Effects of Supplementing Corn on Alfalfa Pasture on Growth Performance, Carcass and Meat Quality, Fatty Acid Composition and Palatability Attributes in Angus Steers

By
Chloe Elizabeth Gresel

A Thesis
Presented to
The University of Guelph

In partial fulfillment of requirements
For the degree of
Master of Science
in
Animal Biosciences
Guelph, Ontario, Canada

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Abstract

EFFECTS OF SUPPLEMENTING CORN ON ALFALFA PASTURE ON GROWTH PERFORMANCE, CARCASS AND MEAT QUALITY, FATTY ACID COMPOSITION AND PALATABILITY ATTRIBUTES IN ANGUS STEERS

Chloe Elizabeth Gresel

University of Guelph, 2016

Advisor: Dr. Ira B. Mandell

Pasture finishing beef is a production method to value add beef by improving fatty acid composition. However, this occurs at the expense of reduced growth rates and palatability attributes versus grain-fed beef. Supplementing corn grain on pasture may improve performance and palatability without affecting fatty acid composition. Fifty black Angus steers were randomly assigned to 1 of 4 management regimens (high grain, alfalfa pasture, alfalfa pasture plus corn supplementation at 0.5% BW or alfalfa pasture plus corn supplementation at 1% BW) to examine how supplementation affects the carcass, meat quality, and fatty acid traits while attempting to increase cattle performance and beef palatability attributes. Corn grain supplementation on pasture increased gains on pasture. While tenderness, juiciness, and beef flavour attributes were similar across management regimens, corn supplementation on pasture increased omega-3 fatty acid concentrations in beef versus cattle fed a conventional high grain diet.
Acknowledgements

There are many people I need to thank for helping me to complete this stage of my life.

Thank-you to my advisor Dr. Ira Mandell for taking me on as his student and providing me the opportunity to complete a project I love.

A tremendous thank-you to Cheryl Campbell. Your help, knowledge and guidance were irreplaceable.

Thank-you to my committee members Dr. Lisa Duizer and Dr. Brian McBride for your help throughout my project and all your encouragement.

Thank-you to Brian, Judy and Sam in the University Meat Lab.

A giant thank-you to all the staff at the New Liskeard Agricultural Research Station for all their help and putting up with my OCD while running my project. Special thanks to “my” fantastic summer students Bethany Brown and Emily Potter for keeping me sane and for all of your hard work. Thank-you to Leo Giesen for your help organizing everything, Dennis Peddie for fixing all the things and John Kobler for the lunch room entertainment.

Thank-you to Carole Lafreniere at UQAT for your help with analysing the many forage samples taken during the course of this trial.

Thanks to my family for their support and to all my fellow aggies who completed a masters along with me. You guys were my sounding board and I will forever be grateful for not having to struggle through this degree alone. Jocelyn and Kelsie, thanks for whisking me away on our grand adventure to Europe.

I couldn’t write this acknowledgement page without thanking Beef Farmers of Ontario for providing the funding for my project.
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List of Abbreviations

ADG: Average Daily Gain
ADF: Acid Detergent Fiber
ADL: Acid Detergent Lignin
BW: Body Weight
CBGA: Canadian Beef Grading Agency
CLA: Conjugated Linoleic Acid
CP: Crude Protein
DM: Dry Matter
DMI: Dry Matter Intake
FA: Fatty Acid
HCW: Hot Carcass Weight
IMF: Intramuscular Fat
LM: *Longissimus* Muscle
LMA: *Longissimus* Muscle Area
MUFA: Monounsaturated Fatty Acid
n3: Omega-3 Fatty Acids
n6: Omega-6 Fatty Acids
NDF: Neutral Detergent Fiber
NLARS: New Liskeard Agriculture Research Station
PM: Postmortem
PUFA: Polyunsaturated Fatty Acid
QG: Quality Grade
SFA: Saturated Fatty Acid
SOTBW: Start Of Trial Body Weight
TMR: Total Mixed Ration
UIP: Undegradable Intake Protein
WBSF: Warner-Bratzler Shear Force
YG: Yield Grade
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1.0 Introduction

Forage finishing beef can be described as beef that comes from cattle who have been fed to slaughter weight using exclusively grass or conserved forages such as hay or forage silage, and is commonly referred to as grass-fed beef. Forage finishing is a common global practice but grain finishing of beef cattle is common practice in North America with most of the beef for sale in North American grocery stores coming from grain finished cattle. Forage finishing is less common in North America due to challenges such as animals finished on forage taking a longer time to reach market weight. However, more and more consumers are demanding ethically raised, antibiotic free and “natural” meats. This is growing market share for forage finished beef as consumer perception is such that grass-fed beef is produced “naturally” without use of antibiotics and hormonal growth promotants which is not necessarily the case. Due to the lower net energy (NE) values found in forages compared to grains, forage finishing cattle takes longer, leading to a slower turn-over time for facilities and possible lost profits in having to keep the animals longer in order to reach market weight.

