to lengthen the grazing season through the accumulation of pasture forages for use in the fall (Riesterer et al. 2000a). Accumulation must be done to ensure adequate forage dry matter production is available at time of grazing. Once the summer forages have been exhausted, use of stockpiled pastures can be used. Stockpile grazing can also be used in spring prior to the new growth of spring grazing pastures (Allen et al. 1992; Hitz and Russell 1998; Janovick et al. 2004). Success of stockpiling forage depends on the forage species, intensity and time of grazing, soil nutrient management and length of accumulation (Matches and Burns 1995). Length of time suggested for sufficient accumulation is two months during the growing season or late summer (Kerley et al. 1990). Forage species such as smooth bromegrass (*Bromus inermis* L.) and crested wheatgrass (*Agropyron cristatum*) stockpiled for later use may not meet grazing animal requirements every year because of low protein content (Baron et al. 2004). It is important to have sufficient forage biomass up to 2000 kg ha^{-1} for grazing later in the season to ensure grazing efficiency is met (Coleman 1992) and to facilitate accessibility through snow (Baron et al. 2004). In years with minimal snow coverage and mild temperatures, stockpiled forages were used more efficiently throughout the winter months and increased total amount of grazing days for that year, and in turn decreased the amount of harvested hay needed to maintain the cow-calf herd calving in either April or August (Janovick et al. 2004). Kerley et al. (1990) reviewed research examining the value of stockpiled tall fescue (*Lolium arundinaceum*). The authors found the ideal stockpiling period occurred in late summer, 1 June to 31 August or 1 July to 30 September. Yield was greatest and animal response to the forage available to graze in early winter was maximized. Allen et al. (1992) conducted a trial managing stockpiled tall fescue in late summer and showed the forage provided adequate nutrition for winter grazing beef cows in Virginia. Allen et al. (1992) found that pregnant cows grazing stockpiled fescue-red clover (*Lolium arundinaceum - Trifolium pratense* L.) gained more weight from November to January than cows grazing orchard grass (*Dactylus glomerata* L.) stockpiled with either red clover or alfalfa (*Medicago sativa* L.). Weathering can be a concern when managing stockpiled forages because of its effect on reducing forage quality and availability. In addition, leaf aging and senescence, freezing and rainfall are all events which decrease the nutritive value of perennial stockpiled forages (Burns and Chamblee 2000).

At Lacombe, Alberta, 7 different perennial forage species were evaluated to assess the length of time needed and the efficiency of use for grazing as stockpiled forages (Baron et al. 2004). The species studied were “Algonquin” alfalfa, “Carlton” alfalfa, smooth bromegrass (*Bromus inermis* L.), ‘Paddock’ meadow bromegrass (*Bromus riparius* (Rehm.)), ‘Kay’ orchardgrass (*Dactylis glomerata*), ‘Troy’ Kentucky bluegrass (*Poa protensis* L.), and ‘Boreal’ creeping red fescue (*Festuca rubra* L.). The bromegrass and alfalfa species tended to have the shortest accumulation period needed for efficient stockpiled grazing. Meadow bromegrass appeared to be best adapted and produced consistent stockpiled forage yields. Creeping red fescue provided good nutritive value and accumulation period. Quackgrass (*Elymus repens*) can be used for stockpiling but yields tend to be low and nutritive losses are extenuated into the spring.

Allen et al. (1992) compared orchardgrass and tall fescue and found that tall fescue produces more forage and was better utilized for stockpiling. Thus less harvested hay was needed for supplementation compared to the stockpiled orchardgrass system. In years with increased total precipitation, tall fescue had increased production as compared to other grasses used for early spring and late fall grazing.

Following hay cut in July, sub-irrigated meadow re-growth was utilized for 60 d starting in September. Better gains were observed on pre-weaned calves, compared to weaned calves grazing native Sand-Hills range near Whitman, Nebraska (Lamb et al. 1997). The reason for better gains on sub-irrigated meadows may have been a result of the higher quality regrowth available following haying. In the same study, cows grazing sub-irrigated meadow pastures also maintained body weight and condition whereas cows grazing native range lost weight and body condition. Following weaning in September, calves were also managed on meadow re-growth and performed better than pre-weaned calves on the same pastures, thus introducing an efficient way to manage extended grazing programs in a cow-calf system (Lamb et al. 1997).

Including stockpiled forages in the grazing management system can efficiently maintain gestating cows and will significantly decrease the amount of harvested hay irrespective of the calving system. Moreover, the use of stockpiled forages will depend greatly on total snow cover and ambient temperature, which can vary from year to year. Accessibility of the standing forage can be of great concern to producers in some areas of western Canada where an increased amount of snow accumulates (Lawrence and Heinrichs 1974). But it has been found that cattle can graze standing perennial forages in snow depth of 0.5 m if adequate biomass is present (Riesterer et al. 2000b). Perennial legumes are not usually used for stockpiled grazing, because of the exacerbated effects of weathering, leaf loss, disease and maturation and frost in the fall (Matches and Burns 1995).

2.3.2.2 Swath Windrow Grazing

Grazing annual pasture and swathed windrow crops are used to extend the grazing season into the fall. These management systems can also be utilized in the spring prior to the start of summer grazing. The practice of using annual crops to extend the grazing season has been used for the past 100 years (Kilcher and Heinrichs 1961). In western Canada, cool season perennial forages will produce 60% of their seasonal production by 1 July, therefore introduction of annuals for grazing can be implemented when perennial pastures are depleted and allow for higher quality forages available later in the grazing season when perennial pastures are exhausted (Baron et al. 1993). All annual cereal crops and 75% of most forage species are grasses (Moser 2003). Annual crops used for livestock feed can be seeded at a later date to coincide with peak production and time of use (Kilcher and Lawrence 1979). Earlier seeding dates (May vs. June) generally provides 35% more forage yield than late seeded cereals on Black soils in Wyoming (Kibite et al. 2002; May et al. 2007) although, weathering losses or palatability may be an issue when seeded earlier. In central Alberta, annual crops are seeded later in the growing season to coincide with swathing at the mid-dough stage in the fall (McCartney et al. 2008), which provides the cows with the highest quality of forage with minimal dry matter loss (Hutton et al. 2004). Commonly used annual cereals for swath windrow grazing in western Canada include oats (*Avena sativa* L.), barley (*Hordeum vulgare* L.), triticale (*Triticosecale rimpaui* Wittm.), winter wheat (*Triticum aestivum* L.), annual ryegrass (*Lolium perenne* ssp. *multiflorum*) and fall rye (*Secale cereale* L.) (Baron et al. 1991; Beacom 1991; Aasen and Baron 1992; Holt 1993; Willms et al. 1993; McCartney 2000). Swath grazing annuals is similar to stockpiling perennial forages in that they are managed to extend the grazing season. Total precipitation from September to April will also affect the nutritive value of the swathed forages caused by weathering effects and is seen to have similar or lower losses than perennial stockpiled species (Aasen et al. 2004). Years with less total precipitation, including snow, will have less detrimental effects on the nutritive value of the swathed crop. Volesky et al. (2002) reported that standing stockpiled forages seemed to have less nutritive value loss than swathed forages which may have been due to weathering effects in Nebraska. The same results were found in central Alberta where annuals left standing resulted in reduced grazing efficiency which may have been caused by an increase in trampling (Entz et al. 2002). Annual crops can be managed as standing or swathed forage but standing annuals may result in less grazing efficiency. Willms et al. (1993) in southern Alberta reported cows grazing winter wheat and corn in late fall had improved body condition, therefore suggesting nutrient requirements were met or exceeded prior to the winter feeding period.

Annual legumes such as field peas (*Pisum sativa* L.), lentils (*Lens culinaris* Medik.), hairy vetch (*Vicia villosa* Roth) and crimson (*Trifolium incarnatum* L.) can also be utilized for swath windrow grazing on the Canadian prairies and have similar nutritive values as compared to swathed annual cereals or perennial stockpiled forages but should be grazed prior to the winter period because of high losses in nutritive quality (Aasen et al. 2004; Sheaffer and Evers 2007). Aasen et al. (2004) looked at the potential of spring cereals, field peas and mixtures for swath grazing in the fall and spring. Forage mixtures provided no consistent improvement over monocultures in nutritive value compared in November and April. Compared to perennial stockpiled forages, annual crops had similar loss in nutritive value over winter on the Canadian prairies.

2.3.2.3 Winter Grazing Management

Winter feeding costs can be 65 to 70% of total production costs in a cow-calf enterprise system (Miller et al. 2001). To reduce these costs, alternative grazing systems can be adopted. On average, there are 200 winter feeding days recorded on the Canadian prairies which are associated with the elevated feed costs (Entz et al. 2002). Moreover, feed requirements usually increase because sub-zero temperatures are below a beef cow’s thermo-neutral zone (TNZ)

(NRC 2000). Therefore, it is critical to consider various winter feeding options to reduce feeding costs with minimal impact on beef cow productivity.

2.3.2.4 Bale Grazing

Bale grazing is a winter feeding method designed to reduce labour and equipment costs when compared to feeding the cow herd in a drylot system. Bale grazing is a management system that allows the animal to graze and forage its own feed following the placement of the mechanically harvested and baled forage on a winter feeding site. Placement of the winter feeding site can be on a perennial pasture or on annual cropping area. Similarly to the swath windrow feeding site, both options for the bale grazing site allow for the beneficial deposit of nutrients from the animals and can be utilized by the plants in the subsequent year. Bale grazing, if managed properly, is an easy and efficient way to increase total grazing days with minimal impact on cow performance. Compared to swath windrow grazing, bale grazing costs may be higher because of machinery use to bale the feed and hauling the bales to the wintering site, but this management system still places greater reliance on the grazing animal to harvest its own feed as compared to drylot feeding. Moreover, in certain situations, swath windrow grazing can have higher costs because of hauling water or checking cows more often (Nayigihugu et al. 2007). Volesky et al. (2002) found that bale grazing had lower wastage (12.5%) compared to swath-windrow grazing (29%) when calves were managed on both systems. Mature cows are generally more aggressive and would most likely utilize swaths and bales more efficiently which was observed when cows grazed the same areas as calves. Smith et al. (1974) and Kallenbach (2000) estimated a lower percentage of wasted feed, 4.7 and 5.4%, respectively, when bale grazing. However, Smith et al. (1974) also managed the bale grazing site with bale feeders to minimize the animals using the hay as bedding.

Weight gain was similar for calves managed on bale grazing and swath grazing sites on the Nebraska sand hills (Volesky et al. 2002). Years where there was regrowth on the swath grazing site calves tended to have better average daily gains than on the bale grazing site. Kelln et al. (2010) studied various winter feeding systems such as bale grazing, swath grazing and straw-chaff grazing near Lanigan, Saskatchewan and did not find any differences in cow performance. Reproductive efficiency was not significantly affected, nor was maintenance of body condition. Feed quantity and quality was monitored and was adequate for meeting nutrient requirements for gestating beef cows. Typically, forage quality is maintained throughout the winter when baled, although fibre content will increase slightly (Volesky et al. 2002).

As in all winter feeding systems, supplementation may be required to meet maintenance requirements of the foraging animal to retain body condition especially on the Canadian prairies where winter temperatures is typically lower than the cow's thermal neutral zone (Willms et al. 1993). To minimize the need for supplementation and to aid in maintaining body condition, portable windbreaks should be used to decrease the effects of wind chill and winter storms, which is commonly observed in western Canada (McCartney et al. 2004).

2.4 Methods of Forage Quality Evaluation

Correct formulation of beef cow diets is very important as feed costs account for the greatest fraction of the total costs of raising livestock. Accurate knowledge of forage quality and the chemical composition of all feeds available are very important. The response depends both on the nutritive value (concentrations of nutrients per unit mass of forage) and the amount of forage consumed. The chemical composition of forages can vary widely according to the moisture level of the soil, physiological age of the plant and botanical composition (Adesogan et al. 2000). Determining forage quality can only be done accurately with a representative sample of the forage through sub-sampling and proper mixing of the sample prior to analysis (Adesogan et al. 2000). To accurately evaluate the forage the animal is eating, sampling should be done when the animal is foraging (Linn and Martin 1991). The nutritive value of forage is not only determined by its chemical composition but also by its digestibility and the nature of the digested products (Mott 1973). The various chemical and biological methods of evaluation are well described in other reviews and papers, therefore this paper will not attempt to review the various methods (Van Soest 1994b; Weiss and Pell 2007).

2.4.1 Chemical Methods

For over 150 years, proximate analysis has been the principal method for feed analysis (Van Soest 1967,1994b). The separation of the feed's components was extracted through multiple series of chemical separation to determine each nutritive fraction to establish the feeding value of the feedstuff in question. The shortcomings of this method are resultant of uncovering the nutritive fractions but this does not determine the digestibility of each fraction.

2.4.2 Energy Determination

The energy component of feedstuffs provides the body with the ability to do work, which consists of growth, lactation, reproduction, movement and feed digestion. Energy is often expressed as per cent total digestible nutrients (TDN). Usually the largest component of feed costs, and is required by cattle in the greatest amount. The determination of %TDN is the sum of digestible starch, fibre, protein in the feedstuffs. Net energy system (NE) is also used to express energy levels based how they will be used to maintenance, growth, lactation or pregnancy.

2.4.3 Protein Determination

Protein concentration of forages is determined through the determination of nitrogen (N) in the feed and by then converting the N content into protein (N x 6.25). This conversion factor is accurate for most feeds, but other factors have been used based on the protein source (Van Soest 1994c). Nitrogen fertilization can alter the nitrogen distribution in plant sources and can cause nutritional problems for the ruminant such as inefficient nitrogen utilization (Van Soest 1994c). Accurate N results can be achieved through the Kjeldahl technique. The Kjeldahl technique is not a quick way of determining the N fraction of feeds but is quite sensitive to N concentrations. The LECO N determinator is very useful for large batches of samples, which is based on the Dumas combustion method (AOAC method 990.03)**.** Combustion methods often give higher values than Kjeldahl methods. This is a result of measuring some additional N-containing compounds, for example, nitrates (Adesogan et al. 2000).

2.4.4 Fibre Determination

The degree of lignification and cell wall content are two important factors to determine when characterizing the chemical composition of forages because of its influence on the rate of digestion. Crude fibre was traditionally the method used to determine the fibre content of forages, but can result in variable measures that depend on cutting date, species and maturity of the forage sampled. However, prediction equations have been developed to accurately determine the digestibility of lignin (Adesogan et al. 2000). Fibre digestion has been further broken down to its constituents: total fibre fraction (neutral detergent fibre, NDF) and the less digestible fraction (acid detergent fibre, ADF) (Van Soest 1967).

Neutral detergent fibre (NDF) is the portion of the plant that digests in a neutral detergent solution and results in three separate fractions, hemicellulose, cellulose and lignin which are the major components of the insoluble fibre present in the cell wall of plants. Cellulose and hemicellulose are partially available for digestion, but are not uniform among different forages. Heat stable amylase was introduced to help with the degradation of the starch present where most of the fibre may be bound in concentrates (grains). Without heat stable amylase included in the analysis, high levels of starch present in feeds, predominately grains, causes variable and inaccurate levels of NDF measured because of the bound fibre components. Acid detergent fibre (ADF) is the analysis used to identify the more soluble components of the feedstuffs, such as cellulose, lignin and silica. These components are present at varying levels depending on the feedstuffs and are digested using an acid detergent solution. The isolation of this component is also a preparation step for the analysis of acid detergent lignin (ADL), which is indigestible (Van Soest 1967).

Fibre is an important factor of the feedstuffs of ruminant animals and is present in all forages at varying levels. Fibre ensures rumen health by maintaining a neutral rumen environment with a pH of 7. Cell wall intake is proportional to time spent ruminating (Van Soest 1994). Lowering the levels of fibre in a diet decreases retention time and thus, may cause an unbalanced environment in the rumen (Van Soest 1994). Knowing the fibre contents of the feeds presented to ruminants is important.

2.4.5 Biological Methods

2.4.5.1 In Vitro Digestions

Numerous *in vitro* artificial rumen systems have been developed to estimate forage digestibility (Van Dyne 1968; Campbell 1969), which involve the fermentation of a ground forage sample in a flask or tube with rumen microorganisms in a buffered medium. A common digestion technique is the *in vitro* digestion with rumen fluid by Tilley and Terry (1963). This two stage technique determines dry or organic matter digestibility of dried forages. A 48-h digestion with rumen organisms is followed by a second digestion of equal length with pepsin in weak acid (Van Soest 1994a). The technique provides similar values as the *in vivo* digestibility values of many forages and can be more accurate because *in vivo* microorganisms and enzymes are sensitive to undetermined factors that influence rate and extent of digestion (Van Soest 1994b).

Certain disadvantages are the need for a fistulated animal at all times for a constant supply of rumen fluid and the length of time required doing the analysis. The forage fed to the fistulated animal should also be similar to that being analyzed to decrease the need to adjust digestibility results (Tilley and Terry 1963).

An alternative to using rumen fluid is a technique developed to simulate digestion through the use of enzymes. Several cellulose based techniques have been used to estimate forage digestibility. In general, these methods are simple and highly reproducible but precision of the technique is questionable and tends to be less than when using rumen fluid (Van Soest 1994b). The constant supply of cellulose can be expensive and result may vary between laboratories (Gabrielsen 1986). An important factor to consider is the deproteinizing of the sample because of protein's interference with digestion. The same problem can exist if starch is present in the sample (Van Soest 1994b).

2.4.5.2 In situ Rumen Degradability

Forage digestibility can also be determined through the use of polyester bags placed directly in the rumen for a graded amount of time. This *in situ* technique is theoretically superior to *in vitro* digestibility techniques because it provides information on the dynamics of forage digestion (Adesogan et al. 2000). There are important sources of variation with this technique such as, sample preparation, washing and drying procedure, animal effects, bag type, pore size and modelling (Huntington and Givens 1995). Problems with the rumen degradable technique include correction for particulate losses, particularly in starch-rich forages, and choosing the appropriate outflow rate. The bag pore size can be very problematic when considering the amount of outflow of sample through the holes, therefore overestimating the soluble fraction. The final step of washing the bags can also lead to an increase in error. All in all, standardizing this method is important to decreasing errors at each step.

2.5 Measuring Animal Performance

Animal performance must be measured to accurately assess the outcome of a certain treatment, such as calving system or different feeding systems. Change in weight and body condition may be affected by the results of treatments imposed onto the animals, but many environmental factors can influence the outcome thereby affecting animal performance as well. An animal's response to a new environment can indicate a positive or negative impact of the treatment implied and can result in an adverse reaction such as decreased reproductive performance (Bellows and Short 1978; Thompson et al. 1983). Measurements should be taken at regular intervals or at critical points in the production cycle to objectively assess changes in body weight or energy reserves (Thompson et al. 1983; Tennant et al. 2002). There are three available and common techniques used to assess animal performance: live body weight, ultrasonic measurements of body composition and body condition scoring. All three techniques can be learned quite easily but benefits and limitations of each technique must be taken into consideration.

2.5.1 Body Weight

Live body weight change has been used to evaluate beef cow and calf performance in numerous studies and is widely used in industry (Rutledge et al. 1971; Bellows and Short 1978; Whittier et al. 1988; Fiss and Wilton 1989; DeRouen et al. 1994; Arango et al. 2002). Body weight is often used as a stand-alone measurement or can be used to assess a sequence of measurements to assess the change in body weight. Body weight is commonly used to assess animal performance because of its ease of measuring. There can be substantial within day and between animal live weights variations because of gut fill. It has been seen to be as high as 20%, which is associated with the daily pattern of grazing, drinking, urinating and defecating (Coates and Penning 2000). Quantity, quality and availability of feed can also strongly skew the weight measurements. Therefore, standardized weighing procedures can be critical to the interpretation of a weight change and eliminate the effects of gut fill (Corbett 1978; Coates and Penning 2000). Live body weight can also be affected by the physiological status of the cow (Tennant et al. 2002), as a result correction for conceptus weight must be done to accurately assess a change in body weight (NRC 2000).

Body weight measurement following a 12-16 hr fast is a commonly used method to reduce the variation in gut fill. Water is usually also withheld. Fasting may not be logistically possible at times, such as in large grazing studies where separate holding facilities are not available; therefore weight measurement can be done at the same time of day during two to three consecutive days. Grazing animals follow a diurnal pattern of weight loss and gain. Steers were found to lose weight from 6:00 to 8:00 AM and then increased from 8:00 to 10:00 AM, therefore emphasizing the importance of consistency in time of weight measurements (Cook and Stubbendieck 1986). Various studies have shown that one technique will increase or decrease the error of body weight measurements (Cook and Stubbendieck 1986; Coates and Penning 2000), therefore the use of one method throughout the study and used equally on all treatments within one study. In a summary done by Cooke (1959), he found that one-day weighing seems to decrease the discrepancy in interpretation of body weight change in cattle. Animals should be weighed with the least amount of disturbance and excitement. The excessive use of whips, shouting, and any other practice that may cause the animals to be excited is strongly discouraged. Mixing the treatments and weighing in a random order can help in randomizing certain factors that may occur and disturb the animals (Cook and Stubbendieck 1986).

Even though different methods to measure body weight can significantly affect the interpretation of the performance of the animal, these effects are only temporary and will generally have no significant effect on longer-term body weight change. Body weight change may be confounded when comparisons are made over one month or less (Cook and Stubbendieck 1986). Therefore, in the case of a study over two years, such as this one, the use of different methods to measure body weight may not affect the interpretation of the long term outcome of the study.

2.5.2 Body Condition

Procedures have been developed to simplify measuring body composition. Body composition includes water, protein, fat and ash, while chemical composition of the carcass is determined by the distribution of muscle and fat (Coates and Penning 2000). Ultrasonic techniques has been used to assess carcass composition of meat animal species in the livestock industry for more than 40 years (Fisher 1997). The use of this technique to measure carcass composition has been pushed in recent years to have an accurate grading system and to assess the animals prior to slaughter (Perkins et al. 1992a). Ultrasonic measurements are relatively cheap and easily accessible. Moreover, the measurements are objective and accurate, but can be highly variable depending on the training and experience of the technician (Wallace and Stouffer 1974; Perkins et al. 1992b). However, Perkins et al. (1992b) and Herring et al. (1994) found repeatable ultrasonic fat measurements were taken with two highly trained and experienced technicians.

Body condition scoring (BCS) is a subjective technique used to assess the amount of subcutaneous fat present on a cow and is then extrapolated to reflect animal performance (Coates and Penning 2000; Marston 2005). It has been proven to have a direct relationship with body energy reserves (Wagner 1984; Houghton et al. 1990b; Buskirk et al. 1992; Fox et al. 1992; Pang et al. 1998) and affects reproductive performance of the cow (DeRouen et al. 1994). Two BCS systems are typically used today. The Canadian version presently being used, although not exclusively, is a 5 point scale system (Lowman et al. 1976). The system used in the United States is a 9 point scale (Marlowe et al. 1962; Lowman et al. 1976; Tennant et al. 2002). Regardless of the system used, repeatability and validity of the BCS system has been questioned. Not one system is perfect therefore use of more than one technique is appropriate to eliminate bias. Similarly to ultrasonography, it is important to train the technicians that will be assessing the BCS of the animals. Use of the same technician throughout one study and between treatments will also improve repeatability and reduce inaccuracy of the data generated within a study (Perkins et al. 1992b; Herring et al. 1994).