The cost of feed is the number one cost of production when it comes to raising beef. An advantage of feeding forages over concentrates is that it reduces the cost of feed; forage finishing does not use expensive concentrates and when grazing, the cattle harvest the feed themselves saving the producer the cost of harvesting, yardage and labour. Another problem producers face when forage finishing is climate. The Canadian climate does not permit feeding pasture year round for high levels of production; therefore pasture finishing is not feasible due to winter, forcing producers to feed conserved forages if they want to forage finish.
Consumers may not understand the tradeoffs between concentrate and forage finishing, but they do understand health benefits when it comes to how the food they eat affects their health. Forage finished beef contains a fatty acid profile that contains greater amounts of beneficial fatty acids for human health than the fatty acid concentrations found in beef from conventionally raised, grain-finished beef cattle. Omega-3 fatty acids are found in greater concentrations in the muscle and fat from cattle that are forage finished (Daley et al., 2010). Human diets that are high in omega-3 fatty acids are known to decrease the risk of cardiovascular disease, cell proliferation of humans with colorectal cancer and the risk of breast cancer in women (Simopoulos, 2002). This increase in omega-3 concentrations from forage finishing leads to a decreased omega-6:omega-3 fatty acid ratio for beef in the human diet. A high omega-6:omega-3 fatty acid ratio such as the one found in many western diets, is linked to many diseases such as cardiovascular disease, cancer and inflammation (Simopoulos, 2002). Conjugated linoleic acid (CLA), specifically the cis-9, trans-11 isomer is another fatty acid with benefits linked to human health. CLA is found in fat and meat of animals that are forage fed, with ruminant sources containing the greatest concentrations of CLA in animal products that people can buy in the store (Chin et al., 1992). CLA cis-9, trans-11 has been shown to decrease the proliferation of human malignant melanoma, colorectal and breast cancer cells in vitro (Schultz et al., 1992). While CLA is found in grain-fed beef, the concentrations of this FA are often greater in forage-finished beef (French et al., 2000a).

A challenge that has plagued the beef industry is providing consumers with beef that is consistently flavourful, tender, and juicy. A consumer’s perception of beef flavour differs with their cultural practices, preparation and the products that they are accustomed to eating. In North America, most cattle are finished on high concentrate rations with corn being the primary feed
grain for feeding beef cattle in eastern U.S. and Canada, and the American Midwest. This has led North Americans to expect the taste of concentrate finished beef when they purchase beef at a grocery store. When consumers try forage-finished beef, they may experience different flavour profiles such as organ or livery meat flavour (Duckett et al., 2013) and the presence of off flavour(s) such as soured dairy or grassy/cowy (Melton et al., 1982; Garmyn et al., 2010). In contrast, forage finishing is the primary method of finishing cattle in many countries around the world and consumers from these countries often detect off flavours such as soapy in grain-finished beef (Daley et al., 2010).

The tenderness of beef also plays a large role in the consumer’s eating experience. Tenderness is affected by a range of different factors including animal genetics, pH of the carcass, time the carcass has been aged for, and age of the animal at the time of slaughter. Due to forage finished cattle being older at the time of slaughter, some studies have found forage-fed beef to be less tender than conventionally raised, grain-finished beef (Garmyn et al., 2010; Bjorklund et al., 2014).

Consumers need to first purchase the beef and this is done by visually assessing the colour of beef in the display case of the grocery store. Consumers look for beef that is bright red in colour and tend to pass over beef that is dark in colour or oxidized in the meat case (Garmyn et al., 2010).