2.6 Evaluation of Body Condition Pre- and Post-Calving

Body condition at calving is strongly correlated to calving difficulty and subsequent fertility (Wiltbank et al. 1962; Dunn and Kaltenbach 1980; Richards et al. 1986; Buskirk et al. 1992; Fields and Sand 1994; Stonehouse et al. 2003). Dunn and Kaltenback (1980) reported that pre-partum weight change affected reproductive performance of cows in moderate body condition at calving. The authors reported that 69 to 74% of cows in moderate body condition showed signs of estrus 60 d post-partum, compared to only 48 to 51% of cows that lost body condition prior to parturition (Dunn and Kaltenbach 1980). Houghton et al. (1990a) reported that cows that lost a full body condition score prior to calving remained open for over 80 d following calving. Moreover, if cows have improved body condition post-partum and during early lactation, reproductive performance can improve significantly (Wiltbank et al. 1962). These results are also supported by Renquist et al. (2006) and Selk et al. (1988) who reported that good body condition at breeding increased pregnancy rate. Richards et al. (1986) found that cows that calved with BCS $\geq$ 3 had a shorter PPI than cows with BCS $\leq$ 1.8. Cows that calved with BCS $\leq$ 1.8 had a PPI 12 d longer than cows with a higher body condition score irrespective of the nutritional management group.

Cow BCS at parturition affects the length of the postpartum interval (PPI), and length of time for cows to show estrus post-partum (Wiltbank et al. 1964; Richards et al. 1986). Houghton et al. (1990a) found that cows with a BCS < 2.7 at parturition had an extended PPI, 28 to 58 d longer than moderately conditioned or fleshy cows. Studies found that as long as BCS at parturition was adequate (>2.7), the high body energy reserves may be enough to carry the cow through the critical post-calving period (Bellows and Short 1978; Bellows et al. 1982; Graham et al. 1982).

The conclusion of several studies (Dunn and Kaltenbach 1980; Selk et al. 1988; Whittier et al. 1988; Freetly et al. 2000) is that cows with good BCS prior to parturition will be reproductively successful. To manage nutritional status so that optimal levels of reproductive performance level can be achieved, targets need to be established for cow BCS at critical points in the annual cow production cycles (Table 2.1). Many Canadian (Pang et al. 1998; Stonehouse et al. 2003) and American (Adams et al. 1996; 2001; 2003; Grings et al. 2007; 2008) studies have found that delaying the calving date by 30 to 120 d did not significantly affect cow reproductive performance and body condition was maintained by providing adequate pasture forage. Thus, by comparing late winter, early spring calving systems to summer calving systems, cow performance was not diminished. Body condition was maintained at adequate levels at critical points in the annual production cycle of the beef cow, therefore subsequent fertility was not jeopardized.

Table 2.1. Recommendations for body condition score (5 pt-scale) at critical points in the annual production cycle of the beef cow [z]

Critical Point	Recommendation
At calving	Too high can cause dystocia, delay rebreeding (Recommendation 2.5-3.5)
Calving to breeding	By breeding (Recommendation: 3), if BCS at calving is lower, feed to increase BCS; if adequate at calving, feed to maintain BCS
During summer	Grazing and livestock management should allow BCS to increase
In fall	BCS should be highest seen during year; if it does not exceed 3, winter feed costs will be high to maintain or improve condition
During winter	BCS will usually decrease under winter grazing or feeding; if fall BCS is not greater than 3, extensive hay feeding or supplementation will be required (Recommendation >2.5)

[z] Adapted from Olson (2005) and DeRouen et al. (1994)

2.7 Factors Affecting Calf Growth Rate

Factors that have the greatest effect on calf birth weight are breed of the sire and dam (Andersen and Plum 1965; Bellows et al. 1982; Reynolds et al. 1990). Heterosis, parity of the dam, foetus number, sex of the foetus, environmental temperature, and nutrition of the dam can also affect calf birth weight and subsequently, calf growth rate (Bellows and Short 1978; Burfening et al. 1978; Bellows et al. 1982; Nelson and Beavers 1982; Doornbos et al. 1984; Marshall et al. 1990; van Oijen et al. 1993; Browning et al. 1994). Underfeeding of protein during gestation was found to affect pre-weaning calf growth rate (Bellows and Short 1978; Kroker and Cummins 1979). Pre-weaning calf weight is directly correlated to total milk production of the dam (Renquist et al. 2006). Younger cows normally produce lower quantities of milk than multiparous cows (NRC 2000), therefore calf growth rate can be significantly affected by age of the dam. Multiparous cows normally calve and wean heavier calves than do first calf heifers (Notter et al. 1978; Doornbos et al. 1984; Barkhouse et al. 1998; Renquist et al. 2006). Cow nutritional requirements are elevated during lactation and if these requirements are not met, body fat reserves will be mobilized to maintain adequate milk production (Buskirk et al. 1992). It is critical to maintain cow`s body condition to ensure maximum milk production, as dietary energy intake by the cow can affect pre-weaning calf gains (Houghton et al. 1990a; Renquist et al. 2005). Rutledge et al. (1971) reported that milk production accounts for 66% of the variance in calf weaning weights. Cows that received low energy diets post-partum, have lighter weight calves, 14.3 and 15.1 kg, respectively, at 60 and 105 d of age (Rutledge et al. 1971). Similarly, Richards et al. (1986) studied cows that were fed low energy diets (≤ 20.7 Mcal ME) post-partum raised a calf that had significantly lower weaning weights than the other treatment groups. Wiltbank et al. (1962) reported that low energy intake by the cow in late gestation had an adverse effect on both calf growth rate and survival. When the calves remain in the breeding herd, underfeeding of heifers can result in lower gains and delayed onset of puberty. This was shown when Angus-Hereford crossbred heifers were fed to gain 0.27, 0.45, or 0.68 kg/day, reached puberty at 433, 411 and 388 d of age, respectively (Short and Bellows 1971). Not only was the onset of puberty affected, but it also affected the subsequent pregnancy rate where the same rates of gain resulted in lowered pregnancy rates, 50, 86, and 87 percent, respectively.

Providing calves with supplemental nutrition prior to weaning can be an efficient way of maintaining cow body condition by removing the stress of supplying 100% of the calf's nutrition and to improve calf growth rate. This management style is referred to as creep feeding and can be supplied in a variety of ways. Allen et al. (1992) provided additional nutrients to calves with orchardgrass-red clover and orchardgrass-alfalfa pasture mixtures. The calves grazing the orchardgrass-red clover pastures had greater gains and weaning weights. Myers et al. (1999) used grain as a creep feed for 55 d prior to weaning and found that calves that were supplemented while suckling the dam gained 32% faster compared to calves that were not supplemented but were still on the same pastures as the supplemented calves. Reed et al. (2006) used a supplement pellet as a creep feed source that consisted of wheat middlings, soyhulls, molasses and limestone. Calves remained with the dam throughout the study. The authors did not find an increase in BW gain compared to the calves that were not supplemented. However, forage organic matter intake did decrease because of intake of the creep pellet, therefore allowing for increased forage availability for the dam and decreased the need to suckle (Reed et al. 2006). Therefore, depending on the source of creep feed supplement, supplementation prior to weaning can be used to increase weaning weights, reduce grazing pressure and improve feed intake at weaning (Allen et al. 1992; Myers et al. 1999; Reed et al. 2006). Supplemental feeding of calves via creep feeding is most likely something that later (summer) calving systems may need to consider. Ideal usage of creep feeding would be during the time when forage quality is declining later in the summer and fall months. By providing additional energy to the calf through supplementation, the cow could meet her nutrient requirements through the additional forage available.

2.8 Herd Health

An important management area is a preventive herd health program that focuses on control and prevention of disease related problems that may cause economic loss. Bellows et al. (2002) reviewed several sources from USDA National Animal Health Reporting System early State plot studies and more recent national studies and estimated that reproductive disorders of major importance include female infertility, abortions/stillbirths, dystocia, retained placentas, and metritis. Of all these factors, 80% of the problems occur because of female infertility, dystocia and abortions/stillbirths.

2.8.1 Cow Health

Viral and bacterial infections can cause many adverse consequences in both the cow and calf. Abortions, dystocia, death, lowered reproductive performance and low calf growth rate can be some outcomes (Laster and Gregory 1973; Bellows and Short 1978; Doornbos et al. 1984). Infertility, which refers to decreased conception or failure to conceive, is costly because producers will typically cull and market open females. To this point, the producer has associated costs of purchasing and raising the animal and the additional expense of replacing the animal (Bellows et al. 2002). Vaccination against the viral and bacterial diseases can help reduce the long term effects on the cow and calf. Fetal infections associated with the bovine viral diarrhoea virus (BVDV) can result in infertility, abortions, stillbirths and weak calves (Baker 1995). Infection of the fetus from 58 to 120 d of gestation may create persistently infected (PI) calves that shed the virus continuously and perpetuate the herd infection (McClurkin et al. 1984; Van Campen et al. 2000).

Cows and heifers that are managed in small areas experience more dystocia and stillbirths (Dufty 1981). This situation is often observed in winter and late spring calving systems where cows or heifers are housed indoors or in drylot pens. Consequently, the environment may be the cause for increased calf morbidity and mortality in winter calving systems because cold temperatures and wet conditions usually will provide a perfect environment for pathogens (Dufty 1981). As a result, summer calving may have an advantage to late winter, early spring calving because of the ability to calve on well-drained, open pastures. Cows will have additional space that usually aids in alleviating the stress of calving and will in turn reduce the incidences of dystocia, stillbirths and the transmission of viruses and bacteria during gestation.

2.8.2 Calf Health

Calving can be a very stressful time for the new born calf. It is critical for the new born calf to consume the colostrum in the first 24 to 48 h after birth (Bush and Staley 1980; Drost 1994). Passive immunity is defined as the transfer of immunoglobulins from the colostrum from the cow to the calf (Muggli et al. 1987). Inadequate transfer of colostral immunoglobulins occurs in 10 to 25% of newborn calves (Perino 1997). A study in Nebraska looked at the interactions of immune traits in beef calves (Muggli et al. 1987). Angus calves were observed to be more active in the first 24 h after birth and had higher immunoglobulin ingestion in the first 24 h. Higher activity early in life may increase ingestion of immunoglobulins because of increased suckling within the first 48 h of life, therefore increasing ingestion of colostrum. Calf growth was also significantly affected through to 12 mo of age. Weaning weights were greater from calves with higher titers at birth (Larson et al. 2004).

Calf treatments for winter born calves were much higher than for summer born calves, 33% vs. 14%, respectively, in a study in Ontario (Stonehouse et al. 2003). Exposure of pathogens to winter born calves is assumed to be higher because of calving environment, therefore increasing the need for treatments. Summer born calves have a relatively uncontaminated environment on pasture. The major symptom of the disease was calf scours.

2.9 Environmental Effects on Cow-Calf Production

2.9.1 Breeding Period and Performance

The breeding period of any calving system impacts the success of the cow-calf production system. If the cow fails to conceive, there will be no marketable calf to sell. Seasonal differences in fertility occur and are directly related to changes in ambient temperature and day length (Christensen 1980). Sprott et al. (2001) reviewed many studies evaluating the effects of high temperatures at the time of conception and before and after breeding. Results reported showed significant increases in embryonic death as temperature increased impacting the female reproductive system. In contrast, as the temperature drops, cow nutrient requirements will increase to maintain body temperature and cows in average body condition are known to be cold stressed at temperatures below -20 ^{o}C (NRC 2000). Conception rates were reported to have dropped as a result of cold stress but also as a consequence of decreasing day length (Mercier and Salisbury 1947b,a; Neuendorff et al. 1984). In the southern United States, when natural breeding was managed from a November to January period, conception rates of beef cows were 93 and 94% , respectively (Sprott 1999). These results suggest the beginning of the breeding season should be while day length is increasing. However as the period of increasing day length progresses, environmental temperature also increases in this region of the United States and this can cause heat stress. However, average daytime temperatures are elevated (> 25 ^{o}C), if the night time temperature cools down (< 15^{o}C), the detrimental effects of heat stress may be negated (Monty and Wolff 1974). Effects of high temperatures are usually more of a concern in southern United States where humidity exacerbates the effects of high temperatures (Sprott et al. 2001).

Similarly, on the Canadian prairies, temperatures increase in late summer, from July to September, therefore the possibility of heat stress affecting the success of the breeding season is plausible. By late August, day length is decreasing. The breeding season for summer calving cows starts in late August but effects as seen in southern United States are not mimicked on the Canadian Prairies. Pang et al. (1998) found that summer calving cows had a shorter calving period than did the late spring calving cows. The extent to which the environment affects calf birth weight, also involves the severity, duration and timing of exposure of the insult as well as the genotype of the dam (Collier et al. 1982).

In the male, heat stress reduces sperm quality and numbers (Meyerhoffer et al. 1985). An insult of heat stress of 12 h in duration can reduce sperm production and cause an effect that lasts 6 to 8 wk which is the length of time sperm maturation needs to recover following an offence (Meyerhoffer et al. 1985; NRC 2000). Heat stress increases the temperature of the testis and cessation of the insult will dictate the severity of the outcome on the bull's reproductive status (Chenoweth 2005). Semen quality is affected by many factors, including abnormal scrotal thermoregulation (Coulter and Kozub 1984; Coulter et al. 1997), stress (Barth 1994), body condition (Barth et al. 1995), testicle size (Almquist et al. 1976; Palasz et al. 1994), age and season (Fields et al. 1979; Kumi-Diaka et al. 1981). Management factors, body condition, environmental stresses and photoperiod related endocrine changes may result in differences in the proportion of bulls with satisfactory breeding soundness classifications at different times of the year (Barth and Waldner 2002). Therefore, when temperatures on the Canadian prairies reach their peak during the late summer months, this could have a detrimental effect on the breeding period for the summer calving period.

Development of a replacement heifer in a late winter, early spring (early) calving system vs a summer (late) calving system has not shown to be advantageous in one system over another. The differing nutrient intake patterns for heifers born in either early or late systems were successful in rearing heifers to successful maturity weight for the subsequent breeding season. This was found by Grings et al. (2007) in the Northern Great Plains of the United States where pregnancy and growth rate did not differ significantly. Similar results were found for mature cows in the Northern Great Plains by Grings et al. (2005). From these studies, we may conclude the same effect on heifer development and mature cows when comparing early and late calving systems.

2.9.2 Cold Stress and Calf Performance

Temperature extremes can greatly affect calf health and survivability. New born calves cannot withstand heat or cold stress as can older calves (Gonzales-Jiminez and Blaxter 1962). Hypothermia can occur in calves that are born into cold, wet, snowy conditions which can occur in early spring in regions that experience cold weather (Olson et al. 1980). The potential for recovery of hypothermic animals depends on the duration and the severity of the insult (Robinson and Young 1988). If hypothermic calves are exposed for an extended period of time, this can result in physical exhaustion, dystocia, depletion of metabolic substrates and a shift in body fluids (Robinson and Young 1988). Reynolds et al. (1990) found that environment played a large role in affecting calf birth weight and calf growth rate and was highly variable from one year to the next. The environment in late winter, early spring on the Canadian Prairies could cause significant cold stress on calves born in this period but variation from one year to the next would occur.

2.9.3 Precipitation and Water Management

Water is often overlooked as the most important nutrient for livestock. Total precipitation, which includes rain and snow, is critical for pasture growth and is essential for recharging surface water sources for livestock watering. Availability of water plays a large role in managing grazing programs but also an important role in cow and calf performance through the regulation of body temperature, growth, reproduction, lactation, digestion, metabolism, excretion, and maintenance of mineral homeostasis, hearing and eyesight (NRC 2000; Kerley and Lardy 2007).

Water quality is also very important and can impact cattle performance on pasture. Grazing cattle will consume water from all available sources which can directly affect performance (Pandey et al. 1989; Lardner et al. 2005). Daily water consumption (24 to 54 L/d) is approximately three-fold greater than dry matter intake (Hyder et al. 1968; Kerley and Lardy 2007) and can directly affect cow performance by influencing total feed intake. Lardner et al. (2005) reported that steers had improved performance on pasture when drinking from aerated water from a trough compared to steers drinking water directly from a dugout. Availability of a good water source is therefore also critical for lactating cows in the summer months because of risk of dehydration. Quantity of milk produced is directly related to nutrient intake which includes water (NRC 2000).

2.10 Cow-Calf Production Economics

2.10.1 Economic Factors Affecting Cow-Calf Systems

Identifying the factors affecting the economic efficiency of a cow-calf enterprise is the basis to understanding which management decisions will greatly influence profit margins. The economic efficiency of the cow herd is greatly dependent on strategically matching feed resources with the rest of the production system (Vavra and Raleigh 1976; Adams et al. 1996; Anderson et al. 2005; Reisenauer Leesburg et al. 2007b). The factor with the greatest impact on the economic efficiency of the cow-calf enterprise is feed (Miller et al. 2001; Stonehouse et al. 2003). In many forage based production systems, there are periods during which nutrient availability from grazing is limited. Allowing cow body weight to fluctuate with nutrient availability is a potential management option that could reduce the cost of cow-calf production. However, incorrect timing of nutritional restriction can decrease reproductive performance and therefore the efficiency of the production system (Adams et al. 1996; Grings et al. 1996). By delaying the calving period from March into June, the cows are in an earlier stage of pregnancy therefore can maintain lower body condition throughout the winter on lower quality feedstuffs. A study conducted in Ontario by Stonehouse et al. (2003) found that summer calving systems reduced labour needs because of decreased use of mechanically harvested forages and less supervision and assistance at calving.

In Alberta, Basarab (2001) reported the cost of feed over the winter ranged from $88 to $320 per cow per winter feeding period, which would be higher today because of increased labour and fuel costs. This range in feed costs may be attributed to different cow type, body condition score, time of calving and management practices. Economic data was collected from Illinois and Iowa cow-calf producers to analyze which variables affect the profitability of cow-calf production systems (Miller et al. 2001). The most influential variable on profitability was feed costs which accounted for 50% of total variables costs, with depreciation (9%) and operating (5%) costs as the second and third critical factors affecting cost, respectively. In Nebraska and in Iowa, savings due to winter grazing are a result of reduced harvesting, handling, feeding and manure removal costs (Hitz and Russell 1998; Volesky et al. 2002). The various management practices that can increase the cost are fall and winter grazing programs, balancing winter rations, rotational grazing and supplement programs (Kruse et al. 2008). Timing of calving can also affect the synchrony between the nutrient dynamics, producing a large effect on inputs and outputs from rangeland-based cow-calf production systems (Adams et al. 1996; Stockton et al. 2007). An optimal calving system balances outputs and inputs to maximize profit.

2.10.2 Value of the Calf

The breakeven point and net profit from marketing the calf at weaning is heavily influenced by the cost to maintain the cow during the year and seasonal variance in market price. Feed grains exhibit seasonal variation in price and are important components of beef cattle supplements. It is well known that feeder cattle prices are influenced by feed grain prices (Dhuyvetter et al. 2002). Generally, the heavier the weaned weight of the calf, the higher the price received for the animal as payment is based on price per pound. Typically, summer or fall born calves are more commonly marketed after an extended period of backgrounding (Stonehouse et al. 2003). This is in contrast to selling the animal at a lighter weight at weaning and to hit a higher target market weight. If the calf is retained in the herd for a longer period of time, it is critical to minimize the cost to raise the calf through efficient feeding practices to minimize the cost of feeding the pair or post-weaning (Carriker et al. 2001). When calves are weaned early at 160 to 180 d of age, summer costs are less than costs associated with late winter or early spring born calves due to the lower costs of maintaining the lactating cow throughout the summer months (Adams et al. 1996; Carriker et al. 2001; Stonehouse et al. 2003). Increasing the amount of pounds weaned per cow exposed is an important factor that incorporates good conception and calving rates, and growth and weaning rates. These are factors that imply optimal cow and calf performance. When managing the summer calving system, alternative marketing options should be considered because of lighter calves in the fall when markets are open to weaned calves. Therefore, unless there is available fall grazing programs, the cost of raising a late born calf will not be less than an early born calf.

By calving in May, market opportunities increase for the calves throughout the year. Therefore, instead of managing the cow-calf herd for one market, calves are managed to be either sold at weaning, in the spring time, or in the following fall as a yearling. Market prices for the available animal weights will determine whether the animals are sold.

2.11 Summary

Regardless of the cattle industry's economic situation and market stability or instability, producers will continue to express a need to reduce production costs. New management methods can be applied but the impact of alternative strategies on animal performance and economic efficiencies are often questioned. An alternative calving system can be implemented but the impact of one change in the management system will influence the congruence of the remainder of the system. Therefore, proper management of the whole system is imperative to reap the economic and production benefits of a new system.

The hypothesis of the research undertaken in this thesis is that cow and calf performance will not differ between spring (March) and summer (June) calving systems. The objectives of this project were to evaluate the effects of early (March) and late (June) calving systems on cow and calf performance. Cow performance was assessed based on cow body weight and condition. Cow reproductive efficiency, which includes calving span, calving pattern and pregnancy rate, was also used to assess performance in both calving systems. Furthermore, calf performance was assessed through the evaluation of calf growth rate and weaning rate. Finally, an assessment in feeding system costs of both calving systems will be calculated.

3 EFFECT OF CALVING SYSTEM ON COW PERFORMANCE AND REPRODUCTIVE EFFICIENCY

3.1 Introduction

The Canadian prairies cover over 5.61 million arable ha of land across three provinces (Statistics Canada, 2010). The characteristics of this land are unique to each area. Such characteristics are temperature, humidity, and precipitation that strongly influence the climate of the rangeland and available biomass. The characteristics of the soil differentiate each area, whereas each province will have dry areas such as the Brown soil zone to more wet areas such as the Dark Brown and Black soil zones. Even though dynamic and vast differences across the prairies exist, the common theme is a narrow period of high quality forage during the growing season in May, June and July, and decreasing forage quality into the fall and winter. Meeting the beef cow's nutritional requirements is crucial to ensure that performance parameters can be met. When nutritional requirements are limited or not met, cow performance may be sub-optimal. Nutritional requirements are constantly changing and vary depending on environmental constraints and reproductive status of the cow. Management of the cow changes depending on calving period. Understanding the relative performance of cows calving during different seasons of the year is important to meet specific goals (Reisenauer et al. 2001). Calving season also changes the time of year that weaning occurs therefore affecting market choices for the weaned calf.

In recent years, the optimal calving season has been debated. Input costs, such as fuel, labour and feed have increased and narrowed profits for cow-calf producers. Labour availability is limited and has forced the cow-calf producer to become more efficient with less assistance. Delaying the calving season has become common to further minimize the need for various inputs and to manage the cow in synchrony with availability of high quality summer pasture forages to meet the nutrient requirements of the cow during the lactation period. Adams et al. (1994) in Nebraska found that by managing the lactating cow during the summer months, less harvested forages were needed and in turn, reduced the overall costs of feeding the cow. Furthermore, the cow performance was maintained or even enhanced in some cases. Grings et al. (2005) in Montana found cows in the summer calving system to have better body weight and condition and less fluctuation from pre-calving to breeding than the early spring calving cows. Reproductive performance in this study was not affected by calving system.

Although limited research exists on calving systems in western Canada, Pang et al. (1998) in Alberta found that summer calving would be a successful alternative to winter and spring calving based on similar pregnancy, calving and weaning rates, heavier birth weights and a tighter calving period. The study was conducted on a research cow-calf herd calving in April and May/June. Research in Ontario by Stonehouse et al. (2003) found cows in the summer calving system had consistently greater body conditions than did April calving cows. Maintaining good body condition (> 2.5 BCS) was done by delaying the calving season which in turn reduced labour, bedding and animal treatment costs. The authors compared winter calving cows managed in confinement in a barn to summer calving cows managed outside on pasture.

In the last decade, there has been no research conducted comparing calving systems on the western Canadian Prairies. Therefore, in 2007 and 2008, two calving systems were compared at the AAFC-Brandon Research Centre, Brandon, Manitoba; the AAFC-Semiarid Prairie Agriculture Research Centre at Swift Current, Saskatchewan; and the Termuende Research Ranch at Lanigan, Saskatchewan. The objectives of this study were to evaluate the effects of an early (March) (ECS) and late (June) (LCS) calving system on cow performance and reproductive efficiency.

3.2 Materials and Methods

3.2.1 Research locations

The study was conducted at three different locations in western Canada which included; 1) AAFC-BRC in Brandon, Manitoba (49^{o}52'N: 99^{o}59'W) (BR); 2) AAFC-SPARC in Swift Current, Saskatchewan (50^{o}16'N:107^{o}44'W) (SC); and 3) Western Beef Development Centre's (WBDC) Termuende Research Ranch near Lanigan, Saskatchewan (51^{o}51'N:105^{o}02'W) (LA). Brandon is located in the Black soil zone, Lanigan is in the Dark Brown soil zone and Swift Current is located in the Brown soil zone.

3.2.2 Animals

At each location, cows were randomly allocated to 1 of 2 replicated (n=2) treatments (calving systems): (1) Early calving system (ECS) to calve starting 23 March and (2) Late calving system

(LCS) to calve starting 10 June (Table 3.1). All treatments had 2 replicates, each managed separately and assigned to a separate paddock (30 cows/paddock for BR; 12 cows/paddock for SC; 25 cows/paddock for LA). Calving systems were managed similarly with 120 cows at BR (60 cows for ECS; 60 cows for LCS), 50 cows at SC (25 cows for ECS; 25 cows for LCS) and 100 cows at LA (50 cows for ECS; 50 cows for LCS). All cows were crossbred and were predominately of British origin (Angus or Hereford). Cow age ranged from 3.8 to 4.3, 5.5 to 6.3 and 7.4 to 8.3 years old for cows at BR, SC and LA, respectively. Once cows were assigned to a calving system and replicate groups, they remained within these groups for the full length (2 yr) of the study. All cows reared their own calves and were pregnant when the study began in March of 2007. Animals used in this experiment were cared for under the guidelines put forward by the Canadian Council of Animal Care (2007).

Table 3.1. Average calving dates for ECS and LCS at Brandon, MB, Swift Current, SK and Lanigan, SK in 2007 and 2008.

	Early Calving System		Late Calving System	
	2007	2008	2007	2008
Brandon	28 March	28 March	10 June	15 June
Swift Current	23 March	26 March	13 June	16 June
Lanigan	15 April	2 April	23 June	19 June

All cows were bred by natural breeding by either a Gelbvieh (LA) or Red Angus (BR; SC) bull (average age, 3.5 yr). The same bulls were used for each calving system and for the full length of the study. A bull to cow ratio was maintained at 1:20 within each calving system at each location, where BR used 3 bulls, SC used 2 bulls and LA used 3 bulls per calving system. Breeding season was from 30 May to 31 July and 20 August to 25 October for early calving system (ECS) and late calving system (LCS), respectively. Bulls were evaluated for breeding soundness each year prior to the start of the breeding season. All bulls were vaccinated with Express 5 (Boehringer Ingelheim® St.Joseph, MO), Covexin 8 (Schering-Plough®, Omaha, NE) and Fusogard (Novartis®, Mississauga, ON).

Body weights and body condition score (BCS) of all cows were determined at 3 different times, pre-calving, breeding and weaning. Body condition scoring was done by assessing fat cover on the short ribs of the left side of the cow (5 point scale [1=thin, 5=fat]). Technicians at each location were cross-trained for the BCS technique and the same technician was used for the full length of the study. Ultrasonography was used to assess subcutaneous fat depth at 2 different locations; between the 12th and 13th rib and on the rump near the tail head of the left side of the cow using Aloka SSD-500V ultrasound machine and Aloka UST-5044 probe [3.5 MHz]. Ultrasound technicians were cross-trained at each location and the same technician was used the full length of the study. Cows were vaccinated with Covexin 8 (Schering-Plough®, Omaha, NE) and Express 5 (Boehringer Ingelheim® St. Joseph, MO). The ECS at each site was also vaccinated with Scourguard 4KC (Pfizer ® New York, NY). Only the ECS cows were vaccinated for scours because of the calving environment in drylot pens and the potential of being exposed to scour causing bacteria. At pasture turnout, all cows at LA were vaccinated with Anthrax Spore Vaccine (Colorado Serum Company ®, Denver, CO). In the fall, all cows were given vitamin A and D (1 mL per 100 kg for cows; 1 mL per 50 kg for calves) (Dominion Veterinary Laboratories Inc., Winnipeg, MB), E and selenium (2 mL/45 kg of calves) (Dystosel, Pfizer® Kirkland, PQ). Cows were pregnancy checked via rectal palpation by a veterinarian approximately 70 d after bull removal. Cows were culled if not pregnant for the second time or if they lost their calf for the second consecutive year. Cows were also culled if udders were physically damaged or structurally not sound or if the cow was lame and unresponsive to treatment. Heifers were chosen at weaning as replacements and were randomly placed in the corresponding replicate groups. Replacement heifers were chosen based on birth to weaning performance and on the dam’s previous year’s performance. A replacement rate or culling rate of 10% was used for both herds at all locations every year based on a minimum rate used in the beef industry; Brandon culled 6 cows per calving system every year, SC culled 3 cows per calving system every year and LA culled 5 cows per calving system every year.

3.2.3 Feeding Management

Each group of cows (ECS and LCS) were managed separately throughout the year, with harvested feeds allocated to meet specific nutrient requirements (NRC 2000) according to calving system. Quantity and quality of hay, supplements (0.70 to 2.5 kg cow^{-1} d^{-1}) and total ha provided for grazing were based on forage and weather conditions, physiological status of the cows and available harvested feed resources within each year. Cows were managed as similar as possible at all locations. Trace mineralized salt with Ca (9%, as fed), P (10%, as fed), Na (10%, as fed), I (100 mg/kg, as fed), Cu (2,500 mg/kg, as fed), Mn (6,000 mg/kg, as fed), Zn (7,500 mg/kg, as fed), Fe (4,750 mg/kg, as fed), F (1,000 mg/kg, as fed), Vitamin A (1,000,000 IU/kg, as fed), Vitamin D3 (140,000 IU/kg, as fed) and Vitamin E (2,500 IU/kg, as fed) (Beef Breeder Mineral, Feedrite, A Division of Ridley®) were available free-choice.

All cattle had *ad libitum* access to good quality water from dugouts and wells that had acceptable salinity (total dissolved solids) or sulphate concentrations. This was certified through duplicate testing of all water sources each year at all research locations by the Saskatchewan Research Council water testing laboratory, Saskatoon, Saskatchewan and results are presented in Appendix D (Table D1).

3.2.3.1 Early Calving System

Drylot Pen Management (DL). Early calving system cows calved in drylot pens. The drylot pens were primarily used during the pre-calving and calving phase of the ECS. Total number of days, bales fed, supplement amount, mineral, vitamin, treatments and labour were recorded during this feeding phase. Ten representative samples were taken from all bales fed in the DL system for chemical analysis of forage quality. Bales were produced from hay fields at each research location except at Lanigan where hay was purchased from local area producers. Bales were also weighed to ensure average bale weight was recorded and total amount of feed offered was recorded.

Pasture Grazing (PG). Pastures were grazed when sufficient pasture forage was available to support both the cow and calf. Summer grazing period on mixed cool season species pastures occurred from May to September. Cattle movements among pastures were based on forage availability and management needs. Ten representative samples (0.25 m^2 quadrat) of forage were taken at entry of a new pasture. These samples were compiled and stored for quality analysis.

Swath-windrow Grazing (SG). Following summer pastures, grazing and weaning, cows were moved to a SG annual crop for approximately 30 d period (start and end date varied depending on the year). Annual crops were swathed at soft dough stage early September. Prior to swathing, estimates of annual crop DM yield were determined by clipping and weighing 0.25 m^2 quadrat. Total swath length allotted during graze period was measured and therefore total dry matter (DM) available was calculated. Swathed feed was allocated on a 3 to 4 d basis to reduce feed wastage. At Swift Current, both ECS and LCS cows did not swath-windrow graze. Lack of precipitation and rodent infestation decreased crop yield at this location; thus cows grazed the standing crop only. Table 3.2 indicates cow d per ha which was calculated for each SG period.

Bale Grazing (BG). Bale grazing commenced following the swath grazing period. While bale grazing, cows were supplemented with either rolled barley grain (1 to 3 kg cow^{-1} d^{-1}) or range pellets (2 to 3 kg cow^{-1} d^{-1}) depending on environmental conditions and pregnancy status. Calves were weaned prior to the commencement of bale grazing. Early calving system cows at BR did not BG in 2007 because of the lack of a separate winter grazing site available.

3.2.3.2 Late Calving System

Pasture Grazing (PG). Late calving system cows were managed to calve on summer pasture. Pasture grazing management and sampling were similar to the ECS section.

Swath-windrow Grazing (SG). Following summer pasture grazing, cows were moved to a SG annual crops for approximately 30 d (start date and end varied depending on the year). The swath-windrow grazing management and sampling were similar to the ECS section.

Bale Grazing (BG). Cows were moved to the winter management site for bale grazing until spring pastures were available for the following calving season. Management of cows in the BG feeding system was similar to the ECS section.

Drylot Pen Management (DL). When needed and dependant on location, cows were managed in drylot pens for a shortened period.

The number of hay bales (fed in a drylot pen or bale grazing fields), supplements fed; total ha grazed, and total amount of swath grazed forage was recorded daily. Quantity of feed offered and utilized per system was then calculated for each system.

Table 3.2. Total cow days per hectare for each grazing system in 2007 and 2008

	Early Calving System		Late Calving System	
	2007	2008	2007	2008
Brandon				
Pasture Grazing	608	260	208	367
Swath Grazing	446	583	685	256
Bale Grazing[z]	-	-	1577	1145
Swift Current				
Pasture Grazing	21	29	15	14
Swath Grazing[y]	20	21	30	48
Bale Grazing	340	214	276	366
Lanigan				
Pasture Grazing	28	14	22	17
Swath Grazing	160	220	160	140
Bale Grazing	164	346	555	941

[z] Brandon early calving system cows did not bale graze
[y] Swift Current cows grazed standing annuals

3.2.4 Data Collection

3.2.4.1 Pasture Grazing (PG)

Diet quality of available pasture forage (pre-grazing) was estimated prior to animals entering each pasture type by clipping 10, 0.25 m^2 quadrats randomly throughout the pasture. Herbage biomass out (residual forage; post grazing) was also estimated. All estimates were converted to a dry matter (DM) basis. Forage samples at all locations were utilized for quality analysis of pasture species. Due to timing and labour constraints, no samples were taken for DM yield. Perennial pasture forages included crested wheatgrass (*Agropyron cristatum*), Russian wild ryegrass (*Psathyrostachys juncea)* and alfalfa (*Medicago sativa* L.) mixtures at Swift Current; Russian wild ryegrass, crested wheatgrass and smooth bromegrass (*Bromus inermus*) at Lanigan; and Kentucky bluegrass (*Poa pratensis* L.), smooth bromegrass and tall fescue (*Lolium arundinaceum*) at Brandon. A full summary of quality analysis results are presented in Table C1 in Appendix C.

3.2.4.2 Swath-Windrow Grazing (SG)

Annual forage data was collected similar to the perennial forage data. Estimates of forage yield and quality were taken prior to swathing by randomly sampling 10, 0.25 m^2 quadrats when the plant reached the soft dough stage. Total amount of feed allotted to cows or cow-calf pairs was for a 3 d grazing period. Amount of feed allotted was calculated based on estimated feed intake for beef cows based on feed quality (NRC 2000). There was 1.4 kg of DM per 0.3 meters of swath. Therefore the length of swath allotted for 3 d was determined by the amount of cows per replicate. Longer periods of swath grazing can amount to more feed waste and therefore lowered utilization of available feedstuff and lowered animal performance (McCartney et al. 2004). Samples were taken at time of grazing for further quality analysis. The forage quality analyses for the annual forages were similar to analysis for perennial forages. A full summary of quality analyses results represented in Appendix C (Table C1).

Residual (refusal) feed was not estimated following the SG period, therefore estimated apparent (DM) intake and feed utilization was estimated according to Kelln (2010) for each corresponding feeding system. Kelln (2010) measured allocated and residual feed by using two techniques, similar to those used by Volesky et al. (2002) and Baron et al. (2006). The first method used 0.25 m^2 quadrat samples (n=15) where each location was determined in the fall for each replicated paddock prior to swathing at an early dough stage. The second technique used was to randomly weigh 10, 30 x 3 m sections of swath in each SG paddock where each section was placed on a tarp, weighed and replaced. Estimated apparent dry matter intake for swath grazing was calculated using the following equation:

Equation 4.2 $(\text{kg DM } p^{-1} \text{ allocated} - \text{kg DM } p^{-1} \text{residual})/n^{-1}/p$

where p = 3 d feeding period, n = 15 cows per experimental unit.

The estimated apparent DMI for SG in the current study was then calculated using the following equation:

Equation 4.3 (kg DM allocated) x % Utilization

Where the % utilization (87.7%) was calculated based on Kelln (2010).

3.2.4.3 Bale grazing (BG)

Prior to the start of BG, mixed grass legume round hay bales were placed in a previously determined winter grazing site which was either a perennial or annual cropped field. In some years, BG started earlier than expected due to a shortage of perennial forage or poor annual forage production for SG. Forage samples were collected by coring a representative number of bales (n=10) and collected for quality analysis. A representative number of bales (n=10) were weighed for determining available forage fed to the cows. Bale fed cows were moved every 4 d to reduce wastage. Cows or cow-calf pairs were fed either an energy or protein supplement based on weather conditions and amount of snow cover. Quality analysis of baled hay forage was similar to analyses for perennial forages. A full summary of quality analysis is presented in Table C1 in Appendix C.

As mentioned in the section 3.2.4.2, residual (refusal) feed was not estimated following the feeding system grazing periods, therefore estimated apparent (DM) intake and feed utilization was estimated according to Kelln (2010), where twelve round bales in each BG paddock were weighed using a portable scale to ensure total allocated DM was recorded. Bales were placed on a tarp to weigh refused forage. Estimated apparent DMI for BG was calculated using the same equation as SG (Equation 4.3), but with percent utilization of 73.4% (Kelln 2010).

3.2.4.4 Drylot (DL)

Feed quality values from laboratory analysis and ration formulated for beef cows (at varying stages of lactation or gestation) according to NRC (2000). Estimated apparent DMI was calculated as described in section 3.2.4.2 and based on methods used by Kelln (2010). Twelve round bales were weighed using a portable scale to ensure total allocated DM was recorded. Estimated apparent DMI was then calculated using the same equation as SG (Equation 4.3), but with percent utilization of 75.3% (Kelln 2010).

3.2.5 Chemical Analysis

3.2.5.1 Forage Analysis

All forage samples were ground using a Wiley mill (Model no. 4; Arthur H. Thomas Co., Philadelphia, PA) through a 1 mm screen and stored in glass jars for future analysis. Laboratory analysis of all samples for forage quality, including pasture, swath and bale grazing, which included organic matter (OM), organic matter digestibility (OMD), crude protein (CP), total calcium (Ca), total phosphorus (P), acid detergent fibre (ADF) and neutral detergent fibre (NDF).

Total digestible nutrients (TDN) were calculated using the Pennsylvania State Equation based on acid detergent fiber (ADF) content (Adams 1995).

Equation 3.1 TDN = 4.898+{89.796*[1.0876-(0.0127*ADF)]}

where ADF is expressed on a DM basis.

In vitro organic matter digestibility (OMD) was determined according to the procedure established by Tilley and Terry (1963) as modified by Troelsen and Hanel (1966). Dry matter weight was recorded after drying samples over night at 105^{o}C. Ash was determined by weighing a 1 gm of sample into porcelain crucibles. Samples were then heated at 600^{o}C for 2 hr to determine the ash content (AOAC method 923.03; AOAC, 2005). Calcium (Ca) was determined using the methodology adapted from Steckel and Flannery (1965). Phosphorus (P) levels were determined using the protocol adapted from Varley (1966) and Milbury et al. (1970). Crude Protein (CP) was determined using the protocol of the Methods Manual Scientific Section (AAFC 1998) that was adapted from Varley (1966) and Noel and Hambleton (1976). The total Kjeldahl N was multiplied by 6.25 to determine the level of crude protein (AOAC 1984). Acid detergent fibre (ADF) and Neutral detergent fibre (NDF) was determined using the ANKOM^{200} fibre analyzer (ANKOM; Model 200; Fairport, New York). Acid detergent lignin (ADL) was determined using the ANKOM Technology-08/05, Method for Determining ADL in Beakers using the ANKOM^{200} fibre analyzer (ANKOM; Model 200; Fairport, New York; 14450).

3.2.6 Experimental Design and Statistical Analysis

Experimental design was a randomized complete block design (RCBD) where location was the blocking factor and each treatment (ECS and LCS) was replicated (n=2) in each block. Each replicate group was the unit of analysis for all parameters. Cow and calf production data were analyzed using the PROC MIXED procedure of SAS (SAS Inst. Inc. Cary, NC). Treatment (calving season), location and treatment x location interactions were analyzed as fixed effects and year was included as a repeated measure. A number of covariance structures were tested for each variable and the final covariance structure was selected on the basis of the lowest AIC value. Cow reproductive performance and weaning rate data was analyzed using a generalised linear mixed regression model with a logit link function and a binomial error distribution using the Proc GLIMMIX procedure of SAS (SAS Inst. Inc. Cary, NC) where year was accounted for as a random effect. Treatment comparisons used least squares means by PDIFF options with a TUKEY adjustment. Differences between treatment means were determined at a significance level of $P < 0.05$ (Steel et al. 1997).

3.3 Results and Discussion

Temperature and precipitation data for all years and research locations are presented in Appendix B (Figures B.1-3 and Table B.1). Average total precipitation in 2007 and 2008 at Brandon was 459 and 666 mm, respectively. These values were lower in 2007 and higher in 2008 than the 30-yr average (474 mm) for Brandon. Swift Current's average total precipitation in 2007 and 2008 was 262 and 411 mm, respectively. In 2007, these values were lower and in 2008, higher than the 30-yr average (349 mm) for Swift Current. Total precipitation at LA for 2007 and 2008 was much lower than the 30-yr average (435 mm) at 218 and 209 mm, respectively.

Average cow age at LA was highest, followed by SC and then Brandon. Cow age at LA, BR and SC were 8.4, 6.2 and 4.4 ± 0.26 yr, respectively, and were significantly different across all locations.

3.3.1 Grazing System Forage Quality

Forage quality results are presented in Appendix C (Table C.1). Diet quality was closely monitored to ensure forage quality met the nutrient requirements of the cow and calf at different stages of production. Data is reported based on months post-calving, therefore including all forages fed during the lactation period (pre and post-weaning). The data shows the fluctuation in forage quality that occurred starting at calving, which is nested within feeding systems (Figure 3.1 to 3.6). Forage quality of every month was averaged and reported as %CP and % TDN values. At Brandon, CP content in forages in the LCS is lower compared to ECS until before weaning time, where CP levels increase into the fall when SG started (Figure 3.1). A similar pattern is observed when looking at energy levels of forages at BR, except that energy levels were similar for ECS and LCS following weaning (Figure 3.2). At SC, late calving system CP levels are lower than the ECS, but at weaning the inverse occurs when the LCS starts grazing standing annuals (Figure 3.3). A similar pattern occurs for the energy content of the forage at Swift Current (Figure 3.4). At LA, late calving system CP started higher than the ECS, and then remained lower until weaning (Figure 3.5). The energy content of forages for ECS was lower for the first two months, and then was similar throughout all feeding systems (Figure 3.6). On average, forage CP levels were lower for the LCS compared to ECS, even though LCS cows were managed on PG whereas ECS cows were managed in a DL system and fed baled hay. This similar pattern seemed to have occurred at all three locations. Forage crude protein levels during the SG period from this study were lower at BR in 2007 and 2008, by 3%, than those previously reported by McCartney et al. (2004). Crude protein and energy (TDN) values for annual forages at LA were similar or higher than those reported by McCartney et al. (2004). Crude protein values of feeds in ECS and LCS at Lanigan for both years were similar (14%) to those reported by Kelln (2010). Crude protein levels were also similar for SC except for the LCS in 2008 where protein levels of the standing annuals was 4% lower. At Brandon, annuals used in SG for both years and calving systems were 4% lower in protein quality than what was reported by Kelln (2010). Cows in the early calving system at BR were not managed in the BG system. Hay bale quality values were similar to other studies conducted on the Canadian prairies (Kelln 2010) and in Nebraska (Volesky et al. 2002). At Lanigan, Kelln (2010) found that hay CP ranged from 12.7 to 14.0%, which was similar to CP content in the current's study across years and locations which ranged from 10.0 to 14.9 percent. At North Platte, Nebraska, Volesky et al. (2002) reported quality of baled hay used for bale grazing ranged from 10.3 to 10.5%, slightly lower than forage protein content in the current study.

Crude protein and TDN values for the perennial pastures in this study were similar to those previously reported on the Canadian Prairies (Kusler 2009) and were adequate to meet energy and protein requirements of the cow-calf herd. At Lacombe, AB, McCartney et al. (2004) conducted a study comparing three different winter feeding systems, swath grazing (barley), traditional drylot feeding and alternate day feeding of the energy supplement, with spring calving cows (March-April). Cows that were swath grazing lost more weight over the winter feeding period, while consuming more energy and DM, however this did not affect reproductive performance and all cows were in similar body condition (2.5-3.0) throughout the trial. Similarly, Aasen et al. (2004) found that gestating and lactating beef cow requirements could be met through swath grazing annuals, although the type of annual forage played a large role in the success of this winter feeding practice, whereas mixtures of annuals typically had a better chance of meeting nutrient requirements. Regardless of calving systems, feeding systems and locations, forage quality met or exceeded NRC (2000) nutrient requirements of the beef cow in the current study.