Feeding grain to cattle on pasture is a way to increase the amounts of daily energy intake to increase average daily gain. While grain supplementation can decrease the amount of forage consumed per day (Pavan and Duckett, 2008), the major benefit of grain supplementation is the decreased amount of time on feed for pastured cattle and increased turnover rate in forage
finishing operations (Roberts et al., 2009). Shortening the time on feed for pasture finished cattle with supplementation may also help with diluting the off flavours of forage finished beef, and help to increase tenderness as the animals will be younger at the time of slaughter. Providing grain on pasture may also serve as a strategy to increase concentrations of beneficial fatty acids in beef from pasture finishing while decreasing time on feed due to restricted energy intakes from only consuming pasture (Daley et al., 2010). Carcass traits of cattle fed on pasture and supplemented with grain, such as hot carcass weight, may be increased as a result of the extra net energy provided by grain when cattle are fed on pasture (McCaughey et al., 1999).

It is hypothesised that supplementing corn to cattle on alfalfa pasture will increase weight gain, alter the fatty acid profile of the carcass and mitigate some of the negative attributes associated with forage finished beef such as off flavour.

The objectives of this study are to examine the effects of grain supplementation of alfalfa pasture on cattle growth performance, carcass characteristics and meat quality, fatty acid profile, and beef palatability attributes. These traits will be compared to animal performance and beef from cattle finished exclusively on pasture with no corn supplementation and cattle finished on a high grain diet.
2.0 Literature Review

2.1 Introduction

In North America, beef cattle are conventionally finished in drylot or feedlot systems on diets made up largely of grains such as corn or barley. Forage finishing or grass-fed beef refers to beef cattle that are finished on grass or conserved forages and are generally sold to local niche markets. Grain finished cattle tend to achieve market weight faster than grass finished cattle, providing conventional feedlot producers an advantage over grass-fed beef producers for the number of cattle they can finish per year. Keeping cattle on forages after weaning rather than placing them in a feedlot for finishing, increases the amounts of PUFA, omega-3 fatty acids and CLA in their meat (Noci et al., 2005). In fact, any changes to the ingredient composition of beef cattle finishing diets can alter the quantitative composition of beef lipids (Daley et al., 2010). Studies directly comparing grain- and grass-fed beef consistently demonstrate differences in overall fatty acid profile found in the lipid deposits and body tissues regardless of the genetic makeup, gender, age or species of the meat animal (DeSmet et al., 2004; De la Fuente et al., 2009; García et al., 2008). Fatty acids are of particular interest when examining ways to manipulate the diet of beef cattle to improve the nutritional quality of beef. Beef from animals that have been forage finished contain greater amounts of omega-3 polyunsaturated fatty acids (PUFA) and conjugated linoleic acid (CLA) (French et al., 2000a). These fatty acids are known to have positive effects on human health and are normally only present in beef at significant levels when the animal has been finished on forages (Chin et al., 1992; Noci et al., 2005).
However forage finishing has some limitations over conventional finishing methods. Forages are less energy dense than concentrates; therefore daily gains are lower for forage versus concentrate finished cattle (Dierking et al., 2010). This lower average daily gain (ADG) in forage finished cattle may be as low as 0.2-0.4 kg/day (Dierking et al., 2010). These slower rates of gain also translate into the animals having to be kept on feed longer and therefore being older at time of slaughter. Animals who are finished on high concentrate diets typically spend between 80 to 180 days in a feedlot before they are ready for slaughter; whereas forage finished animals spend 18 to 24 months on pasture before they are ready for slaughter (Dierking et al., 2010).

The number one cost for cattle production is the cost of feed. This makes lowering feed costs an everlasting goal for beef producers as saving a few cents per day per animal on a ration can net large financial saving to producers. Rapid turnover of cattle is another goal for producers as the more cattle they can get through their yard per year on a low cost ration, the better their profit margins are. Pasture is the most economical way to feed cattle and is less expensive than feeding concentrates as the producer doesn’t have to pay yardage to deliver the feed, pay for the cost of the feed item itself, or spend time harvesting and storing the feed.