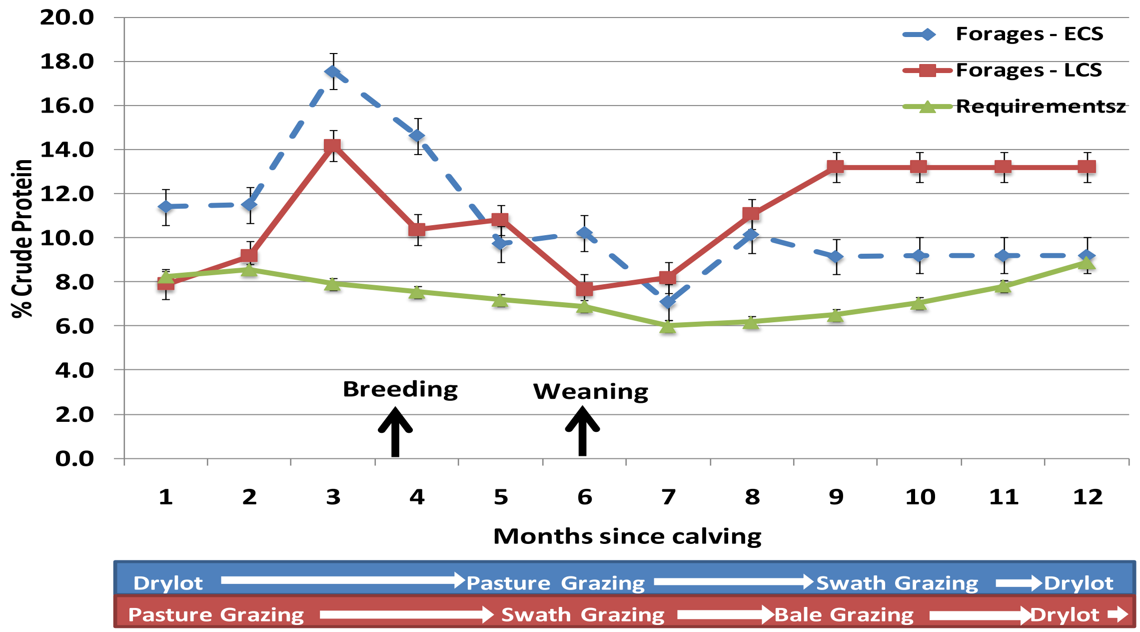

Figure 3.1. Comparison of average (±SE) crude protein (%, DM basis) content of forages and supplement fed to early and late calving systems, cow requirements and feeding systems during the months post-calving at Brandon, Manitoba for 2007 and 2008 (^{z} NRC, 2000)**.**

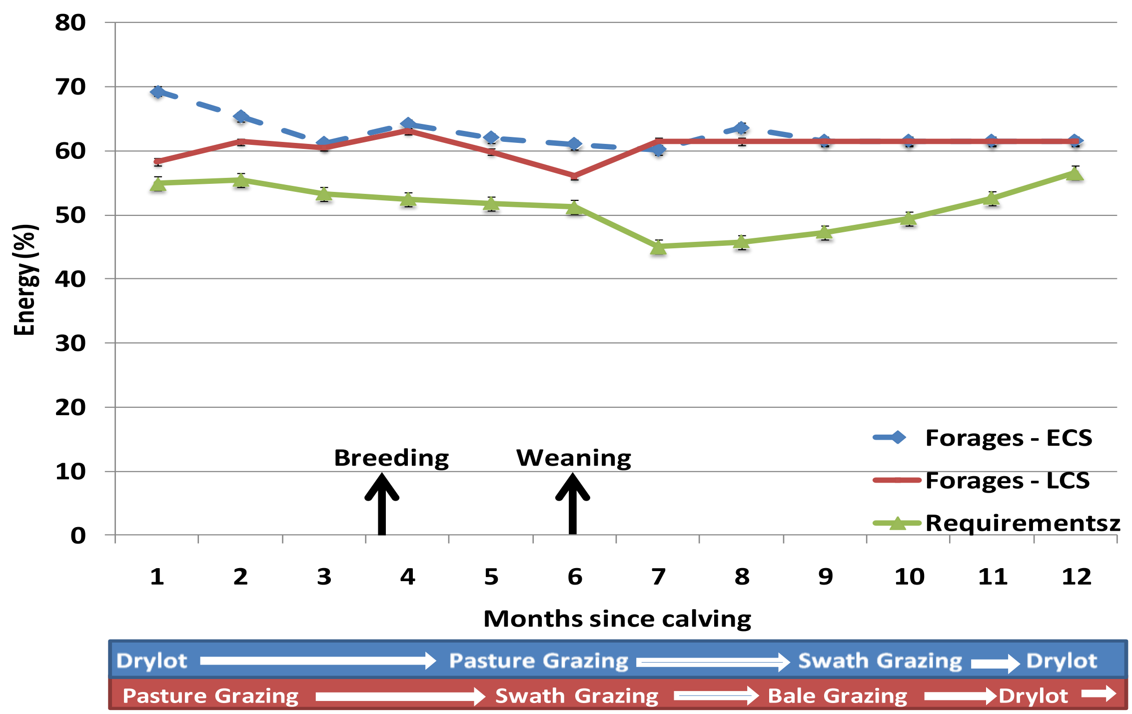

Figure 3.2. Comparison of average (±SE) energy (%TDN) content of forages and supplement fed to early and late calving systems, cow requirements and feeding systems during the months post-calving at Brandon, Manitoba for 2007 and 2008 (^{z} NRC, 2000)**.**

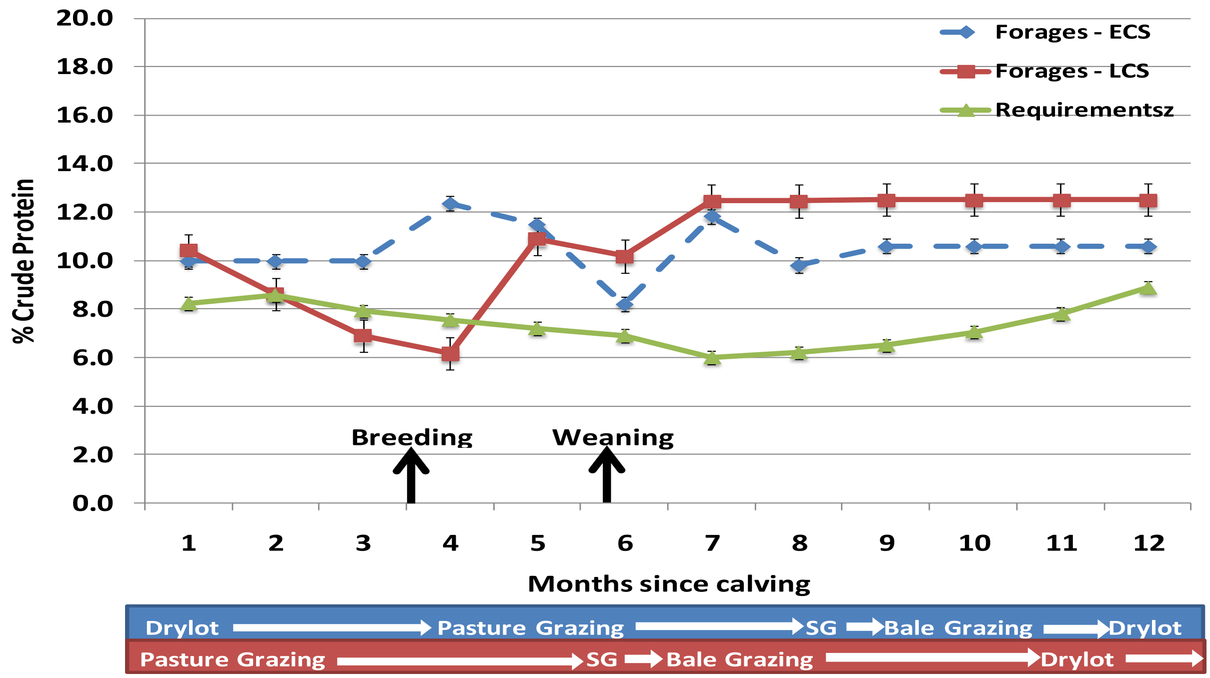

Figure 3.3. Comparison of average (±SE) crude protein (%, DM basis) content of forages and supplement fed to early and late calving systems, cow requirements and feeding systems during the months post-calving at Swift Current, Saskatchewan for 2007 and 2008 ([z] NRC, 2000).

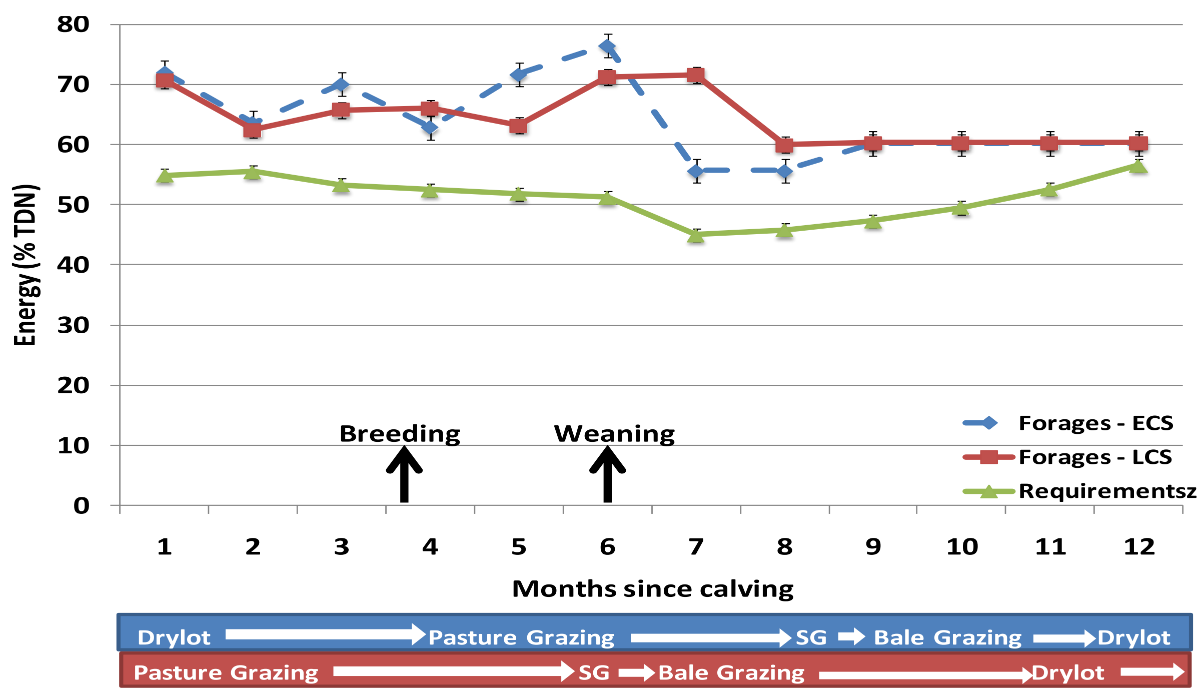

Figure 3.4. Comparison of average (±SE) energy (TDN) content of forages and supplement fed to early and late calving systems, cow requirements and feeding systems during the months post-calving at Swift Current, Saskatchewan for 2007 and 2008 ([z] NRC, 2000)**.**

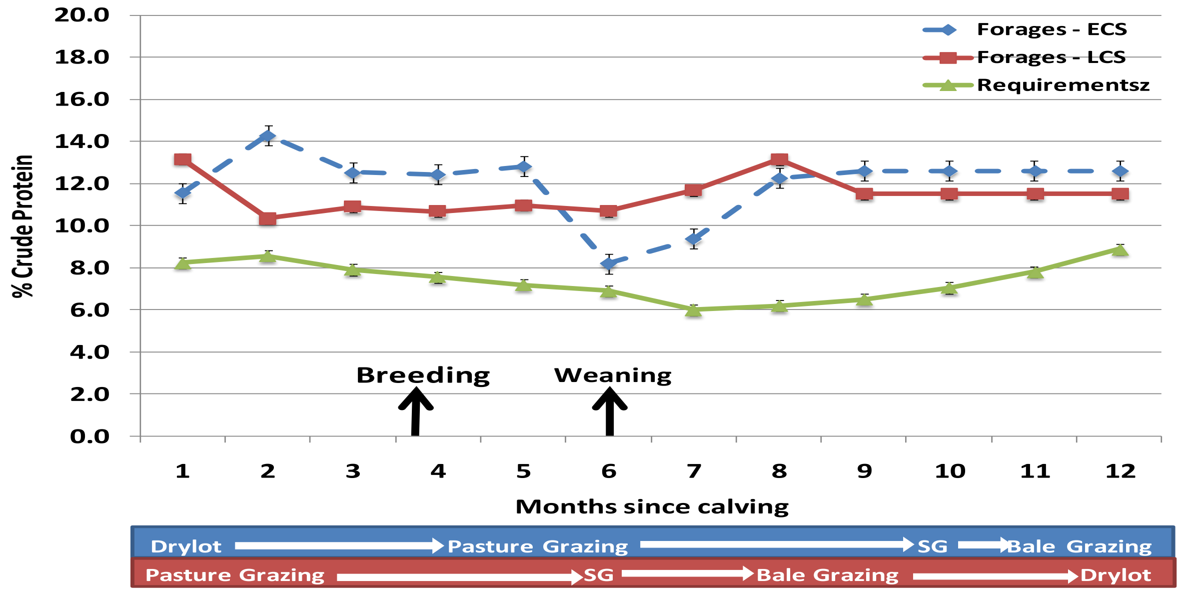

Figure 3.5. Comparison of average (±SE) crude protein (%, DM basis) content of forages and supplement fed to early and late calving systems, cow requirements and feeding systems during the months post-calving at Lanigan, Saskatchewan for 2007 and 2008 ([z] NRC, 2000).

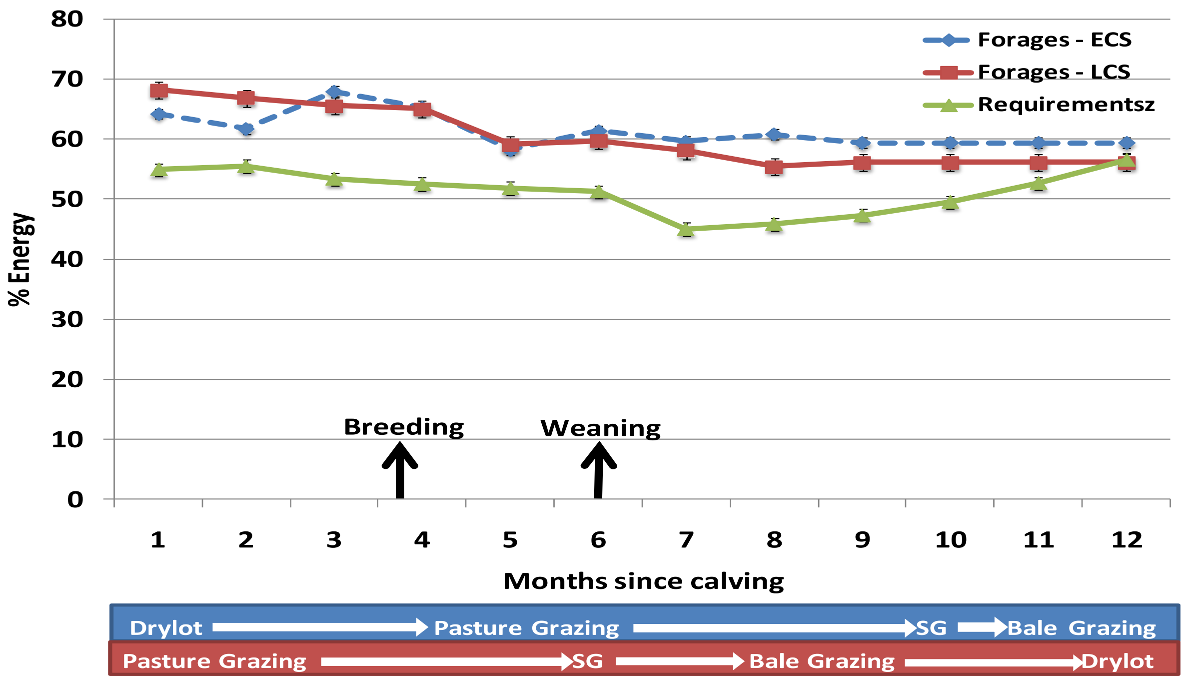

Figure 3.6. Comparison of average (±SE) energy (% TDN) content of forages and supplement fed to early and late calving systems, cow requirements and feeding systems during the months post-calving at Lanigan, Saskatchewan for 2007 and 2008 ([z] NRC, 2000).

3.3.1.1 Estimated Intake

Estimated DMI for cows on SG, BG and DL systems were calculated (Table 3.3) but were not replicated therefore no statistical analysis was done. At SC, DMI while grazing standing annuals was similar between calving systems, 7.5 and 7.4 kg DM hd^{-1} d^{-1}, respectively. At SC, since precipitation was limited and challenges with ground rodents occurred, standing annuals were grazed for 10 and 15 d, depending on the year. At Lanigan, LCS cows on swath grazing had greater estimated intake compared to ECS cows, 17.8 versus 12.4 kg DM hd^{-1} d^{-1}, respectively. Brandon ECS cows on SG consumed over 100% more DM than did LCS cows, 29.8 versus 14.0 kg DM hd^{-1} d^{-1}, respectively. The difference at BR for estimated intake was a result of including the re-growth of the annual forages in 2008, which increased the average DM intake across the 2 years. Late calving system cows at BR were also supplemented with hay during the PG period, because of a feed shortage available to sustain the cow-calf pair. Similar to the estimated intake of ECS cows at LA in the current study (Table 3.3), Kelln (2010) also estimated DM intake to range from 10.3 to 13.3 kg for pregnant beef cows. Therefore, as cow-calf pairs grazed annual forages, there was a need for more DM per cow to account for the lactation period, which also accounted for 30% more feed during this period.

Late calving system BG cows at SC and LA had 15 and 11% greater estimated intakes than did ECS cows (Table 3.3). Bale grazing for the LCS occurred when the calf was still with the cow, which reflected the need for more feed to meet the energy and protein demands of the lactation period. Early calving system cows at BR did not BG in either year of the study.

During the DL feeding system, the inverse occurred where the ECS cows consumed more forage than the LCS cows, which suggested the need for more feed during the calving period when ECS cows are managed in the DL pens. These differences resulted in 38% and 41% more estimated forage intake for the ECS cows compared to the LCS at SC and LA, respectively (Table 3.3). An exception occurred at BR, where LCS cows consumed 39% more total DM compared to ECS cows. This large difference may have been due to increased waste of dry hay because of the inclusion of silage in the feeding program.

Throughout the different feeding systems, it was seen that lactating beef cows had higher estimated DM intakes compared to cows in gestation. This is reflective of the energy requirements of a lactating cow being higher than a gestating cow by 30% (NRC 2000). Apparent estimated intakes can also be indicative of forage quality differences across locations or feeding systems or both. For example, at LA in 2008, hay used in the BG system for LCS cows had lower protein content (11.2% CP) compared to annuals used for SG (14.2% CP) (Table C1, Appendix C). Estimated intakes for swath grazing cows were 22% higher than those estimated for cow in the BG system. The additional energy needed in the swath grazing system may be because of increased requirements associated with walking, environmental stress and activities involved with foraging (McCartney et al. 2004). Cows were lactating during both of these feeding periods, therefore the difference in estimated intake may have been due to lower quality bales, which can be of particular concern to producers using BG for lactating cows throughout the winter months in western Canada. It seems as though stage of lactation and gestation had a larger impact on estimated DMI than did calving system. Based on NRC (2000), cows with a similar weight and gestation stage as the study animals were calculated to have DMI of 11.28 to 11.90 kg. Brandon cows in the SG system had considerably higher (131%) intakes than the lower end of the recommended range. These cows needed to walk longer distances for water and were in the open field with limited shelter, which may have played a role in the increase in forage needed. At BR, cows in the DL system for the LCS 42% higher DMI than the recommended range (NRC 2000), which may be explained by the larger pens that were used during the study. The pens used were closer in relation to pasture paddocks therefore increasing the walking distance, environmental stress and activities involved with foraging. No particular pattern resulted across calving systems, although large emphasis should not be taken because of the lack of statistical analysis.

Table 3.3. Estimated dry matter intake for cows in swath-windrow grazing (SG), bale grazing (BG), and drylot feeding (DL) systems			
	Brandon	Swift Current	Lanigan
Early calving system (kg DM d^{-1})			
SG[z]			
Annual forage	26.1	7.5	13.0
BG[y]			
Hay	-	10.6	12.6
DL[x]			
Hay	8.5	9.5	13.0
Rolled barley grain	-	1.0	0.8
Silage	3.1	-	-
Total	11.6	10.5	13.8
Late Calving System (kg DM d^{-1})			
SG			
Annual forage	12.3	7.4	18.7
BG			
Hay	14.5	8.8	14.0
Greenfeed	-	3.4	-
Total	14.5	12.2	14.0
DL			
Hay	12.2	7.6	9.4
Rolled barley grain	-	-	0.4
Silage	3.9	-	-
Total	16.1	7.6	9.8

[z] Swath graze estimated intake based on 87.7% utilization (Kelln 2010)
[y] Bale graze estimated intake based on 73.4% utilization (Kelln 2010)
[x] Drylot feeding estimated intake based on 75.3% utilization (Kelln 2010)

3.3.2 Cow Body Weight and Condition

A significant three way interaction was observed for cow body weight (BW) at breeding (P=0.003), and for cow BCS at breeding (P=0.002) (Table 3.4). Significant location (P=0.001) and year (P=0.03) main effects was found at pre-calving and a significant location main effect was found at weaning (P=0.0007) for cow body weight. Significant two way interactions (CSxL) for cow BCS were found at pre-calving (P=0.05) and at weaning (P<0.0001). The same two way (CSxL) interaction was significant at pre-calving and weaning for both cow rib (P=0.003; P=0.007) and rump fat (P=0.002; P=0.02). Significant location main effects were found at breeding for cow rib fat (P=0.005) (Table 3.4). Significant location (P<0.0001) main effect were found at breeding for cow rump fat. Only the interactions that are significant and that include calving season will be discussed. Other interactions are presented in Table 3.4 but will not be discussed. Main effects will only be discussed if there are no interactions that are significant

Table 3.4. Analysis of variance comparing cow performance parameters

Item[z]	P values						
	CS[z]	L	Y	CS x L	LxY	CSxY	CSxLxY
Cow body weight (kg)							
Pre-calving	0.08	0.001	0.03	0.19	0.06	0.07	0.91
Breeding	0.0002	0.0005	0.09	0.002	0.0003	0.47	0.003
Weaning	0.61	0.0007	0.15	0.44	0.46	0.45	0.83
Cow body condition (1-5 pt scale)							
Pre-calving	0.42	0.01	0.18	0.05	0.31	0.86	0.38
Breeding	0.0004	<0.0001	<0.0001	<0.0001	0.04	0.002	0.002
Weaning	0.006	<0.0001	0.21	<0.0001	0.71	0.09	0.32
Cow rib fat (mm)[y]							
Pre-calving	0.32	0.0001	-	0.003	-	-	-
Breeding	0.34	0.005	-	0.10	-	-	-
Weaning	0.25	<0.0001	-	0.007	-	-	-
Cow rump fat (mm)							
Pre-calving	0.001	<0.0001	-	0.002	-	-	-
Breeding	0.10	<0.0001	-	0.06	-	-	-
Weaning	0.80	<0.0001	-	0.02	-	-	-

[z] CS = calving system; L=location; Y=year

[y] Cow rib and rump fat measurements were not taken in 2007, therefore no year main effect or interactions were evaluated.

Average cow BW at the pre-calving period for SC and LA differed from each other with SC having the highest (P<0.05) value and LA having the lowest (P<0.05) value. Average cow BW for BR was similar to both SC and LA and the values were 664, 684 and 645 ±9.0 kg, respectively. Comparison of cow body weight at pre-calving across years shows that in 2008 BW was higher (P=0.03) than in 2007, 671 and 657 ± 8.6 kg, respectively. Comparing within research location across Y and CS the results found no differences in cow BW at breeding (P>0.05) at Brandon (Table 3.5). At SC, LCS cows were greater in 2007 compared to ECS cows, but were similar in 2008. At LA cow BW were similar in 2007 and 2008 (P>0.05) (Table 3.5). Comparing within ECS and research location across Y the results found that in 2007 cow BW at breeding at BR was greater (P<0.05) than in 2008. At SC, the opposite occurred in 2007 where BW at breeding was smaller than in 2008; however at LA BW at breeding were similar. Body weight at LA, SC and BR at breeding for LCS were similar (P>0.05) when comparing within location and across years. At weaning, cow BW at SC was the heaviest (P<0.05) compared to LA but was similar to BR and the values were 681, 631 and 655 ±11 kg, respectively. Lanigan cows were the lightest (P<0.05) BW in any location comparisons.

At pre-calving period, BR BCS was greater (P=0.05) for LCS cows compared to ECS cows (Table 3.6). The inverse occurred for SC where ECS cows were greater (P=0.05) than LCS cows at pre-calving period and LA cows were similar. Body condition score at breeding (Table 3.5) indicated there was a significant (P=0.002) three way interaction. There were no differences when comparing across CS within the same Y and L for BR and LA. In 2007 and 2008, Swift Current LCS cows had greater (P=0.002) BCS compared to the ECS (Table 3.5). In the ECS, BR and SC had no differences (P>0.05) when comparing across years, but at LA BCS was greater (P=0.002) in 2008 compared to 2007. In the LCS, SC cows had greater BCS in 2008 compared to 2007 when comparing within locations. There were no differences found for LA or BR between 2007 and 2008 (Table 3.5). Body condition score at weaning, ECS cows at BR and SC were not different (P>0.05) to the LCS cows in their respective locations, but at LA, cows in the LCS had lower body condition (P<0.05) than ECS (Table 3.6). Lanigan cows at weaning had the lowest (P<0.05) BCS compared to BR and SC when comparing within CS across locations. In the ECS, BR and SC had similar BCS but SC was greater than BR in the late calving system (Table 3.6).

Table 3.5. Least square means of the effect of early and late calving systems on cow performance at Brandon, Swift Current and Lanigan in 2007 and 2008

Item[z]	Early Calving System					
	Brandon		Swift Current		Lanigan	
	2007	2008	2007	2008	2007	2008
Cow body weight (kg)						
Breeding	682 ±10.4def	637 ±8.7abc	617 ±6.8b	676 ±6.9cef	614 ±9.7abd	614 ±10.8abd
Cow body condition (1-5 pt scale)						
Breeding	3.3c	3.4cd	3.3c	3.5cd	2.5a	2.7b

Item[z]	Late Calving System						SEM
	Brandon		Swift Current		Lanigan		
	2007	2008	2007	2008	2007	2008	
Cow body weight (kg)							
Breeding	655 ±11.4bcdef	656 ±9.5bcdef	679 ±7.0ef	696 ±6.9f	635 ±10.2bcde	650 ±10.6bcdef	7.3
Cow body condition (1-5 pt scale)							
Breeding	3.1c	3.5cd	3.5d	4.0e	2.6ab	2.7b	0.04

[z] Item= body weight adjusted for conceptus weight
[y] SEM = standard error of the mean
[a-f] within row means having the same letters do not differ significantly (P<0.05)

Table 3.6. Least square means of the comparison of cow BCS, rib and rump fact measurements between calving systems within each location.

	Early Calving System			Late Calving System			
	BR[z]	SC	LA	BR	SC	LA	SEM[y]
BCS (5-pt scale)							
Pre-calving	3.4b	4.6d	2.6ab	4.0c	3.6b	2.5a	0.5
Weaning	3.2cd	3.5de	2.7b	3.0bc	3.7e	2.3a	0.1
Rib fat (mm)							
Pre-calving	5.2ab	9.5c	6.5bc	7.2bc	9.9c	3.1a	0.71
Weaning	4.5ab	8.0bc	6.4bc	3.3ab	9.8c	3.2a	1.06
Rump fat (mm)							
Pre-calving	7.2bd	18.6e	10.9cd	3.3ac	19.7e	4.1ab	0.82
Weaning	5.2a	9.8b	7.8b	4.7a	13.8c	3.8a	0.73

[a-e] within row means having the same letters do not differ significantly (P<0.05)
[z] BR, Brandon; SC, Swift Current; LA, Lanigan
[y] SEM = standard error of the mean

Comparing within locations, only LA cows had greater (P<0.05) rib fat thickness at pre-calving between ECS and LCS, 6.5 and 3.1 mm, respectively (Table 3.6). In the ECS at pre-calving, BR and SC cows had a difference of 4.3 mm (P<0.05) whereas LA was similar to both BR and SC (Table 3.6). In the LCS, LA cows had less rib fat compared to SC and BR cows (P<0.05), but rib fat was similar between BR and SC LCS cows. At breeding, location effect (P<0.005) occurred where SC cows were greater than BR and LA and the values were 10.8, 4.7 and 4.1 ±2.04 mm, respectively, but BR and LA were similar. At weaning, rib fat measurements were similar for BR and SC when comparing between ECS and LCS cows. Lanigan cows in the ECS had greater rib fat measurements than LCS cows. In the ECS, measurements were similar across locations, which were also found in the LCS cows between BR and Lanigan. However, SC cows had the greatest (P<0.0001) rib fat measurements compared to BR and LA in the late calving system.

Rump fat measurements at pre-calving period for the ECS cows at BR and LA were greater than the LCS rump fat measurements when comparing within each respective location (Table 3.6). Swift Current rump measurements were similar between calving systems. Swift Current cows had higher (P<0.0001) rump fat in the ECS and LCS than cows at LA and BR (Table 3.6). Brandon and LA cows had similar rump fat measurements at pre-calving period when comparing across locations for both ECS and late calving system (Table 3.6, CSxL). At breeding, rump fat was greater (P<0.0001) at SC than at LA and BR and the values were 13.4, 6.6 and 5.1 ±1.1 mm, respectively, whereas Lanigan and BR were similar (P>0.05). Brandon cows at weaning were similar when compared across calving systems (Table 3.6). Swift Current ECS cows were smaller than late calving systems cows and then inverse occurred for LA where ECS cows were greater than LCS cows (P<0.05) (Table 3.6). Early calving system cows at Brandon were smaller than both SC and LA, however the latter were similar. In the LCS, SC had greater rump fat measurements than both BR and LA. Brandon and LA were similar to each other when comparing within calving system (Table 3.6).

Body weight and condition at calving is an important measure for reproductive efficiency. There was no clear pattern related to body condition fluctuation across locations and calving systems in the current study. Since there were multiple factors affecting the outcome of each treatment (ECS and LCS), it is difficult to clearly compare to other studies conducted of this sort. However, other researchers have seen differences between calving systems in various locations. Deutscher et al. (1991) found that later calving cows (April) lost less BW than March calving cows. This is in agreement to a study conducted by Grings et al. (2005) at Montana where cows lost less BW between calving and breeding and were heavier at breeding. Fluctuations in body fat reserves varied depending on the calving system and location. The different utilization of body fat during certain periods may be explained by the environmental conditions (monthly temperature) before and during these phases of production (Table B.1). Variations between years and among calving systems were the results of varying annual patterns of environmental temperature and total precipitation. Deutscher et al. (1991) compared March vs. April calving dates for range cows in Nebraska and reported similar results to this study where a later calving date resulted in heavier cows and less body weight fluctuation. Bellido et al. (1981) conducted a study in New Mexico and reported greater fluctuations in cow BW for March calving cows than the late calving cows, similar to the March calving cows in this study. Similarly, Stonehouse et al. (2003) reported cow body condition at breeding was consistently higher at breeding for summer calving cows compared to winter calving cows in Ontario. This was similar to findings in the current study but only for 2007 where BCS fluctuation from pre-calving to breeding to weaning from 2007 to 2008 where cows in ECS were able to maintain a consistent body condition from pre-calving to weaning and had a slight loss of BCS (0.3) for cows in the late calving system.

Understanding the annual variation in cow performance at a specific location is important to better distinguish where differences observed in cow performance or differences due to location occur. Managing for fluctuations in cow BW and BCS throughout the production year is key to understanding treatment effects (calving season) on cow performance and reproductive efficiency. To manage cow performance so that optimal levels of reproductive efficiency can be achieved, targets need to be established for maintaining cow condition and weight at critical points in the annual cow production cycle. Therefore, measurements should be taken at critical periods to ensure interpretation of performance is accurate. A BCS of 3.0 is considered moderate and adequate for a high pregnancy rate (Richards et al. 1986). If cows at a BCS of 3.0 at parturition are able to maintain this throughout the lactation period, then cows should return to estrus relatively quickly with a short post partum interval (PPI) (DeRouen et al. 1994; Olson 2005). The winter months for a lactating cow and calf can be a nutritionally stressful time. The significant differences that were observed in this study are due to the lower BCS of cows at

Lanigan. Maintenance of body condition greater than or equal to 2.5 is not a concern as long as it is maintained throughout the production cycle (DeRouen et al. 1994). Stonehouse et al. (2003) found that cows in a late calving system (June) were able to maintain a higher BCS at breeding as compared to cows in an early calving system (March), and this alone was considered a beneficial advantage for the summer calving cows. Pang et al. (1998) found no significant differences ($P>0.05$) of BCS at calving between calving systems.

It is typical for a beef cow to lose body condition and fat reserves throughout the lactation period (NRC 2000; Lake 2006). However cows in the LCS in this study seemed to take advantage of the milder summer temperatures and good quality pasture forages when peak milk production occurred which coincided with increased nutrient intake. With the colder environmental conditions post-calving in spring for the ECS cows, cows will usually lose condition during the lactation period (Pang et al. 1998; Stonehouse et al. 2003), which was observed in this study. Similarly, Basarab et al. (2007) compared cows calving from early March to the end of May and observed that cows lost body fat as a result of fat mobilization during the lactation period. In general, in the current trial, cows did lose condition and body fat reserves from calving to weaning regardless of the calving system. March calving cows experienced a period of greatest nutrient requirements in late gestation and early lactation during the winter months, therefore causing the cow to lose body fat post-calving. The June calving cow experienced the greatest nutrient requirements during summer and fall pasture period when forage quality may be declining but the cows were able to maintain body fat reserves until later in the production cycle (from breeding to weaning) and then lost body fat reserves until the calf was weaned. Swift Current cows across calving systems were heavier (body weight) on average than cows at Lanigan or Brandon (Table 3.5). Differences in performance did not occur because of this variance in cow BW between locations. Cow age was significantly different between locations. Even though age of cow was not considered as a variable within the treatments, cows in Lanigan were older on average and seemed to have lower BCS, rib and rump fat measurements in the LCS cows, when comparing with BR and SC within calving systems, which may have been a factor of age.

Cow performance would have been seriously compromised if supplementation of energy and protein were not provided during periods of cold temperatures and snow accumulation. Variation in management of low cost feeding systems occurs because of the influence environment has on the outcome of the feeding period. This is an important factor to consider in areas that have increased snow fall such as Lanigan, Saskatchewan and Brandon, Manitoba. Cows in both calving systems experienced variable nutritional patterns relative to their physiological status. Early calving system cows had more fluctuation in BW and BCS, three to four months post-calving, which included the beginning of the breeding period. Late calving systems cows had greatest fluctuations in body condition during the later part of the production cycle (breeding to weaning). Both these periods coincided with lower environmental temperatures as well as periods that experienced spring and fall winter storms. An advantage for cows in a late calving system is the environmental temperature during the calving period is more favourable and the nutritional advantage that occurs with access to high quality productive pasture forage that can meet animal requirements during the lactation period. This is an advantage and viable management option for the late calving system. Cows in early calving systems calve in the colder months of late winter and early spring and this can be quite stressful on nutrient intake. As the temperature drops, the animal needs more feed to maintain body temperature and beef cows in average body condition are known to be cold stressed at temperature below -20^{o}C (NRC 2000). Temperatures on average were higher than -20 ^{o}C (Table B.1) during the lactation period (March and April) but were observed to be lower (-10 ^{o}C) during the gestation period for the cows in early calving system.

3.3.3 Reproductive Performance

Average calving distribution for both calving systems based on a 21 d interval is presented in Figure 3.7. Similar calving patterns were found for both calving systems (P=0.69). Location (P=0.59) and calving system by location interaction (P=0.84) differences were not significantly different. This suggests that delaying the calving season did not significantly affect the reproductive efficiency of either the cow or the bull, even though the breeding season was later in the calendar year when day length is shortening, which has been suggested to affect reproductive performance of the cow herd (Christensen 1980). Calving distribution could have shown that environment affected the breeding season, moreover the pattern the cows were bred within each production system, but we were not able to show a difference within the parameters of the current study.

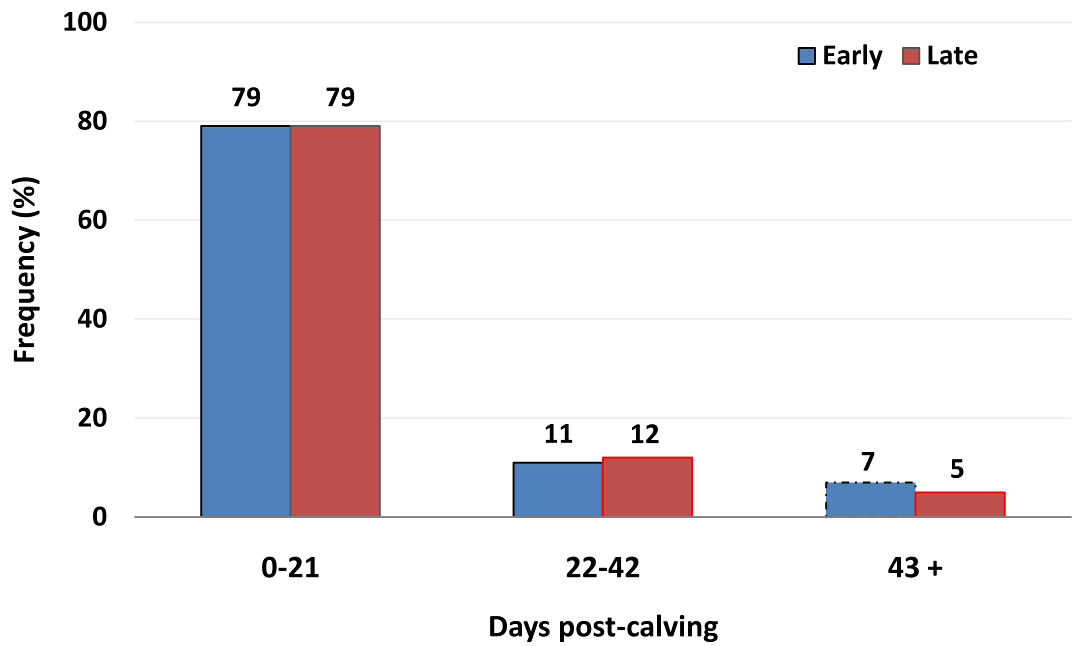

Figure 3.7. Calving distribution for early calving system and late calving system (2008 only).

Calving system (CS), location (L) and CS x L interaction had no effect (P>0.05) on pregnancy rate, calving rate, calving span or weaning rate (Table 3.7). Even though pregnancy rate was numerically higher at Lanigan for the ECS cows compared to the LCS cows. This was in contrast to pregnancy rate observed at SC, where the ECS cows had slightly lower pregnancy rates compared to the LCS cows. Pang et al. (1998) found no significant differences in pregnancy rates between early (89.2%, April) and late (91.9%, May/June) calving systems. The authors reported that the pregnancy rate for April calving cows was numerically lower than May/June calving cows, which is similar to pregnancy rates for cows at Swift Current in this study. Stonehouse et al. (2003) and Bagley et al. (1987) found similar results to Pang et al. (1998) for pregnancy rates. Calving rate (ECS vs. LCS) for this study (95.2 vs. 93.8%; pooled data not shown) were in contrast to results for Pang et al. (1998) (82.2 vs. 83.0%). Stonehouse et al. (2003) found no significant differences in weaning rates between winter (February-April) and summer (June-August) calving systems (78 vs. 80%), which was similar to Pang et al. (1998). Even though differences were not found in the current study, weaning rates were numerically higher for ECS cows compared to LCS cows (Table 3.7), which is in contrast to earlier studies (Bagley et al. 1987; Pang et al. 1998; Stonehouse et al. 2003).

Calving span for ECS cows was longer than LCS cows, 58 vs. 55 d, respectively (Table 3.7). The tighter calving period can be considered an advantage for the late calving cows which is similar to results found in the study conducted by Pang et al. (1998).

Finally, similar pregnancy, calving and weaning rates and calving span for cows in ECS and LCS across locations suggests that summer (late) calving has no negative effect on the cow and may be a viable alternative to a late winter, early spring (early) calving systems. Generally, cow BW, BCS and fat reserves tended to have less fluctuation for cows in the late calving system. During the lactation period, a period of high nutritional requirements, late calving cows may have been able to maintain their body weight, condition and fat reserves on summer pastures without any added environmental stresses. Any net loss in BW or BCS later in the year (breeding to weaning) did not significantly affect reproductive performance for the late calving system therefore supporting the adoption of a summer calving system. Since the study was started in 2007 when the first calf was born in each calving system at each location, the reproductive performance data is limited, as only reproductive parameters for the 2008 calving season are presented. Interpretation of the effects of calving system on cow reproductive performance from this data is therefore limited.

Table 3.7. Least square means of the effect of calving system on cow reproductive efficiency

	Early Calving System			Late Calving System			SEM	P values		
	BR[z]	SC	LA	BR	SC	LA		CS[y]	L	CSxL
Pregnancy rate (%)	-	94	96	-	97	88	2.6	0.57	0.43	0.09
Calving rate (%)	94	93	97	94	90	96	2.6	0.51	0.24	0.84
Calving span (d)	56	55	64	54	58	54	8.5	0.89	0.65	0.74
Weaning rate (%)	91	92	93	87	90	91	8.1	0.32	0.57	0.96

[z] cows were not pregnancy checked at Brandon, MB
[y] CS = calving system; L=location

3.4 Conclusion

Cow body weight and condition varied in both calving systems but during different periods throughout the production year. Differences in cow body weight and condition at key points, such as at pre-calving, breeding and weaning, throughout the year was found to vary within year, calving system and location. It is presumed that variation in cow body weight and condition may affect milk production. Even though LCS cows were in better body condition, which included rib and rump fat, throughout the production system, reproductive performance for both early and late calving systems across locations were not significantly different. An advantage may be that the calving span was shorter for the late calving cows but only by three days. This may suggest that bigger body fat reserves for the LCS had improved the early cycling of cows, but is difficult to conclude since the difference is so small. The results of this chapter indicate that summer calving may affect cow performance by altering body weight and condition fluctuation in gain and loss patterns throughout the production year; however later calving does not significantly affect reproductive performance when compared to spring calving systems, regardless of location.

4 EFFECT OF CALVING SYSTEMS ON PRE-WEANING CALF PERFORMANCE

4.1 Introduction

The increased cost of raising a beef calf has always been a challenge for producers in the beef industry. Lowering input costs is difficult as the cost to raise a calf is directly related to feed cost and cow management through gestation and up to weaning of the calf. Pre-weaning calf performance is therefore directly related to the performance of the cow. Environment is also an important factor that influences the nutritional needs of the calf and calf performance (Gonzales-Jiminez and Blaxter 1962; Reynolds et al. 1990; NRC 2000). The environment impacts the rate of growth of the calf because of its influence on nutrient requirements. Therefore, understanding the relative performance of cattle born during different seasons of the year is important to meet specific goals (Reisenauer et al. 2001).

Calf pre-weaning growth performance is critical to the sustainability of the beef cow-calf industry because producers are paid on a calf weight basis. Therefore, the cost of feeding and maintaining the cow must be accounted for through the sale of the calf. As a result, a management strategy that reduces the cow's feeding costs may increase the calf revenue return in some situations. Delaying the calving period has been shown to reduce cow feed costs, because of the availability of good quality summer pasture forages and minimal need for harvested forages (Adams et al. 1996). Calf health has also been shown to improve and calf mortality decrease for summer born calves compared to late winter or spring born calves (Stonehouse et al. 2003). Pang et al. (1998) in Alberta found decreased average daily gains for calves born in late May compared to April-born calves. Adams et al. (2001) reported decreased weaning weights for June versus March born-calves raised in Nebraska. Smith et al. (2001) found similar results in Wyoming. Grings et al. (2005) concluded that decreased weaning weights in late-born calves was a result of declining forage quality and different environmental conditions than the calves born earlier in the year,

There is limited information on the effects of calving system on calf performance on the Canadian Prairies. The objective of this study was to compare the effect of early (March) and late (June) calving systems on calf pre-weaning performance as depicted by growth rate, weaning rate and calf health. The hypothesis is that calf performance will not differ between early (March) and late (June) calving system.

4.2 Materials and Methods

4.2.1 Research Locations

The study was conducted at three different locations in western Canada which included; 1) AAFC-BRC in Brandon, Manitoba (49°52'N: 99°59'W) (BR); 2) AAFC-SPARC in Swift Current, Saskatchewan (50°16'N:107°44'W) (SC); and 3) Western Beef Development Centre's (WBDC) Termuende Research Ranch near Lanigan, Saskatchewan (51°51'N:105°02'W) (LA).

4.2.2 Animals

At each location, cows were randomly allocated to 1 of 2 replicated (n=2) treatments (calving systems): (1) Early calving group to calve starting in March (ECS) and (2) Late calving group to calve starting end of May (LCS). All treatments had 2 replicates, each managed separately and assigned to a separate paddock (30 cows/paddock for BR; 12 cows/paddock for SC; 25 cows/paddock for LA). Calving systems were managed similarly with 120 cows at BR (60 cows in ECS; 60 cows in LCS), 50 cows at SC (25 cows in ECS; 25 cows in LCS) and 100 cows at LA (50 cows in ECS; 50 cows in LCS). All cows were crossbred and were predominately of British origin (Angus or Hereford). Once cows were assigned to a calving system and their replicate groups, they remained within these groups for the full length of the study. Animals used in this experiment were cared for under the guidelines put forward by the Canadian Council of Animal Care (2007).

Calves were managed based on the cow treatment groups and remained in each respective treatment group until weaning. All cows were bred by natural breeding by either a Gelbvieh (Lanigan) or Red Angus (Brandon; Swift Current) bull. The same bulls were used for each calving system and for all years of the study. Breeding season was from 30 May to 31 July and 20 August to 25 October for Early and Late calving, respectively (exact dates varied by year).

Average calving dates for Early and Late calves were 24 March and 9 June, respectively. All calves were weighed within 24 h after birth (150S Calf Chute, 7-L Livestock Equipment Ltd., Lakeland, Manitoba), at approximately 60 d of age and at weaning (weights adjusted to 205 d weight; Tru-Test XR 3000 scale). At birth, calves received an injection of vitamin A and D (Dominion Veterinary Laboratories Inc., Winnipeg, MB), E and selenium (2 mL/45 kg of calves) (Dystosel, Pfizer® Kirkland, PQ). Calves with horns were dehorned using the dehorning paste

(D-HORN Paste (DVL), Dominion Veterinary Services). All bull calves were castrated using castration rings. At 60 d of age, calves were vaccinated with Somnu Star pH (Novartis®, Mississauga, ON), Covexin 8® (Intervet/Schering-Plough®, Omaha, NE), and Express 5® (Boehringer Ingelheim®, St. Joseph, MO). At weaning, calves were vaccinated again with a booster shot of the same vaccines. At 60 d of age, all calves at LA were vaccinated with Anthrax Spore Vaccine (Colorado Serum Company®, Denver, CO). Weaning occurred on 1 October and 1 January for Early and Late calving systems, respectively (exact dates varied by year). Calf weaning weights were adjusted for 205 days of age.

Calf health was monitored and assessed by determining the total cost of treatments given to calves at each calving system. Treatment assessment was done by taking the calf's body temperature and by physical assessment. Prolonged suffering of diarrhoea or pneumonia resulted in treatment with a long acting antibiotic such as florfenicol (1.0 mg per kg SQ, Nuflor® Intervet/Schering-Plough, Omaha, NE) or trimethoprim-sulfa (dose IM, Trivetrin® Intervet/Schering-Plough, Omaha, NE).

4.2.3 Experimental Design and Statistical Analysis

Experimental design was a randomized complete block design where location was the blocking factor and each treatment (ECS and LCS) was replicated in each block. Calf production data was analyzed using the PROC MIXED procedure of SAS (SAS Inst. Inc. Cary, NC). Treatment, location, year, treatment x location, treatment x year, location x year and treatment x location x year interactions were analyzed as fixed effects. Year was also included as a repeated measure. The calf weight data was evaluated using a sex correction based on the trait mean. A number of covariance structures were tested for each variable and the final covariance structure was selected on the basis of the lowest AIC value. Weaning rate and calf mortality data was analyzed using the Proc GLIMMIX procedure of SAS (SAS, Version 9.1, SAS Inst. Inc. Cary, NC). All calf data was analyzed based on treatment groups that were established based on replicated cow data, therefore all calf data Tukey's multiple range test was applied to determine the treatment means separation differences and were considered significant when $P < 0.05$ (Steel et al. 1997).