The forage species that are present in the pasture are important for producers to pay attention to as some varieties are better for cattle weight gains than others. For example, alfalfa’s popularity as a grazing crop has improved over the last number of years as beef producers have found their cattle’s ADG improved while grazing the legume as compared to cattle grazing other grass varieties (Smith and Sing, 2000). The development of bloat reduced cultivars, anti-bloating agents and better grazing management strategies has helped to increase alfalfa’s popularity as well due to producers becoming less concerned over losing cattle due to bloat (Smith and Sing,
Past research has shown that alfalfa can sustain higher stocking densities on pasture than using grasses alone in pasture mixtures (Lauriault et al., 2005). Pasture is not as simple as placing them out into an area that looks green and expecting them to gain weight. Producers need to evaluate forage species for their potential gaining power and nutritional content, and its ability to re-grow after grazing. Additionally, producers need to ensure their forage is at the optimal stage of growth, can withstand the amount of trampling it will receive, is planted in a suitable soil type and will grow with the amount of moisture the area usually gets. Energy demands of cattle and their stage of production must also be considered. Pastured cattle have greater energy demands than those housed in barns as pastured cattle must walk further for the same amount of food and expend more energy battling the elements than cattle housed in drylots (Huuskonen et al., 2010). Producers typically focus on increasing animal production (kg/d body weight gain) or production per hectare (kg beef produced per hectare) (Smith and Sing, 2000). Legumes are commonly included in grass pastures as they have high nutritional value and greater protein content than grasses. Legumes also do not require nitrogen fertilizer to sustain them which is a decreased expense and increased time savings for the producer (Smith and Sing, 2000).

In a study where pastured Angus cross steers were finished on tall fescue only, tall fescue mixed with red clover or tall fescue mixed with alfalfa, the steers in the tall fescue only group had the poorest performance at 0.24 kg/d ADG (Dierking et al., 2010). Steers on the tall fescue and alfalfa mixture gained 0.3 kg/d while steers on tall fescue and red clover gained 0.4 kg/day.
In comparing the pastures containing legumes, steers pastured on the alfalfa and tall fescue mix had numerically lower ADG on a per animal basis than steers pastured on red clover and tall fescue pastures but on a per area basis there was no difference in cattle performance. The crude protein (CP) content in all pasture regimen exceeded National Research Council (NRC) (2000) recommendations; however the alfalfa pasture had the most CP and the highest in vitro true digestibility (Dierking et al., 2010). The researchers also hypothesised that heat stress and shade could be a differentiating factor in steer performance as natural shade was used for steers pastured on red clover/tall fescue while artificial shade was provided to the steers pastured on alfalfa/tall fescue and tall fescue (Dierking et al., 2010). The trial conducted by Lorenzen et al. (2007), found that including just 30% legumes into a cool season grass mixture pasture could sustain ADG of 0.51 kg/d on pasture alone. These gains were 0.2 kg/d lower than what the researchers were expecting due to drought conditions (Lorenzen et al, 2007).

Grazing alfalfa provides the opportunity for producers to increase animal production as it is not uncommon for beef stockers to gain 0.9-1.36 kg per day on alfalfa (Smith and Sing, 2000). Lauriault et al. (2005), reported that pastures containing grazing tolerant alfalfa increased average daily gains by 15% and total gains by 107% when compared to monocultures of tall wheatgrass (Lauriault et al., 2005). Butler et al. (2012), continually grazed steers on alfalfa for two different grazing periods, short season (end of July termination) or full season (until forage ran out). The researchers reported a 0.12 kg/d difference in ADG with the full season grazing having a lower ADG than gains for short season grazing (Butler et al., 2012). However producers tend to shy away from just using legumes, most notably alfalfa, in pasture as animals can more easily bloat on many varieties of legumes.
In fact, fear of bloat has been cited by Canadian researchers as the greatest barrier to the expanded use of alfalfa as a grazing forage (Smith and Sing, 2000). Gains of 0.9-1.36 kg per day are possible when cattle are grazing cool season grasses but it takes intensive management of the pasture by the producer in the form of high cost frequent fertilizer application (particularly nitrogen), strict rotational grazing, and thick grass stands in order to keep the pasture highly productive for achieving high rates of gain (Smith and Sing, 2000). However alfalfa produces rhizomes in its roots which allow the microbes in the rhizomes to produce its own nitrogen. This eliminates the need for the producer to fertilize with nitrogen and leaves producers with plants that produce high yields and high quality feed (Smith and Sing, 2000). New grazing tolerant and “bloat safe” alfalfa cultivars are being developed which will help make managing cattle on alfalfa easier than it has been in the past (Smith and Sing, 2000). The issue of poor stand persistence, and more grazing tolerant varieties is also being addressed making alfalfa a better option to consider when planning out how to plant pastures (Smith and Sing, 2000). Full season grazing of monoculture alfalfa (from early June to late September) produced an ADG of 0.93 kg/d in steers (Butler et al., 2012) but gains from stockers grazing monoculture alfalfa ranged from 0.36 to 1.2 kg/d (Lauriault et al., 2005; Cassida et al., 2006).

Like any forage, the nutritional quality of alfalfa varies depending on the growth stage the plant is at when the cattle are grazing it and the age of the stand. These two factors will affect gains for the cattle eating the alfalfa. Steers fed high quality alfalfa hay (2.1 Mcal/kg ME) gained 0.82 kg/d and had greater intakes than steers fed either medium (2.10 Mcal/kg ME) or low quality (2.08 Mcal/kg ME) alfalfa hay (Ringkob et al., 1982). Although the low quality hay had only a slightly lower metabolizable energy (ME) level than high quality (2.08 Mcal/kg versus 2.1 Mcal/kg respectively), lower intakes of the low quality alfalfa hay lead to ADG at a reduced rate.
of 0.59 kg/d (Ringkob et al., 1982). Villalba et al., (2015) evaluated cattle grazing 4 treatments consisting of alfalfa, sainfoin, tall fescue and a choice of the three forages. Each treatment was strip grazed by three steers between June 14 - July 15 (period 1) and from Aug 5 to Aug 23 (period 2). During period 1, steers who grazed the choice and alfalfa treatments had the greatest ADG (1 and 0.8 kg/d respectively) while cattle grazing the tall fescue and sainfoin gained just 0.4 and 0.5 kg/d respectively. During period 2, sainfoin steers gained the most (0.7 kg/d) while alfalfa steers gained just 0.3 kg/d. Based on averaging gains across periods, cattle grazing sainfoin and choice had the greatest gains at 0.6 kg/d while gains for cattle grazing alfalfa fell just short of that at 0.5 kg/d. Tall fescue was the only grass represented in the study and was the poorest performer with cattle gaining just 0.3 kg/d overall (Villalba et al., 2015). In a three year study conducted from 1998-2000, Lauriault et al. (2005), found that gains were greater for continually or rotationally grazed pastures containing alfalfa alone or a mixture of tall wheatgrass and alfalfa than gains from pastures planted in a monoculture of tall wheatgrass. In this study, ADG for animals on pasture containing alfalfa was 0.94 kg/d while ADG for monoculture wheat grass was 0.82 kg/d (Lauriault et al., 2005). Hermann et al. (2002) placed cow calf pairs on either smooth brome, a mixture of grazing alfalfa and smooth brome or a mixture of hay type alfalfa and smooth brome pastures and found, ADG for calves to be greater in all alfalfa treatments than the smooth brome grass treatment (1.2 vs. 1 kg/day). They also found that during the pre-breeding period, cows on the smooth brome treatment lost body condition, also known as body fat, while cows grazing alfalfa pastures maintained their body condition (Hermann et al., 2002). During a two year trial where heifers were grazed on either bermuda grass or alfalfa, heifers had greater ADG and gain per hectare in year two when grazed on alfalfa (Cassida et al., 2006). Additionally heifers grazing alfalfa were able to start grazing
one month earlier than heifers grazing bermuda grass. However, even when cattle graze high quality pasture, ADG values are still lower than the gains found in feedlot cattle fed high concentrate diets.

2.3 Supplementation of Pasture with Grain and its Impact on Cattle Performance

In North America, most cattle producers opt to finish their cattle on high concentrate diets because foraged-finished cattle take longer to reach market weight and have smaller amounts of backfat. In addition, there is the perception that the quality of grain-finished beef is superior in tenderness, juiciness, and flavour attributes versus grass-finished cattle. Finishing cattle on grass not only means slower rates of gain but also results in a longer time on feed before marketing the cattle for slaughter. This decreased production in grass-finishing can lower overall profits. In contrast, pasture-finishing cattle reduces the feed costs compared to feeding high concentrate diets.

Cattle fed high forage (roughage) diets, such as grazing cattle, develop fewer metabolic disorders such as acidosis, liver abscesses and frothy bloat than grain-finished cattle (Galyean and Rivera, 2003). This is because roughages typically have lower amounts of readily fermentable carbohydrates than grains. The presence of roughage in the diet also stimulates rumination and saliva production in the animal which aides in moderating the ruminal pH, leading to lower incidences of acidosis (Galyean and Rivera, 2003). Owens et al. (1986) found that unprocessed corn has the lowest ruminal and total tract starch digestibility values in comparison to corn that has been physically processed in some form. This is due to the fact that processed grain breaks open the grain’s protective shell allowing microbes from the
gastrointestinal tract better access to the starch and increases the surface area for the microbes. When ground corn was used as a supplement to evaluate the effects of feeding corn on rumen function, nutrient digestion and hay intake, digestion of hemicellulose and cellulose decreased linearly in relation to increasing the amount of supplemental corn in the diet (Chase and Hibberd, 1987). Feeding 3 kg of corn per day reduced hemicellulose digestion by 56% while cellulose digestion fell by 36% (Chase and Hibberd, 1987).