4.3 Results and Discussion

4.3.1 Environmental Data

All calves in this study were managed as a pair with the dam at all times as growth and performance of the calf were closely monitored from birth to weaning. Early calving system calves were born at pasture in 2007 and 2008 at each location, but environmental conditions (temperature and precipitation) varied at each research location in each year (Table 4.1). An exception to normal management protocol occurred at BR where LCS cows and calves born on pasture but were fed supplemental hay to ensure adequate quantity of nutrients were available to maintain an early lactating cow. This was done because pasture forage quantity and quality were not adequate to meet the lactating cow's daily nutrient requirements. Cows and calves in the LCS had consistently colder temperatures during the 60 d before weaning than did cows and calves in the ECS (Table 4.1). The calving season for the ECS (March, April and May) is colder across the three months compared to the calving season for the LCS cows (June, July and August) (Table 4.1).

Table 4.1. Mean monthly hourly temperature from birth to weaning for ECS and LCS at three locations

	2007			2008		
	BR[z]	SC	LA	BR	SC	LA
Early Calving System (ECS)						
March	-4.9	0.6	-4.5	-7.0	-2.3	-6.1
April	4.5	4.7	4.0	-3.4	3.0	2.8
May	11.3	11.6	10.4	9.1	10.8	9.6
June	16.7	16.0	15.4	24.0	14.1	14.6
July	20.9	22.5	20.7	17.9	17.9	17.3
August	16.8	17.8	15.5	18.8	18.1	17.3
September	12.5	11.7	10.6	30.8	12.3	11.3
Mean	*11.1*	*12.1*	*10.3*	*12.9*	*10.6*	*9.5*
Late Calving System (LCS)						
June	16.7	16.0	15.4	24.0	14.1	14.6
July	20.9	22.5	20.7	17.9	17.9	17.3
August	16.8	17.8	15.5	18.8	18.1	17.3
September	12.5	11.7	10.6	30.8	12.3	11.3
October	6.2	6.8	5.4	5.9	6.2	5.4
November	-4.7	-3.1	-5.5	2.3	0.1	-2.9
December	-15.7	-10.6	-15.4	-19.2	-14.8	-19.3
Mean	*7.5*	*8.7*	*6.7*	*11.5*	*7.7*	*6.2*

[z] BR=Brandon, SC=Swift Current, LA=Lanigan

Precipitation was also different at each research location. Figures B.1, B.2 and B.3 (Appendix B) illustrate how BR generally had above average precipitation (30-yr average) during the two yr study, whereas SC had lower (40%) than average precipitation for 2007, which could be considered a drought year. However in 2008, SC had above normal precipitation throughout the growing season. In 2007 and 2008, LA received lower than average precipitation levels. Adequate precipitation during the growing season will alter forage yield and quality (Grings et al. 2005) thereby affecting total milk production of the cow (NRC 2000; Sprott et al. 2001) and this can alter the expected level of calf growth and performance. Neonatal calves from the early age of one to four mo typically depend solely on the dam's milk (NRC 2000), therefore any circumstances that affect cow performance and in turn milk production will affect calf growth and weaning performance and health.

4.3.2 Calf Health

Calf vaccination and treatment costs are presented in Table 4.2. Vaccination costs reflect location differences, however at LA vaccination costs were higher because of the additional Anthrax Spore vaccine used. Calf treatment costs were higher for animals in the LCS at LA, which is different from what occurred for BR and SC. Additional treatments for the LCS at LA occurred during the last two months prior to weaning in winter which resulted in higher treatment costs of 119% and 119% compared to ECS at LA for 2007 and 2008, respectively. Brandon ECS calves had higher treatment costs because of high occurrence of scours in the first two months following birth. Overall, costs for vaccinations and treatments were lower for LCS calves compared to the ECS calves by 15%, 19% and 4% for BR, SC and LA, respectively. This is similar to a study conducted in Ontario by Stonehouse et al. (2003) found the ECS calves had higher treatment costs on average than did the LCS calves. Adequate precipitation may be beneficial for good forage production which in turn helps with milk production (Sprott et al. 2001), but when the precipitation comes in the form of snow this may act as a stressor on the calf and increase the incidences of disease (Gonzales-Jiminez and Blaxter 1962; Reynolds et al. 1990). This may have been an important factor for the LCS calves later in the growth period prior to weaning and could affect health of ECS calves early in the growing period. Exposure of pathogens to winter or early spring born calves is assumed to be higher because of the calving environment, which may be the reason for increased need to treat sick calves (Stonehouse et al.

2003). In Alberta, Pang et al. (1998) noted the benefit of calving later in the year (summer months) resulted in less cold environmental stress on the calf early in life. Grings et al. (2005) found increased calf mortality for February born calves compared to April and June born calves which was caused by climatic differences.

Table 4.2. Vaccine and treatment costs - 2007 and 2008 ($ cow^{-1})

	Brandon				Swift Current				Lanigan			
	ECS[z]		LCS		ECS		LCS		ECS		LCS	
	2007	2008	2007	2008	2007	2008	2007	2008	2007	2008	2007	2008
Vaccines	9.54	11.11	9.54	10.92	5.30	7.82	5.60	5.43	11.13	11.63	10.08	9.69
Treatments	2.81	1.27	-	0.77	0.61	0.14	0.03	-	0.93	0.90	2.04	1.97
Average	12.37		10.62		6.80		5.53		12.30		11.89	

[z] ECS = Early Calving System; LCS = Late Calving System

Calf mortality was recorded and no differences were found within calving systems (P>0.98; Table 4.4). Brandon had numerically higher calf mortality than LA and Swift Current. In 2007, higher calf mortalities occurred for LCS compared to ECS across all locations. In 2008, LA ECS calves had higher mortalities, but BR and LA had similar mortalities. All calf mortalities were due to calves born dead or born weak, except for one calf that was found dead at SC for the LCS and may have died of dehydration during a hot period in July. Results found by Pang et al. (1998) for mortalities from birth to weaning were similar between early (22%) and late (22%) calving systems. Stonehouse et al. (2003) reported 7.0 and 7.7% mortality for calves in the late winter and summer calving systems, respectively. Lesmeister et al. (1973) found no significant difference between early (13%) and late (0%) calving systems mortalities. However in Nebraska, Deustcher et al. (1991) found lower calf mortality for calves born in the summer months. This was similar to a study by Grings et al. (1996) found in Montana, where February born calves had higher mortality (3.5%) than April and June born calves (1.5%). In the current study, calf mortality was similar between calving systems and there appeared to be no obvious pattern across locations, years or calving systems.

Table 4.3. Calf mortality (± SEM[z] %) for 2007 and 2008

	2007		2008	
	ECS[y]	LCS	ECS	LCS
Brandon	5 ±2.8%	6 ±3.2%	5 ±2.6%	5 ±2.6%
Swift Current	0	3 ±3.6%	3 ±3.1%	3 ±3.3%
Lanigan	0	6 ±3.4%	4 2.3%	2 ±1.8%

[z] SEM = standard error of the mean
[y] ECS = Early Calving System; LCS = Late Calving System

Table 4.4 Analysis of variance comparing calf mortality							
	P value						
	CS	L	Y	CSxL	CSxY	LxY	CSxLxY
Calf Mortality	1.0	1.0	0.98	1.0	0.98	1.0	1.0

[z] CS = calving system; L=location; Y=year

4.3.3 Calf Performance

A significant two way (CSxY) interaction was observed for calf BW at birth (P=0.002) and 60 d of age (P=0.02) (Table 4.5). Location main effect were significant for calf BW at birth (P<0.0001), at 60 d of age (P-0.01) and at weaning (P=0.05). Treatment (CS) was also significant at weaning (P<0.0001). Treatment (CS) (P<0.0001) and year (Y) (P=0.05) main effects were significant for ADG (Table 4.5). Weaning rate was not affected by calving system, location or year. Only the interactions that are significant and that include calving season will be discussed. Other interactions are presented as tabled data but will not be discussed. Main effects will only be discussed if there are no interactions that are significant.

Table 4.5. Analysis of variance comparing calf performance and reproductive parameters							
	P value						
	CS	L	Y	CSxL	CSxY	LxY	CSxLxY
Calf weight (kg)							
Birth	0.03	<0.0001	0.04	0.27	0.002	0.14	0.17
60-d of age	<0.0001	0.01	0.57	0.78	0.02	0.15	0.50
Weaning	<0.0001	0.05	0.11	0.77	0.07	0.15	0.74
Performance							
ADG (kg d^{-1})	<0.0001	0.14	0.05	0.71	0.15	0.12	0.86
Weaning rate (%)	0.32	0.59	-	0.92	-	-	0.57

Late calving system calf BW at birth in 2008 was heavier (P=0.002) than LCS calves in 2007 and ECS calves in 2007 and 2008 (Table 4.6). Calf BW across locations were 45, 41 and 42 ± 0.8 for BR, SC and LA, respectively, where BR calf BW was significantly heavier (P<0.0001) than SC and LA, which may have been related to the supplemental hay that was fed during the LCS calving period. Swift Current and LA were similar for calf BW at birth (P>0.05). At 60 d of age, ECS calves had greater BW in 2007 and 2008 compared to LCS calves. Early calving system 60 d weights were greater (P=0.02) in 2007 compared to 2008 and the opposite occurred for the LCS where calves in 2008 were heavier than calves in 2007 (Table 4.5). Location differences in calf BW at breeding were found where BR was greater (P=0.01) than both SC and LA, 111, 103 and 101 ±1.7 kg, respectively. Swift Current and LA were similar (P>0.05). Early calving system calf weight at weaning was heavier (P<0.0001) than LCS BW, 273 and 240 ±1.8 kg, respectively. Calf weaning weight at BR (270 kg) was higher (P<0.0001) than wean weight at SC and LA, 255 and 244 ±4.3 kg, respectively, but only different from Swift Current. Early calving system calf ADG was higher (P<0.0001) than LCS calf ADG, 1.13 vs. 0.96 ±0.01 kg d^{-1}, respectively. There were no significant interactions or main effects for weaning rate over the 2 yr study (P>0.05). Weaning rate (%) was similar over CS and L with values ranging from 87 to 94%. Average weaning rate was higher for calves in the ECS compared to calves in the LCS, 92 vs. 90%, respectively, but not different (P>0.05) (Table 4.5).

Table 4.6. Least square means of the effect of calving system on calf weight for 2007 and 2008

	ECS		LCS		SEM
	2007	2008	2007	2008	
Calf weights (kg)					
Birth	42a	41a	41a	44b	0.5
60-d	111d	108c	100b	102a	1.1

[a-c] Within row means having the same letters do not differ significantly (P<0.05)

In this study, location differences in calf BW at birth was expected and may have been affected by management, precipitation and quantity and quality of available forage. At Brandon, ECS and LCS cows were fed supplemental hay on pasture because of limited available pasture forage for cows pre and post-calving. This lower available forage could have affected calf birth weight because nutrient intakes of cows pre-calving can significantly affect calf birth weight by limiting nutrients to the fetus (Ferrell et al. 1976a), but supplemental hay was provided. Total precipitation at BR was above average for some of the study period and may have improved forage quantity and quality for this location. The heavier birth weight for cows in summer calving systems has been reported by Pang et al. (1998), which is similar to LCS calf BW found in this study in 2008. However in Ontario, summer born calves had lighter birth weight than late winter born calves, which was similar to the current study for 2007. Early calving cows in the current study were supplemented barley grain prior to calving to ensure energy requirements were met for the cow in late gestation and the growing fetus. This additional energy provided to the ECS cows did not affect calf birth weight in 2008 but appeared to in 2007, where calf birth weights were higher for the ECS. Environmental differences across locations and differences across years of the study are presumably a large factor affecting the results of calf performance in this study (Figures B1, B2 and B3 in Appendix B). Youngberg (1999) also found that calves born in the summer months were heavier at birth, which was in agreement with the current study. It has also been found that cows that consume excessive protein prior to calving were observed to have increased calf birth weights (Bellows and Short 1978).

Another factor that affects calf birth weight is age of the dam (Barkhouse et al. 1998; Renquist et al. 2006). In the studies done by Barkhouse et al. (1998) and Renquist et al. (2006), cow age did not significantly affect calving system, but it is known that multiparous cows normally give birth to heavier calves than do first calf heifers (Notter et al. 1978; Doornbos et al. 1984; Barkhouse et al. 1998; Renquist et al. 2006). However, in the current study, cow age was not extensively evaluated; therefore no deductions can be made comparing the differences in cow age across locations.

Pre-weaning calf weight gain is directly correlated with milk production of the dam (Renquist et al. 2006). Milk production in the first 60 d post-calving is steadily increasing, thereby affecting calf growth during this period. Figures 3.2, 3.4 and 3.6 illustrate for the most part that energy requirement were met at all three locations, with protein being limited at times. The differing environmental conditions and forage quality may have been a significant factor affecting calf growth rate for the late born calves compared to the early born calves (Figures B.1, B.2 and B.3 in Appendix B). Snow cover for the last three months pre-weaning may also influenced LCS calf growth (Grings et al. 2005). Lanigan experienced below normal precipitation for both years of the study, SC experienced drought conditions for 2007 but not 2008, suggesting a reason for the lighter calf weaning weights at LA and SC compared to BR which did not experience below average rain for either year of the study (Figures B.1, B.2 and B.3 in Appendix B). Location differences in weaning weights are evident across many studies. Environment conditions the cow is managed in plays a large role in calf performance, and differences are expected when comparing locations. Grings et al. (2005) found similar results where summer born calves had lighter weaning weights compared to late winter or early spring born calves. It was reported that a decreased weaning weight in December was a seasonal effect which is related to declining forage quality resulting in decreased calf gain related to both milk production reduction and a decline in intake with declining forage quality (Rutledge et al. 1971; Adams et al. 1993; Grings et al. 1996). Studies conducted in Nebraska and Wyoming also found lighter weaning weights for June born calves compared to March born calves (Adams et al. 2001; Smith et al. 2001).

In agreement to our results, Pang et al. (1998) also found a reduced ADG for summer born calves and this was caused by decreased forage quality and lighter weaning weights. This was also found in a study conducted by Grings et al. (2005) in Montana when comparing April and June calving. The researchers concluded the reduced weaning weight was a seasonal effect caused by the declining forage quality, thus decreasing calf gains with advancing season (Grings et al. 2005). This would therefore be a factor of decreased milk intake and quality forage consumed by the calf. Adams et al. (2001) in Nebraska and Smith et al. (2001) in Wyoming also reported lighter weaning weights for June born calves as compared to March born calves. Pang et al. (1998) had compared different breeds of cattle (dairy line vs. beef line), where the author found that calf pre-weaning growth was significantly affected by the dam's milk production abilities where the dairy line would have the ability to produce more milk than the beef line. On the western Canadian prairies, temperature and snow depth may also play a role in decreased weaning weights for calves born later in the year. A theory also supported by Grings et al. (2005) in Montana. Furthermore, lighter weaning weights are a common result in summer calving herds. One universal factor across various studies is that forage quality declines in late summer and into the fall which coincides with the lowered ADG for the summer calf (Adams et al. 1994b; 2001; Stonehouse et al. 2003; Grings et al. 2005; 2007). The late winter, early spring calf is typically weaned prior to the commencement of the fall period, therefore not exposed to lower quality feed pre-weaning. These yearly variations in calf body weight are expected as both milk production and quality of forage consumed by calves are affected by precipitation pattern and its effect on quantity and quality of available forage (Sprott 1999; NRC 2000; Grings et al. 2005; 2008). Environmental differences would be the largest influential factor in both cases, where from one year to the next, there can be large variations in forage quality and quantity which is affected by total precipitation. Regional differences would then be the factor influencing the significant outcome between locations where LA and SC had lower than average precipitation and BR precipitation was around the 30 year average, therefore assumed to have normal environmental conditions (Figures B.1, B.2 and B.3 in Appendix B). Even though there were differences between locations and years, similar patterns occurred specific in each calving system (Lardy et al. 1998; Pang et al. 1998; Stonehouse et al. 2003; Grings et al. 2005). In Stonehouse et al.

(2003) study, calves were born approximately 16 d earlier therefore reducing the total amount of time to gain prior to weaning.

Weaning rates across calving systems were not different (Table 4.4). This was similar to Pang et al. (1998) where there were no differences between calving systems (April vs. May/June), 78.3% and 78.3%, respectively, over the 3 years of the study. Grings et al. (2005) also reported no differences in calf survival through to weaning on calves born in February or April and June. This does not coincide with other studies that reported lower weaning rate for the early winter, late spring calving systems as compared to summer calving systems (Youngberg 1999).

Adjusting calving period for beef cows from late winter through later spring or summer affects the quality of forage available for milk production and the growth of calves on the Canadian Prairies. Systems leading to decreased milk throughout lactation are expected to result in decreased calf gains for that system, especially where forage quality or quantity may be limiting to calf growth in the days leading up to weaning. Calves suckling dams with lowered milk yield tend to eat more forage to compensate (Baker et al. 1976; Ansotegui et al. 1991), however this parameter was not measured in the current study.

4.4 Conclusion

Calving in June (LCS) improved calf health by decreasing the cost and number of treatments for the calf prior to weaning, although this is only a numerical difference. However, calf weaning rate were not affected and calf mortality did not differ across calving systems, locations or years. Calf birth weight was higher for the LCS in 2008 compared to the ECS, although weaning weights were greater for ECS calves compared to LCS calves. Calf growth rate (ADG) overall was higher for the ECS as compared to LCS. Weaning LCS calves in early January may have affected calf growth rate and weaning weight because of decreasing forage quality in the fall, which in turn may have affected milk production and total nutrients consumed by the calf. The poor performance of calves born in the summer period may affect the competitive advantage of calving later in the calendar year to better match nutrient availability and requirements an advantage which is quickly lost when calf growth is lower and does not result in heavier weaning weights at five to six months of age. Further research is required to measure the impact on calf growth rate and weaning weight when implementing creep feeding practices in later calving systems. Calf health may also be improved with creep feeding later in the growth period, which could have helped calves at LA in both years of the study where the cow-calf pair was managed throughout the winter snow storms with high levels of snow accumulation. Calf performance parameters indicate that summer calving is a potential alternative to replace spring calving when focusing on calf birth weight. Weaning rate could be improved although a study conducted during more years may be able to test for any differences. However, final weaning weight and overall ADG may be negatively affected. The competitive advantage for the summer calving period may be strongly influenced by the reduced need for labour during the calving period.

5 ECONOMIC EVALUATION OF TWO CALVING SYSTEMS ON FEEDING MANAGEMENT

5.1 Introduction

A beef production system is a highly complex combination of many biological and economical factors. Biological factors may be cow weight, forage growth and climatic conditions. Economical factors may include overhead costs such as buildings, machinery and labour that influence the profitability of the production system. The cow-calf system must be viewed in its entirety to understand how its components interact with one another. Understanding the relative performance of cattle born during different seasons of the year is important to meet specific goals and optimize economic returns (Reisenauer et al. 2001). Classifying management practices that will efficiently utilize all on-farm resources is difficult due to unforeseen economic conditions. Various methods used to assess the variables that have the largest impact on cow-calf enterprise profitability include simulation models (May et al. 1999; Pang et al. 1999; Carriker et al. 2001; Reisenauer Leesburg et al. 2007b,a; Sirski 2011) and summarizing regional producer data (Larson 2010). All approaches are meant to characterize specific factors that impact cow-calf production and cost of production, but are limited by the assumptions of each model, whether simulated or real. The results are then very specific to the year and the region and based on the assumptions were made.

To improve profitability, cow-calf producers have considered changing in the date of calving as a means to reduce feed costs (Adams et al. 1996; Basarab 2001; Stonehouse et al. 2003). When calving seasons were changed, other management factors were changed as a result (May and Van Tassell 1999). For example, peak pasture forage production and the association with an animal's physiological status (Vavra and Raleigh 1976; Adams et al. 1996) will be impacted. Sirski (2011) reported net economic returns were affected by calving system, with cost of production being lower for summer versus spring calving. Over the years, summer calving systems have gained popularity for this reason in western Canada.

Few studies related to alternative calving season have systematically evaluated the effects of calving season in combination with various feeding management systems on the Canadian prairies (Basarab 2001). Lowering production costs by using efficient management practices is of interest to ranch enterprises (Adams et al. 1996; Basarab 2001; Carriker et al.

2001). Using strategies that extend the normal grazing season for beef enterprises is one approach that can reduce costs. Stonehouse et al. (2003) in Ontario reported that summer-calving herds unequivocally reduced labor and animal treatment costs. Less mechanically harvested forages were used and therefore reduced feeding costs. In contrast, a study by Reisenauer et al. (2007) reported that spring calving is more profitable than summer calving.

This section will evaluate the relative costs of four feeding management systems for two calving systems, early (March) and late (June) calving systems at three locations, Brandon (BR), Swift Current (SC) and Lanigan (LA) for two production years (2007 and 2008). There are few studies comparing calving systems in western Canada, therefore evaluating production conditions in western Canada is important to be able to directly assume any differences in cost. Two pre-weaning calf growth periods (2007 and 2008) will be examined. Cost of production within each calving system will also be evaluated. The objective will be to determine the effect of early and late calving systems on production and treatment costs from calving to weaning for the cow and calf.

5.2 Materials and Methods

5.2.1 Research locations

The study was conducted at three different locations in western Canada which included; 1) AAFC-BRC in Brandon, Manitoba (49^{o}52’N: 99^{o}59’W) (BR); 2) AAFC-SPARC in Swift Current, Saskatchewan (50^{o}16’N:107^{o}44’W) (SC); and 3) Western Beef Development Centre’s (WBDC) Termuende Research Ranch near Lanigan, Saskatchewan (51^{o}51’N:105^{o}02’W) (LA). Brandon is located in the Black soil zone, whereas LA is in the Dark Brown soil zone and SC is located in the Brown soil zone.

5.2.2 Animals

At each site, cows were randomly allocated to 1 of 2 replicated (n=2) calving systems: (1) Early calving system (ECS) to calve starting in March and (2) Late calving system (LCS) to calve starting in June (Table 3.1). Calving systems were managed similarly with 120 cows at BR (60 cows for ECS; 60 cows for LCS), 50 cows at SC (25 cows for ECS; 25 cows for LCS) and 100 cows at LA (50 cows for ECS; 50 cows for LCS). All cows were crossbred and were predominately of British origin (Angus or Hereford). Once cows were assigned to a calving system and their replicate groups, they remained within these groups for the full length (2 yr) of the study. All cows reared their own calves and were pregnant when the study began in March of 2007. Animals used in this experiment were cared for under the guidelines put forward by the Canadian Council of Animal Care (2007). The same bulls were used for each calving system and for the full length of the study. Breeding season was from 30 May to 31 July and 20 August to 25 October for early calving system (ECS) and late calving system (LCS), respectively. Average calving dates for ECS and LCS were 24 March and 9 June, respectively.

5.2.3 Feeding Management

Early and late calving systems were managed in four different feeding systems (pasture grazing (PG), swath-windrow grazing (SG), bale grazing (BG) and drylot pens (DL)) but the time animals were in a system varied depending on calving period. Each feeding system was managed similarly for animals in either calving system. Early calving system cows calved in drylot pens in contrast to LCS cows which calved on pasture. The drylot pens were used primarily during the pre-calving and calving period of the early calving system. Pastures were grazed when sufficient pasture forage was available to support both the cow and calf. Summer grazing period on mixed cool season species pastures occurred from May to September. Cattle movements among pastures were based on forage availability and animal requirements. Following summer pasture grazing and weaning, cows were moved to annual crop SG fields for approximately 30 d period (start and end date varied depending on the year). Annual crops were swathed at soft dough stage in early September. An exception was at SC, both ECS and LCS cows did not swath-windrow graze. Lack of precipitation and rodent infestation decreased crop yield at this location, therefore cows' grazed standing crop only. Bale grazing commenced following the swath grazing period. Cows were supplemented with either rolled barley grain (1-3 kg d^{-1}) or range pellets (2-3 kg d^{-1}) depending on environmental conditions and nutritional requirements. Calves were weaned prior to cows managed in the bale grazing system. Early calving system cows at BR did not BG in 2007 due to lack of an available winter grazing site. Amount of feed offered and consumed per system was calculated for each system.