Duynisveld et al., (2006) found that the total estimated DMI for cattle fed barley were lower than the estimations for cattle fed whole roasted soy beans. These findings were further supported by Pavan and Duckett (2008) who found that forage Dry matter intake was decreased by 34% when cattle were supplemented on pasture regardless of supplement type used (corn grain or soybean hulls with corn oil). DMI values were compared between cattle supplemented on pasture and cattle fed a high concentrate diet; with no differences in DMI between supplement types on pasture (Pavan and Duckett, 2008). DMI were found to be 34% lower for pastured cattle that were supplemented, regardless of the supplement type (corn grain or soybean hulls with corn oil) in comparison to DMI values for cattle consuming a high concentrate diet (Pavan and Duckett, 2008). French et al. (2000b) also found that decreasing the amount of grain supplementation fed on pasture increased the amount of grass consumed. Feeding 0.45 kg of ground corn can save between 1.23-1.68 kg of hay when the corn is fed at an inclusion rate of 20, 40 or 60% (Embry et al., 1969). Roberts et al. (2009) concluded that stocking densities can be increased because of greater forage availability when steers are supplemented with corn without affecting quality grade of the carcass. Increasing the stocking rate on rotational pastures maintains the plants at a more immature growth stage which in turn increases crude protein content and in vitro organic matter degradation of alfalfa (Schlegel et al., 2000). Over all
stocking rate on pasture did not influence forage quality, but animals do select higher quality forages to consume first (Schlegel et al., 2000).

Choosing the type of supplement to use with pasture can be challenging and dependent on the cost of the supplement as well as geographical region where the cattle are grazed. In western Canada, barley is the major cereal grain used for cattle finishing as the area lacks the heat units to grow corn. In southern Ontario and many parts of the American midwest, corn is the primary grain used to finish cattle. However there are important differences in the way corn grain is processed as to the digestibility and availability of corn nutrients to cattle. The energetic efficiency of whole shelled corn diets was superior to that of diets containing dry rolled corn by 1.9% (Owens et al., 1997). This advantage was attributed to the lower amount of roughage typically fed in diets where whole grain corn is fed. Metabolizable energy content was lower for dry-rolled corn than whole shelled corn (Owens et al., 1997). Gorocica-Buenfil and Loerch (2005), examined the impact of cattle age (weanling versus yearling) and corn processing method (whole versus ground corn) and found that neither age or processing method affected digestibility of dry matter, organic matter, starch, crude protein, neutral detergent fiber, or acid detergent fiber. The researchers did find that feeding whole corn increased the amount of starch in feces by 44% compared to feeding ground corn; however the differences in digestibility due to corn processing was less than 2% and was not significant (Gorocica-Buenfil and Loerch, 2005). Processing corn can lead to improvements in ruminal starch fermentation, but these improvements in starch fermentation can be offset by excessive acid production in the rumen leading to subclinical acidosis (Fulton et al., 1979). Starch that escapes the rumen, such as starch that is present in whole corn, can be digested in the small and large intestines. This leads to a total tract starch digestibility similar to total tract starch digestibility values for cattle fed both
cracked and whole corn (Owens et al., 1986). In feedlot diets where differing amounts of forage (corn silage) and types of corn (cracked or whole corn) were fed, steers on high forage diets with cracked corn consumed 7% more DM than steers fed high forage diets consuming whole corn (Gorocica-Buenfil and Loerch, 2005). It should be noted that no interactions were found between the level of forage in the diet and corn processing method for feed efficiency and that starch digestion was not influenced by forage level or corn processing. When whole corn was fed to cattle, less than 10% of the corn kernels fed could be counted in the feces of the animals leading researchers to conclude that starch digestibility of whole kernel diets is similar to a diet containing processed corn. The researchers stated that finding whole kernels in feces should not be the only justification for feeding processed corn to feedlot cattle (Gorocica-Buenfil and Loerch, 2005). If cattle are restricted in their herbage allowance, the digestibility of the whole diet linearly increases with increasing levels of corn fed (Machado et al., 2006). Of course the combined effects of high forage and whole corn may lead to a better ruminal environment for fiber digestion leading to increased NDF and DM digestibility values (Gorocica-Buenfil and Loerch, 2005).

In a study conducted by Pavan and Duckett (2008), steers grazed tall fescue pastures and were either not supplemented or were supplemented with whole corn grain or soybean hulls plus corn oil. ADG for cattle supplemented with whole corn grain or corn oil was greater than gains for cattle just receiving pasture as supplementation increased ADG by 0.23 kg. There were no differences in ADG when the pastured cattle were supplemented with corn grain or soybean hulls and corn oil (Pavan and Duckett, 2008). Roberts et al. (2009) found that the amount of whole shelled corn supplemented to cattle on winter annual ryegrass had a quadratic effect on the number of days needed on feed for steers to reach a backfat thickness of 0.64 cm. They found a
sharp linear decrease in the days on feed for cattle when supplemented with corn at 0.5 or 1% BW, but increasing the amount of supplementation to 1.5 or 2% BW did not significantly decrease the number of days needed on feed to reach a backfat thickness of 0.64 cm. Increasing the amount of whole shelled corn supplementation on rye grass pasture linearly increased ADG, dressing percentage, hot carcass weight (HCW), skeletal maturity, and yield grade (Roberts et al., 2009). Backfat is generally lowest in cattle that are finished on only pasture compared to grain-fed cattle, but supplementing with grain can increase the amount of backfat as well as marbling scores (Duynisveld et al., 2006). Of course animals that are finished on a high concentrate diet will still have higher ADG than pastured cattle regardless of supplementation offered (Pavan and Duckett, 2008). Supplementing steers on pasture increased total carcass value compared to animals that were fed only pasture (Pavan and Duckett, 2008). McCaughey et al. (1999) grazed heifers and steers on alfalfa pasture for 110 days and supplemented cattle with 4 kg steam rolled barley, 4 kg steam rolled barley and Tween-80 or provided no supplementation. The unsupplemented animals gained significantly less than the supplemented cattle and had significantly lighter HCW.

2.4 Fatty Acid Composition in Forage

The carcasses from grass or forage finished cattle contain a greater percentage of fatty acids (FA) that are considered beneficial to human health, such as conjugated linoleic acid (CLA cis-9, trans-11 isomer) and omega-3 fatty acids (α-linolenic acid, eicosapentaenoic acid (EPA), docosapentaenoic acid (DPA) and docosahexaenoic acid (DHA) (Daley et al., 2010). Concentrations of total beneficial FA in the carcasses from forage-finished animals can be twice
as much as animals who are grain-finished due to greater amounts of these FA or FA precursors in forages than those found in grains (Daley et al. 2010; Duckett et al. 2009; Lorenzen et al. 2007). Fatty acids are found in all plant material but the qualitative and quantitative concentrations found in forage changes depending on the species of forages offered, the season, weather conditions and plant maturity (Fincham et al., 2009). For example the primary FA found in triticale/ryegrass, alfalfa/orchard grass, and cool season grass/legume mixture is linolenic acid (C 18:3) but the primary fatty acid in feedlot diets consisting of corn grain and corn silage is linoleic acid (C18:2). Fresh pasture forages contain 10 to 12 times more C18:3 than cereal grains (French et al., 2003). The concentration of linolenic acid found in forages decreases over time; however amounts of pentadecylic acid, palmitic acid, and linoleic acid increased over time in forages (Fincham et al., 2009). Immature plants or plants harvested frequently, contain greater levels of FA than plants that are mature (Boufaied et al., 2003; Dewhurst et al., 2001; Elgersma et al., 2003a; Elgersma et al., 2005; Elgersma et al., 2003b). Since cattle eat the most nutrient dense feed first, movement of cattle to a new pasture resulted in cattle first eating the alfalfa portion of the pasture before grazing other forages such as tall fescue (Dierking et al., 2010).

Consumption of specific FA has been linked to many positive human health traits (Noci et al., 2005). Conjugated linoleic acid is a FA that is especially of interest since it may possess anti-cancer properties (Baumen et al., 2001). The cis-9, trans-11 CLA isomer in particular has been reported to inhibit human cancer cells (Schultz et al., 1992). CLA is created in the ruminant as the result of incomplete biohydrogenation of dietary fatty acids, particularly the fatty acid C18:2n6 by rumen microorganisms (Noci et al., 2005). Lipids from ruminant animals are one of the greatest sources for CLA for humans (Chin et al., 1992). The amount of pasture in the diet is positively correlated to the amount of alpha linolenic acid precursors that are available for the
production of CLA (Marmer et al., 1984). Dried and cured forages contain slightly lower amounts of the CLA and omega-3 FA precursors than fresh pasture (DeSmet et al., 2004). Supplementing CLA to livestock did not increase the amount of CLA in the carcass when compared to cattle that grazed high quality pasture (Poulson et al. 2004; Dierking et al., 2010). This is likely caused by the biohydrogenation process in the rumen. The type of forage available in pasture also impacts the amount and types of fatty acids available. For example linoleic acid is significantly increased when adding legumes, specifically red clover and alfalfa, to pastures containing tall fescue (Dierking et al., 2010).