5.2.4 Feeding System Cost

Feeding system cost summaries were compiled for each calving system, research location and year from the start of one calving period through to the beginning of the next calving period.

5.2.4.1 Direct Feeding System Cost

Direct costs were related to hay and feed production, pasture management (confined feeding, bale grazing, swath grazing and pasture), veterinary services, drugs and vaccines and breeding stock use for each calving system. Number of days that animals spent in each feeding system was also recorded. Total amount of hay, supplement, mineral and salt fed to cows and replacements heifers were also recorded. Purchased feed costs for drylot and bale grazing systems were included. Vaccination and treatment costs per calving system were calculated based on calving system.

5.2.4.2 Overhead Feeding System Cost

Overhead costs included costs labour, equipment and yardage. Labour cost was calculated at \$15.00 h^{-1} and multiplied by the number of actual h recorded at each research site for each calving system (Saskatchewan Ministry of Agriculture 2005a; 2005b). Total equipment costs were based on h of use multiplied by cost per hour. Farm equipment use rates were based on the Saskatchewan Ministry of Agriculture 2006-07 and 2008-09 Farm Machinery Custom and Rental Rate Guide (Saskatchewan Ministry of Agriculture 2005a; 2005b).

The yardage rate calculated for each feeding system was determined directly from the data collected. Yardage included cost for feed, equipment use, labour, fuel, building repair, utilities, fence maintenance and water. A standard yardage charge was used for all three research locations to ensure a representative yardage cost was applied and to remove unnecessary variation between feeding systems. For this reason, the actual yardage costs calculated at the Lanigan location was applied to Swift Current and Brandon locations. Lanigan costs were more representative of industry cost of production for a beef cow-calf enterprise.

Pasture Grazing. Due to the difficulty of assessing age and productivity level of forage stands at each location, a constant rate of \$0.80 cow^{-1} d^{-1} was used for cost of pasture grazing at all locations. Variation in pasture costs for each location and calving system is associated with total labour and machinery use while moving animals from pasture to pasture, hauling water and cross-fencing (Table A.1, Appendix A).

Swath-windrow Grazing. Annual cereals for swath grazing were grown at each location; therefore, feed costs are associated with seeding and related field costs. The cost of growing the annual crop was determined by recording labour and input costs for cultivating, disking, fertilizing, seeding, harrowing, spraying herbicide and swathing (Table A.2, Appendix A). Swath grazing not used at SC due to poor moisture conditions, however the annual crop was grazed standing.

Bale Grazing. Hay bales used for bale grazing were purchased off-site at Brandon and Lanigan locations; however bales were harvested and used on-site at Swift Current. Total number of hay bales used in the bale grazing paddocks was recorded and feeding rate was managed based on the DM content of the hay bales. Portable electric fence was used to limit animal accessibility to hay during the feeding period at BR and LA; while a bale feeder was used to reduce the amount of BG feed waste at Swift Current. Labour requirements consisted of moving the electric fence when more feed was required. In 2008, cows in the early calving system (ECS) and cow-calf pairs in the late calving system (LCS) were supplemented with barley grain. Total number of days fed, bales fed, amount of supplement (barley grain), mineral, vitamin, treatments and labour were recorded during the BG feeding period.

Drylot Pens. Drylot feeding was used primarily during the pre-calving and calving phase in the early calving system. Total number of days fed, bales fed, amount of supplement (barley grain), mineral, vitamin, treatments and labour were recorded during the BG period. Dry matter content and hay quality was assessed prior to start of feeding system.

All costs associated with each feeding system are expressed on a per cow per day basis and include amount of feed (supplement and forage) and labour and machinery used to manage animals in each calving system. Costs not included in the feeding system cost are mineral ($0.03/cow/d), salt ($0.01/cow/d), breeding ($0.10/cow/d), taxes and water ($0.10/cow/d), freight/trucking ($0.02/cow/d) and marketing ($0.05/cow/d). These additional costs are not associated with one feeding system, but were designated as a direct cost to both calving systems.

5.3 Results and Discussion

Total feeding system costs for all three research locations for each calving system and for each production year are presented in Table 5.1. To calculate yardage cost per cow per day, the actual costs determined at LA were applied to all three locations. As expected, total feeding system cost for pasture grazing was lowest for both calving systems and the highest feeding system cost was for drylot feeding. One exception occurred in 2008 where the SG cost was \$0.05 lower than pasture grazing. In 2008, feeding system costs for bale and drylot feeding increased by 53 and 16% for ECS and 14 and 28% for LCS over 2007 costs, respectively. The increased cost may be associated with increased fuel and feed costs in the second year. Research station costs are typically inflated because of the extra labour needed to collect data and manage the animals in replicate groups. Lanigan's costs were lower on average and more closely related to industry costs for extensive feeding, which justified its use as production costs from in assessing the cost of managing the cow herd in the four feeding systems and reducing the risk of confounding location costs (Russell 2009). In this study, limitations were experienced in implementing a standard production cost and are confounded by the assumptions made which need to be taken into consideration when interpreting the relative costs of each calving system.

Table 5.1. Feeding system costs for early and late calving systems for 2007 and 2008^{z} (\$ cow^{-1} d^{-1})

	Early Calving System		Late Calving System	
	2007	2008	2007	2008
Pasture grazing	1.01	0.97	1.03	1.06
Swath grazing	1.65	0.92	1.63	1.08
Bale grazing	1.35	2.06	1.74	1.98
Drylot feeding	2.08	2.42	1.72	2.20

^{z} Costs are calculated costs for each feeding system based on Lanigan costs which included feed, labour and machinery

5.3.1 Feeding System Costs

5.3.1.1 Calving to Weaning Period

Late calving system cows spent a longer amount of time in extensive grazing feeding systems (PG, SG and BG) than in DL system, regardless of location from calving and weaning (Table 5.2). In 2007, LCS BR cows spent 24% more time grazing than did ECS cows at BR. This resulted in ECS cows spending more time in DL, which in turn increased total feeding system cost by 12% or $39.32 cow^{-1} (Tables 5.2 and 5.3). In 2008, BR ECS cows spent 50% of their time on either pasture or swath grazing and the other 50% in DL, while LCS cows spent 78% of combined time wither PG, SG or bale grazing. This difference in management resulted in the LCS production period to cost $74.94 cow^{-1} less than the ECS, a decrease of 25% in feeding system costs (Tables 5.2 and 5.3). At SC, LCS cows spent 59% and 104% more time PG, SG and BG in 2007 and 2008, respectively. However feeding system cost was not lower in 2007 at SC, because of the increased costs of grazing standing annual forages, which then increased the time spent bale grazing. As a result, a cost advantage for the ECS was $17.16 cow^{-1} at SC (Table 5.3). In comparison in 2008, LCS costs at SC were lower by $82.35 cow^{-1}, a difference of 29% when comparing to ECS cows in the same year. At LA in 2007, LCS cows spent 5% more time grazing than ECS cows, this small difference resulting in higher costs for the LCS cows by $53.00 cow^{-1}. The increased cost for the LCS cows at LA may have been caused by increased time spent swath grazing. In 2008, Lanigan LCS were managed in the extensive grazing systems and resulted in spending no time in DL pens which reduced the feed system cost by $63.52 cow^{-1} when compared to ECS cows which spent only 57% of the time either PG, SG or bale grazing (Table 5.2).

In summary, LCS cows were managed in extensive grazing systems for longer periods regardless of the year compared to ECS cows, 80 versus 63% and 93 versus 52% for 2007 and 2008, respectively (Table 5.2). The cost differences averaged across locations were higher for the ECS in 2008 by 26% but the inverse occurred in 2007 by 3% (Table 5.3). When averaged across year and locations, cost differences were lower for the LCS compared to the ECS by 10% (Table 5.3), but as seen in the current study, this may not occur every year, even if similar grazing systems are used.

Table 5.2. Percentage of time spent extensive grazing (pasture, swath graze, bale graze) or in drylot for early and late calving systems from calving to weaning (%)

	Early Calving System		Late Calving System	
	2007	2008	2007	2008
Brandon				
Grazing	54	50	67	78
Drylot Feeding	46	50	33	22
Swift Current				
Grazing	58	49	92	100
Drylot Feeding	42	51	9	0
Lanigan				
Grazing	77	57	82	100
Drylot Feeding	23	43	18	0
Average grazing	**63**	**52**	**80**	**93**
Average drylot	**37**	**48**	**20**	**7**

Table 5.3. Feeding system costs for early and late calving systems from calving to weaning ($ cow^{-1})

	Early Calving System		Late Calving System	
	2007	2008	2007	2008
Brandon				
Pasture Grazing	84.84	64.99	95.39	150.12
Swath Grazing	69.30	40.48	105.86	38.84
Bale Grazing	0.00	0.00	0.00	0.00
Drylot Feeding	220.48	268.62	134.05	110.19
Total cost	**374.62**	**374.09**	**335.30**	**299.15**
Swift Current				
Pasture Grazing	98.98	101.85	95.39	163.96
Swath Grazing	18.15	0.00	65.15	12.95
Bale Grazing	18.90	0.00	147.92	108.80
Drylot Feeding	191.36	266.20	36.09	0.00
Total cost	**327.39**	**368.05**	**344.55**	**285.70**
Lanigan				
Pasture Grazing	143.42	98.94	157.96	111.79
Swath Grazing	0.00	20.24	57.00	63.65
Bale Grazing	0.00	0.00	0.00	102.86
Drylot Feeding	89.44	222.64	70.48	0.00
Total cost	**232.86**	**341.82**	**285.44**	**278.30**
Average (across locations)	**311.54**	**361.32**	**321.76**	**287.72**
Average by calving system	**336.43**		**304.74**	

5.3.1.2 Weaning to Calving Period

Management of cows from weaning to calving was recorded to illustrate the effect of different feeding systems on total cost by completing the production year (Table 5.4) with the analysis of cow management cost following the weaning of the calf. At BR, the cost difference between LCS and ECS from weaning to calving was \$52.20 cow^{-1}, a cost advantage of 19% for LCS (Table 5.4). At SC, LCS spent 4% more time in DL and increased the costs by 11% or \$23.47 cow^{-1}. Following weaning at LA, cows were maintained in PG (30%) and SG (47%) which decreased the cost between weaning and calving for that year, a cost advantage of \$16.67 cow^{-1} or a decrease of 7%.

In summary, average LCS costs from weaning to calving were lower across locations by \$4.02 cow^{-1} or by about 2% (Table 5.4). However, the cost advantage for the LCS cows only occurred at one of the three locations, BR, but not at LA or SC. The cost advantage may seem nearly negligible at \$4.02 cow^{-1} but on a large commercial herd, the amount saved may be considerable. The cost advantage occurred at BR because of the increased use of BG for the LCS cows post-weaning. Lower costs associated with the LCS at BR are related to spending less time in the DL system from weaning to calving. Higher costs for the LCS compared to the ECS at SC is associated with higher BG system costs for the LCS versus ECS which comes with higher labour needs because of precipitation accumulation in the form of snow for LCS cows during the BG period in 2007. Higher costs for LCS at LA were associated with more time (45%) spent in DL feeding system. When looking across locations within the LCS, LA had higher total feeding system costs because of more time spent in the DL system compared to BR and Swift Current. Highest costs were associated with BR in the ECS where cows spent more time in the DL system then LA and Swift Current.

Table 5.4. Feeding system costs ($ cow^{-1}) and percentage of time spent grazing (%) (pasture (PG), swath-windrow (SG) and bale grazing (BG)) and in drylot (DL) feeding systems from weaning to calving for 2007-2008.

	Early Calving System		Late Calving System	
	Cost	% days	Cost	% days
Brandon				
SG	100.65	41	-	-
BG	-	-	205.35	89
DL	180.96	59	24.06	11
Total cost	**281.61**		**229.41**	
Swift Current				
BG	183.06	93	205.35	89
DL	22.88	7	24.06	11
Total cost	**205.94**		**229.41**	
Lanigan				
PG	47.47	30	-	-
SG	120.45	47	-	-
BG	37.80	18	120.08	50
DL	14.56	5	116.87	50
Total cost	**220.28**		**236.95**	
Average (across locations)	**235.94**		**231.92**	

Feeding system cost was 10% less for the LCS compared to ECS when averaged across locations and years (Table 5.3). As shown in the current study, management of cow-calf pairs will not remain the same from one year to the next. This may be impacted by yearly differences in total precipitation and temperature fluctuations (Table B1 and B2; Figures B1, B2 and B3). Environmental location differences are evident in this study, despite similar management practices being used. The same yardage rate was used to calculate feeding system costs; therefore, differences that arose are the result of forage availability and labour requirements. Costs associated with the management of the cow during the whole production year reflect the total cost of raising the calf in either an early or late calving system. Therefore, it is important to monitor all costs associated with each system even after the calf is weaned. The availability of forage in extensive grazing systems depended largely on total precipitation and temperature, and therefore affected cost of each calving system. Following weaning, cost for LCS was lower by $4.02 cow^{-1} or by 2% across locations (Table 5.4) compared to ECS costs.

Similarly to the current study, Stonehouse et al. (2003) found the ability to manage the summer calving cows on pasture and with extensive grazing systems was the simplest way to reduce feeding costs. Even though there were yearly variations, on average the cost of producing a summer born calf is less than producing a spring born calf. Variation in perennial forages allowed cow-calf pairs to graze for extended periods in Nebraska, according to Adams et al. (1994), and reduced feed costs for a summer calving herd. Sirski (2011) used a simulation model to analyze the results of the current study and to compare the use of four feeding systems and the assumption that all calves would be sold at weaning. The model results suggested there was increased market risk producing a LCS calf but with less production risk. Moreover, weaning weights of LCS calves were more variable which caused increased market risk. The outcome was that LCS calves had increased returns but returns were still negative in the years the model was run.

Miller et al. (2001) stated that the factor with the greatest impact on the economic efficiency of the cow-calf enterprise is feed costs. The authors found that costs can vary by as much as 50% which is directly influenced by yearly feed resources. In Iowa and in Nebraska, savings due to winter grazing are a result of reduced harvesting, handling, feeding and manure removal costs (Hitz and Russell 1998; Volesky et al. 2002). The use of various management practices that can increase the cost are fall and winter grazing programs, balancing winter rations, rotational grazing and supplement programs (Kruse et al. 2008). This is similar to the current study, where BR cows were fed silage along with free choice hay while in DL and SC cows were not managed in a SG system because of lack of available forage. This increased the costs at these two locations when compared to Lanigan. Therefore, the use of the various feeding systems impacted total overall cost of each calving system, which was influenced by feed resources.

5.4 Calving System Treatment Costs

Treatment costs can be reflective of the health of the cow-calf herd in each calving system. Therefore total treatments per calving system per year were recorded to demonstrate the health of each herd at each location (Table 5.5).

Table 5.5. Average cow and calf treatment[z] costs for 2007 and 2008 ($ cow $^{-1}$) for all calving systems and research locations

	ECS[y]		LCS	
	2007	2008	2007	2008
Cow				
Brandon	4.00	4.00	4.00	4.00
Swift Current	10.18	6.68	0.03	0.02
Lanigan	4.08	4.08	4.36	4.17
Average	*6.09*	*4.92*	*2.80*	*2.73*
Calf				
Brandon	2.81	1.27	-	0.77
Swift Current	0.61	0.14	-	-
Lanigan	0.93	0.90	2.04	1.97
Average	*1.45*	*0.77*	*0.68*	*0.91*

[z] Treatment costs do not include vaccination costs
[y] ECS = Early Calving System; LCS = Late Calving System

Cow treatment costs were higher for ECS compared to LCS an increase of $3.29 and $2.19 cow^{-1} in 2007 and 2008, respectively. The largest difference was at SC due to a problem with mouth abscesses for ECS cows in 2007 and 2008. At BR, calf treatment costs in 2007 for ECS were $2.81 cow^{-1} while; LCS calves were not treated at all. Still at BR, in 2008, ECS calf treatment costs were higher by $0.50 cow^{-1} compared to LCS calves. At SC, in 2007 and 2008, LCS calves were not treated for any sicknesses. At LA, the inverse occurred where LCS calves in 2007 and 2008 has increased treatment costs by $1.11 and $1.07 cow^{-1}, respectively (Table 5.5). Increased costs at LA for LCS calves may have been associated with additional stress during the months prior to weaning. The stress of SG and BG as a cow-calf pair appears to have affected calf health because of the increased need of long acting antibiotics. Treatment costs for calves in the ECS were higher compared to the LCS, a difference of $0.77 cow^{-1} in 2007 (Table 5.5). In 2008, average costs were $0.14 cow $^{-1}$ higher for LCS, across locations. Treatment of calf scours was very common in calves born in spring (March). Similarly, in Ontario, Stonehouse et al. (2003) found that winter-born (February to April) calves had higher treatment costs than summer-born (June to August) calves and this was also related to calf scours. Reisnauer Leesburg et al. (2007) used an 8% calf mortality rate for the spring calving cows in the bio-economic simulation model in their study. This was based on a study that was conducted by Grings et al. (2005) in Montana where mortality rates of 3.5% for spring-born calves were reported, compared to 1.5%

mortality rate for summer born calves. In the current study, Swift Current had the lowest calf treatment costs at only $0.50 for the LCS calves. Environmental temperature and total precipitation could play a large role in calf health, leading to SC calves having the least amount of environmental stressors from calving to weaning. Lanigan's LCS calf treatment costs were apparently related to managing calves on winter feeding systems. In 2007, calves were challenged in extensive grazing systems because of snow accumulation at Lanigan.

5.5 Conclusion

Feeding management systems that have lower cost per day will result in lower total costs per production period for a cow-calf enterprise. On average, total costs from calving to weaning were 10% higher for the early calving system compared to the late calving system. A reduction in labour is possible by moving from an early spring calving system to a summer calving system. The summer calving period resulted in lowered labour requirements by managing beef cows and calves on grass. Managing cows in confinement can often result in opportunities to intervene therefore causing increased labour necessities. A 2% decrease in cow feeding costs post-weaning occurred. This was only calculated over one production year; therefore the variation from one year to the next may greatly vary. Even though a cost savings of 2% may not be large, the difference may be greater in other years when longer periods of extensive grazing programs are used to decrease feeding costs.

Feed costs should also be considered against optimal calving system. The effects of trading harvested feed for grazing of perennial forages need to be considered when altering the calving season. The opportunity to use the current data for a simulation model would be able to apply the relative costs of the two calving systems against averages across more years. This was performed by Sirski (2011).

Limitations exist within the calculation of costs associated with each calving system. The cost of production of each location easily shows the differences that arise when comparing the same calving system across the locations. Therefore, selecting the appropriate values for the variables measured was difficult. Removing location effects is virtually impossible, but taking the relative costs between early and late calving systems is more important to consider. All in all, the current study feeding system data results indicated that LCS reduces labour cost and, for certain years, total feeding system costs, but was not consistent across locations and years. Change in environmental and management scenarios can greatly change cost of feeding system results.

6 GENERAL DISCUSSION AND CONCLUSION

The impact of calving system on cow and calf performance is evident but not easily explained. The objective of this study was to measure the impact of calving system on cow performance and reproductive efficiency. Calf growth rate and weaning rate was also compared and assessed based on the different parameters set in this study. From this research conducted at three different locations, it can be suggested that cow performance is not significantly affected by one calving system over another. The effect on cow performance, such as body weight and condition fluctuation varies depending on the calving system but both result in acceptable reproductive efficiency. The late calving system cows seem to lose more weight from breeding to weaning than from pre-calving to breeding. The inverse occurs for the early calving system, where cows are under a colder environment early on post-calving where body weight and condition fluctuate more drastically. No significant effect was found in pregnancy, calving, and weaning rates ($P>0.05$). Calving span was not significantly different between calving systems but LCS had numerically shorter calving span than did ECS, 55 and 58 days, respectively, when pooling by location and year. Feeding systems used to manage the cows in each calving system supplied adequate nutrition to support the lactation period from birth to weaning. This can also be proven by comparing the reproductive efficiency from one year to the next. There were no year effects on any reproductive performance parameters in 2008 after managing the cows in these feeding systems for one year. Although, the appropriate nutrition was provided based on needs, therefore if environmental conditions called for more energy to maintain body weight and condition, a form of supplement was provided. The goal was not to test whether the feeding systems would provide adequate nutrition, but to superimpose low-cost feeding systems into each calving system to keep feeding system costs low. Implementing the same feeding systems for each calving system and at each location was also a method to attempt to reduce variables when comparing one calving system to another between locations. When applying low-cost extensive feeding systems to LCS cows and calves, realization that calf growth will be affected because of the increase in maintenance needs to maintain body heat and extra energy needed to walk through accumulated precipitation in the form of snow. Cows were also affected by this, whereas previously mentioned, environment played a large role in body weight and condition fluctuation from breeding to weaning.

Calf growth rate was affected by calving system. Calves in the ECS had a stronger ADG than did LCS calves. It was presumed that milk production would have been higher in the LCS cows because of lush pastures post-calving, but calf ADG did not reflect this hypothesis therefore perhaps the LCS calves were not able to suckle all that was produced. Milk production in each calving system was not measured; therefore this is an anecdotal observation.

Cows in each calving system were managed in different feeding systems leading up to calving but nutrient intake was managed as to meet or exceed requirements of pregnant and lactating cows. Moreover, calves born in the LCS were heavier at birth in 2008 and were affected by location. There may be an advantage for the LCS calves, which were faced with a milder environment at birth. A possible proof that calves were not as strong in the ECS is the number of treatments as compared to the LCS. Calves in the ECS were prone to increased treatments for disease, a factor is adding to cost; although, calf mortality did not prove a specific pattern for one calving system over the other.

Costs were lower for the late calving system and may have been a factor of implementing more days on pasture and in extended grazing programs instead of in the drylot system. Choosing low cost feeding systems is critical to keeping costs down in a calving system. However, the best economical feeding system may change from one year to the next depending on available precipitation. Not all feeding systems will be optimal every year because of the uncertainty in environment on the Canadian prairies.

In summary, the goal of cow-calf operations is to obtain and wean one calf per cow per year. Thus, the breeding period is crucial to establish pregnancy within 80 to 85 d post-calving. If one calving system affects the reproductive efficiency of the cow, because of the delayed onset of the breeding season, then this would be an indication of an inferior calving system. However in the current study, reproductive efficiency was not affected when assessed by calving span, calving, pregnancy and weaning rates. Feeding system cost was lower for the late calving system. Consequently, calf growth was affected by calving system where ECS calves had higher ADG and this advantage was maintained through to weaning. Therefore, even though calf birth weight was greater for the LCS, this advantage was not maintained for the whole calving system across years and locations. The objectives of the current study were to evaluate the effect of calving system on cow and calf performance. Cow BW and condition were affected by calving system where fluctuation of gain and loss varied, although the location and year are also important influential factors. Late calving system may have a competitive advantage over ECS where maintenance of body weight was successful, although this same observation cannot be concluded for body condition measurement. Calf performance was affected by calving system where ECS had greater ADG and weaning weights, therefore improving the efficiency of the system. Cost of feeding systems was affected by calving system because of the nutrient requirements of cows calving in March versus calving in June, which in turn affected feeding system used. Therefore by delaying the calving system, labour costs were reduced and, for certain years, feeding system costs were lowered. All in all, making definite conclusions on two years of data collected on cow and calf performance across two calving systems may not be reflective of the actual differences that could be experienced in each calving system. Therefore, even though some differences were found in cow and calf performance perhaps more definite differences could be found in reproductive efficiency if the study was conducted over a longer period.

Future areas of research:

The following list of future areas of research would be additional data to consider collecting to help complete the picture of the effect of calving system on cow and calf performance:

1. Measuring immunoglobulin levels of calves post-calving until 3 d of age.
2. Weaning calves in each calving system at two different time periods
3. Separating out the cow performance data based on cow age and assessing the effect of calving system on the length of the anestrous period post-calving.
4. Measuring cow BW and BCS at the start and end of each feeding system to compare cow performance based on available DM and nutrient composition of available forages.
5. Nutrient intake three weeks pre and post-calving to specifically assess the outcome of calf birth weight.
6. Comparing heifer performance in each calving system and see if age at first calving is affected.

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8 Appendix A:

Table A1. Pasture grazing costs (Lanigan)

Production Expenses	Early Calving System	Late Calving System
	$\$ \ cow^{-1} \ d^{-1}$	
2007		
Labour	0.21	0.23
Yardage rate [z]	0.80	0.80
Total Cost	1.01	1.03
2008		
Labour	0.17	0.26
Yardage rate	0.80	0.80
Total Cost	0.97	1.06
Average Cost	0.99	1.05

[z] yardage rate used for all pastures

Table A2. Swath-windrow grazing costs (Lanigan)				
Production expenses	Early Calving System		Late Calving System	
	---$ cow^{-1} d^{-1}---			
2007	Barley	Millet	Barley	Millet
Labour	0.09	0.09	0.08	0.08
Fencing	0.10	0.10	0.10	0.10
Seeding/Machinery	0.61	0.65	0.63	0.65
Total Cost	0.80	0.84	0.81	0.83
Average (Barley, Millet)	0.82		0.82	
2008				
Labour	0.28	-	0.25	-
Supplement[y]	0.11	-	-	-
Fencing	0.10	-	0.10	-
Seeding/Machinery	0.49	-	0.73	-
Total Cost	0.95	-	1.08	-
Average Cost (2007,2008)	0.89		0.95	

[z] Cost of Production does not include the cost of managing the animals through the feeding system
[y] Supplement – Oat greenfeed hay

Table A3. Bale grazing costs (Lanigan)		
Production Expenses	Early Calving System	Late Calving System
	--- $ cow^{-1} d^{-1} ---	
2007		
Labour	0.36	0.30
Bedding	0.01	0.01
Cross-fencing	0.10	0.10
Feed (Hay)	0.73	0.83
Machinery	0.15	0.10
Total Cost	1.35	1.34
2008		
Labour	0.24	0.23
Bedding	0.02	0.002
Cross-fencing	0.10	0.10
Feed (Hay)	1.21	1.34
Supplement [y]	0.27	0.12
Machinery	0.23	0.24
Total Cost	2.06	2.03
Average Cost (2007,2008)	1.71	1.69

[z] Cost of Production does not include the cost of managing the animals through the feeding system
[y] Supplement – Oat greenfeed hay and barley grain

Table A4. Drylot feeding costs (Lanigan)

Production Expenses	Early Calving System	Late Calving System
	-------------------------------- $ cow^{-1} d^{-1} -------------------------------	
2007		
Hay	0.99	0.77
Greenfeed	0.25	0.07
Barley/Oats	0.05	0.09
Bedding	0.02	0.03
Equipment	0.04	0.05
Fuel	0.19	0.22
Labour	0.29	0.24
Building repair/ Utilities/Manure Removal	0.24	0.24
Total Cost	2.08	1.72
2008		
Hay	1.19	0.99
Greenfeed	0.04	-
Barley/Oats	0.29	-
Bedding	0.05	-
Equipment	0.05	0.08
Fuel	0.20	0.32
Labour	0.37	0.58
Building repair/ Utilities/Manure Removal	0.24	0.24
Total Cost	2.42	2.20
Average Cost (2007,2008)	2.25	1.96

9 Appendix B.

Table B.1. Monthly average air temperature (^oC) and 30-yr averages for Brandon, Swift Current and Lanigan in 2007 and 2008.

	Brandon		Swift Current		Lanigan	
	Mean temp (^oC)	30-yr mean	Mean temp (^oC)	30-yr mean	Mean temp (^oC)	30-yr mean
Jan 07	-14.9	-17.9	-8.0	-12.4	-12.7	-16.8
Feb 07	-17.6	-13.4	-12.9	-8.8	-17.1	-12.5
Mar 07	-4.9	-6.1	0.6	-2.9	-4.5	-5.8
Apr 07	4.5	4.0	4.7	4.9	4.0	4.0
May 07	11.3	11.8	11.6	11.1	10.4	11.3
Jun 07	16.7	16.6	16.0	15.6	15.4	15.9
Jul 07	20.9	18.9	22.5	18.1	20.7	18.1
Aug 07	16.8	18.0	17.8	17.9	15.5	17.3
Sep 07	12.5	11.9	11.7	11.8	10.6	11.3
Oct 07	6.2	4.9	6.8	5.5	5.4	4.5
Nov 07	-4.7	-5.6	-3.1	-3.9	-5.5	-6.0
Dec 07	-15.7	-14.7	-10.6	-10.0	-15.4	-13.9
Jan 08	-16.9	-17.9	-11.6	-12.4	-15.1	-16.8
Feb 08	-33.1	-13.4	-11.0	-8.8	-17.3	-12.5
Mar 08	-7.0	-6.1	-2.3	-2.9	-6.1	-5.8
Apr 08	-3.4	4.0	3.0	4.9	2.8	4.0
May 08	9.1	11.8	10.8	11.1	9.6	11.3
Jun 08	24.0	16.6	14.1	15.6	14.6	15.9
Jul 08	17.9	18.9	17.9	18.1	17.3	18.1
Aug 08	18.8	18.0	18.1	17.9	17.3	17.3
Sep 08	30.8	11.9	12.3	11.8	11.3	11.3
Oct 08	5.9	4.9	6.2	5.5	5.4	4.5
Nov 08	2.3	-5.6	0.1	-3.9	-2.9	-6.0
Dec 08	-19.2	-14.7	-14.8	-10.0	-19.3	-13.9

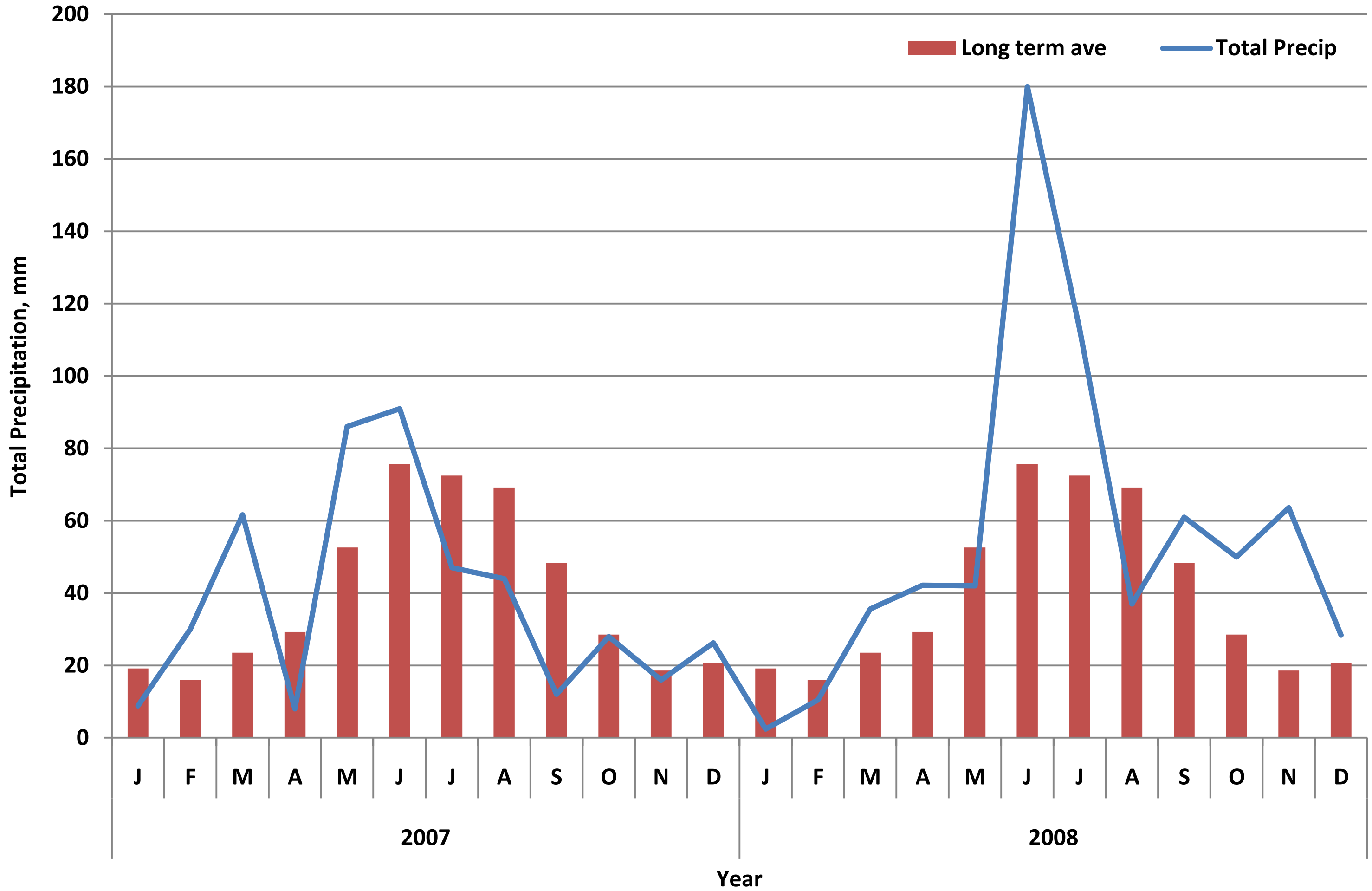

Figure B1. Monthly total precipitation (mm) and 30-yr averages for Brandon in 2007 and 2008.

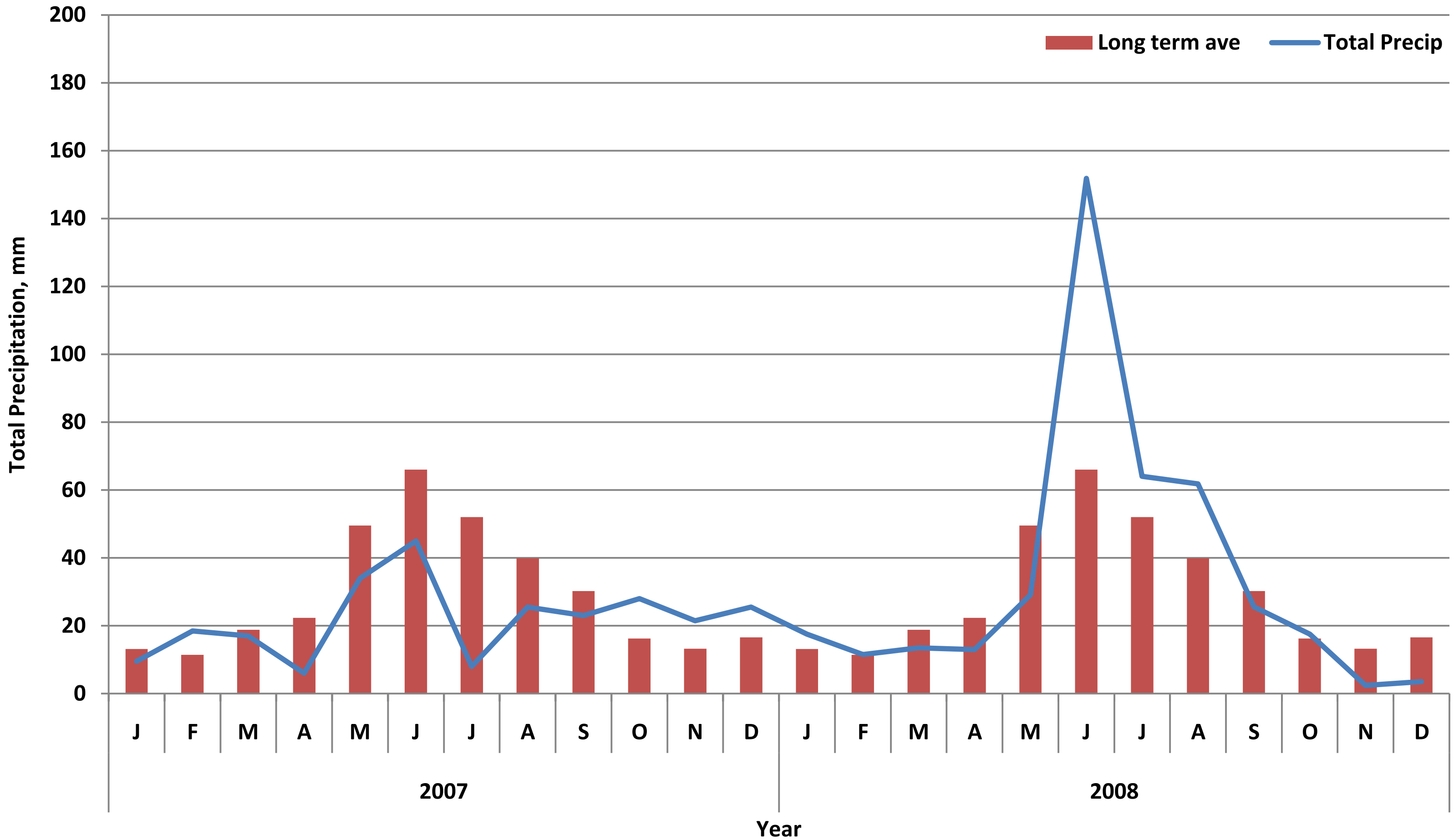

Figure B2. Monthly total precipitation (mm) and 30-yr averages for Swift Current in 2007 and 2008.

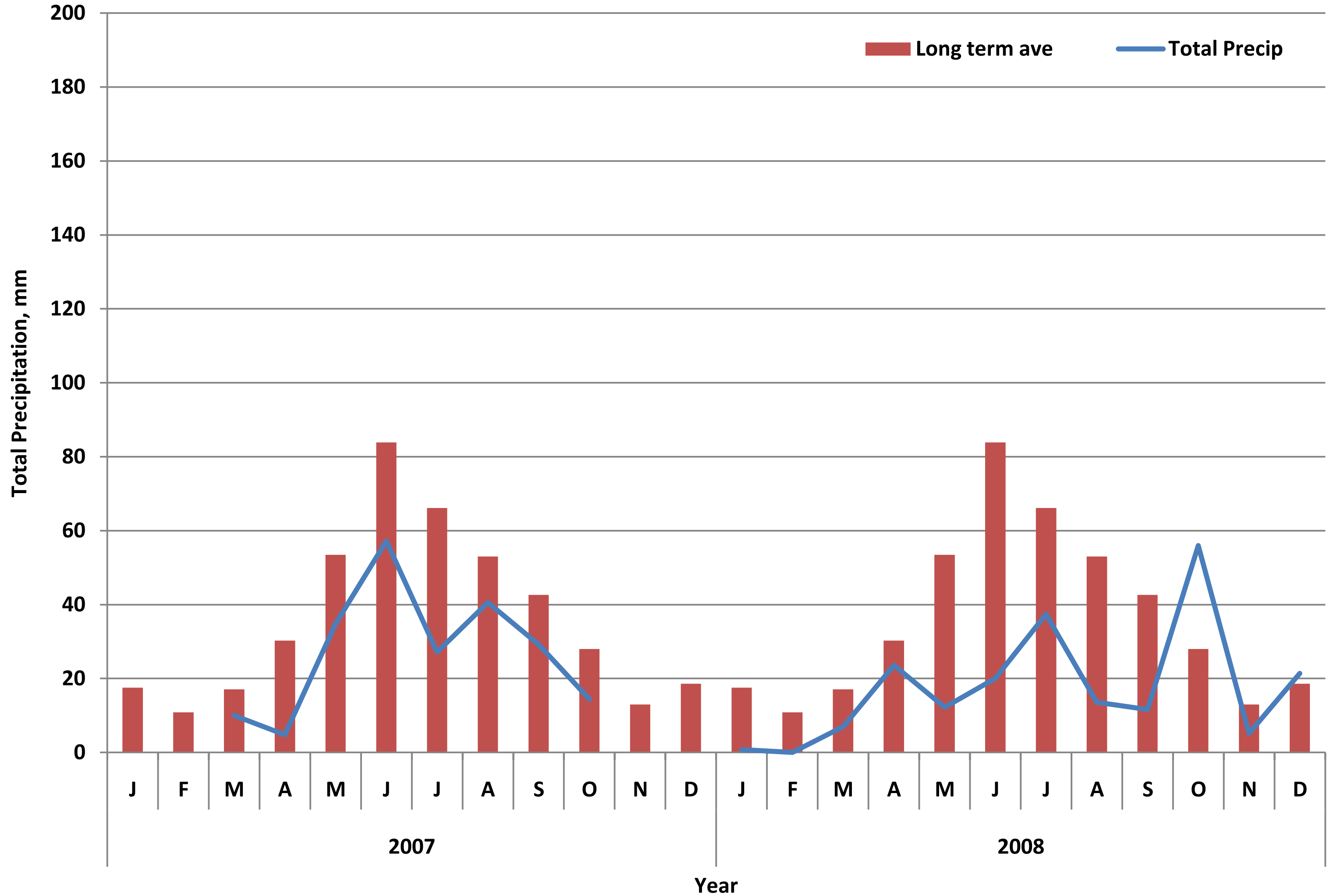

Figure B3. total precipitation (mm) and 30-yr averages for Lanigan in 2007 and 2008.

10 Appendix C.

Table C1. Forage qualiy for the feeding systems for early and late calving systems for Brandon, Swift Current and Lanigan (2007 & 2008).

	2007				2008			
	PG[z]	SG	BG	DL	PG	SG	BG	DL
Brandon								
Early Calving System								
%OM[y]	90.9	93.0	-	92.0	91.4	93.0	90.3	91.4
%OMD	58.1	53.2	-	54.8	56.4	53.2	56.2	53.1
%CP	14.0	9.0	-	11.6	10.7	9.0	11.6	-
%TP	0.3	0.3	-	0.2	0.2	0.3	0.3	-
%TCa	0.4	0.4	-	0.9	0.5	0.4	0.5	-
%ADF	28.6	35.0	-	34.2	35.6	35.0	36.4	43.7
%NDF	53.9	64.5	-	54.7	57.9	61.5	55.6	59.4
%TDN	69.9	62.7	-	63.5	61.9	62.7	61.0	52.7
Late Calving System								
%OM	87.9	90.7	92.0	90.1	91.3	88.3	92.4	92.4
%OMD	51.4	50.7	54.8	44.2	53.4	47.9	59.0	59.0
%CP	8.2	8.3	11.6	9.4	10.6	7.8	14.1	-
%TP	0.2	0.3	0.2	0.2	0.2	0.3	0.2	-
%TCa	0.4	0.2	0.9	0.9	0.9	0.5	1.1	-
%ADF	31.2	32.2	34.2	37.6	42.1	44.1	38.1	38.1
%NDF	55.5	56.5	54.7	60.3	60.7	60.7	55.4	55.4
%TDN	67.0	65.9	63.5	59.7	54.5	52.2	59.1	59.1
Swift Current								
Early Calving System								
%OM	90.0	90.7	92.7	92.7	90.6	91.6	89.6	89.6
%OMD	55.3	68.2	50.9	50.9	49.6	61.1	60.1	60.1
%CP	8.7	14.1	10.0	10.0	8.6	15.6	14.9	14.9
%TP	0.1	0.2	0.1	0.1	0.1	0.2	0.3	0.3
%TCa	0.6	0.5	0.6	0.6	0.5	0.4	0.6	0.6
%ADF	31.5	22.5	41.2	41.2	32.8	24.3	33.6	33.6
%NDF	57.4	44.3	64.7	64.7	58.1	46.8	60.0	60.0
%TDN	66.6	77.0	55.6	55.6	66.4	63.8	76.1	64.2
Late Calving System								
%OM	90.0	90.7	92.7	92.7	91.0	92.8	89.6	89.6
%OMD	55.3	68.2	50.9	50.9	47.8	56.8	60.1	60.1
%CP	8.7	14.1	10.0	10.0	7.6	10.0	14.9	14.9
%TP	0.1	0.2	0.1	0.1	0.1	0.2	0.3	0.3
%TCa	0.6	0.5	0.6	0.6	0.4	0.3	0.6	0.6
%ADF	31.5	22.5	41.2	41.2	32.3	27.6	33.6	33.6
%NDF	57.4	44.3	64.7	64.7	59.1	52.0	60.0	60.0
%TDN	66.6	77.0	55.6	55.6	66.4	63.8	76.1	64.2

[z]PG, pasture grazing; SG, swath windrow grazing; BG, bale grazing; DL, drylot

[y] %OM, organic matter; %OMD, organic matter digestibility; %CP, crude protein; %TP, total phosphorus; %TCa, total calcium; %ADF, acid-detergent fibre; %NDF, neutral detergent fibre; %TDN, total digestible nutrients

Table C.1. Continued								
	PG[z]	SG	BG	DL	PG	SG	BG	DL
Lanigan								
Early Calving System								
%OM	92.5	84.9	83.4	82.6	91.5	66.3	86.3	86.3
%OMD	50.4	-	-	-	48.1	-	-	-
%CP	10.0	12.9	12.9	11.1	10.6	14.2	12.6	12.6
%TP	0.2	0.2	0.2	0.2	0.2	0.3	0.2	0.2
%TCa	-	0.3	1.1	0.8	0.6	0.3	0.7	0.7
%ADF	33.9	35.8	36.8	38.9	33.1	31.8	35.8	35.8
%NDF	60.9	55.5	57.4	57.4	58.8	49.4	53.7	53.7
%TDN	64.0	61.7	60.6	58.2	64.8	66.3	61.7	61.7
Late Calving System								
%OM	93.0	84.9	83.5	86.3	92.1	66.3	85.1	86.3
%OMD	50.0	-	-	-	49.7	-	-	-
%CP	9.7	12.9	11.7	12.6	10.6	14.2	11.2	12.6
%TP	0.2	0.2	0.2	0.2	0.2	0.3	0.1	0.2
%TCa	-	0.3	0.8	0.7	0.5	0.3	0.8	0.7
%ADF	33.9	35.8	37.1	35.8	32.4	31.8	37.9	35.8
%NDF	61.0	55.5	62.1	53.7	58.4	49.4	55.5	53.7
%TDN	63.9	61.7	60.3	59.9	65.6	66.3	59.3	59.9

[z]PG, pasture grazing; SG, swath windrow grazing; BG, bale grazing; DL, drylot
[y] %OM, organic matter; %OMD, organic matter digestibility; %CP, crude protein; %TP, total phosphorus; %TCa, total calcium; %ADF, acid-detergent fibre; %NDF, neutral detergent fibre; %TDN, total digestible nutrients

Appendix D.

Table D1. Water quality (mg L^{-1})at Brandon, Swift Current and Lanigan in 2007 and 2008[z].

Location	2007		2008	
	Sulfate	TDS[y]	Sulfate	TDS
Brandon				
City water	240	819	170	571
Well water (site MH)	52	7990	46	6820
Well water (main)	120	858	130	871
Lake pasture site	97	624	81	469
Johnson Farm site	65	926	63	846
Swift Current				
Conway Farm (city water)	854	250	-	-
Conway Farm (dugout)	19	302	280	850
Southwest Forage (City water)	250	824	280	847
Lanigan				
Main well	1240	2890	1250	2850
Dugout – Section 21	240	802	3.7	316
Dugout – Section 27	2.7	284	3.1	342
Dugout – Section 35	-	-	1.2	205

[z]Water sources with levels above recommendation was not used.

[y]TDS – Total Disolved solids

Safe levels, Sulfate = 1000 mg L^{-1}; TDS = 3000 mg L^{-1} (Source: CCME. 1987. Canadian water quality guidelines. Section 4.2.2.4; NAS/NAE. 1973. Water quality criteria 1972, Table 4-13)