Beef contains saturated fatty acids (SFA), polyunsaturated fatty acids (PUFA), monounsaturated fatty acids (MUFA); this includes fatty acids that make up omega-6 and omega-3 fatty acids such as polymers of linoleic acid, eicosapentaenoic acid and docosohexaenoic acid. The omega fatty acids are more commonly known among consumers compared to CLA due to marketing and the fact that they are essential for normal physiological functions such as membrane integrity and regulation of cell signals (Wijendran and Hayes, 2004). The positive effects of increased consumption of omega-3 (n3) PUFA have been well documented as they decrease the risk of cardiovascular disease, impaired fetal development and may help protect against dementia in humans (Givens and Gibbs, 2008). In beef these fatty acids change in ratio depending on the diet the cattle are consuming. For example having an omega-6:omega-3 ratio that is low, is indicative of cattle that were pasture finished rather than finished on concentrates (French et al., 2000a). Duynisveld et al. (2006) conducted an experiment with steers fed pasture only, pasture plus 4.5 kg of barley, pasture plus 1.8 kg whole roasted soy beans or were fed a TMR mix of 60% grass silage/40% in confinement. The PUFA concentrations in the carcasses increased 1.3-1.5 times when pasture was included in the diet regardless of if the
cattle were supplemented. The predominant FA causing this increase in PUFA concentrations are C18:2 (linoleic acid) and C18:3 (linolenic acid) (Duynisveld et al., 2006). The amount of SFA found in pasture fed beef differs depending on the study. Older studies found that grass-fed beef contained more SFA than conventionally finished grain-fed beef (Melton et al., 1982; Marmer et al., 1984) while more recent studies have found that grass-fed beef has less SFA than conventional grain-fed beef (French et al., 2000a; Yang et al., 2002; Noci et al., 2005). When comparing pastures containing tall fescue with pastures containing red clover or alfalfa, the only FA found to be greater in concentration for the tall fescue treatment was myristic acid. Palmitic, palmitoleic, stearic, oleic, linoleic and total FA concentrations were lower in tall fescue pastures than the combined legume treatments of alfalfa or red clover. Alfalfa pastures numerically contained 0.05 mg g⁻¹ more palmitoleic and 0.06 mg g⁻¹ DM more stearic acid than red clover pastures. Although concentrations of palmitoleic, stearic, and oleic acid differed between pasture treatments, they only comprised approximately 6.5% of total FA found in the forages (Dierking et al., 2010).

2.5 Effects of Forage Finishing on Fatty Acid Composition in Beef

Ruminants such as beef cattle on pasture, naturally consume a diet which is low in fat but high in PUFA. These PUFA are present in fresh grass, conserved forages and concentrates (Warren et al., 2008). However a high proportion of dietary PUFA undergoes microbial biohydrogenation in the rumen of the animal which is the biological addition of hydrogen to a fatty acid such that the unsaturated fatty acid is converted into a saturated fatty acid (Warren et al., 2008). This leads to SFA being the predominant source of FA absorbed from the intestines
and then deposited into animal tissues (Warren et al., 2008). SFA and MUFA comprise the
greatest percentages of fatty acids in beef fat (Leheska et al., 2008). However, beef fat is also one
of the richest sources of natural CLA available on the market (Chin et al., 1992). The production
of CLA in the ruminant is the result of incomplete biohydrogenation of dietary fatty acids
particularly C18:2n6 (Noci et al., 2005). The types of forages fed to cattle not only affect weight
gain, but also affects the fatty acid characteristics of the beef carcass (Allen et al., 1996). Beef fat
deposition is also highly heritable which results in breed differences in total fat content when
cattle are fed the same diet (DeSmet et al., 2004; Itoh et al., 1999). Stage of growth also
influences total fat content in a carcass with certain breeds depositing more total fat and certain
fatty acids at an earlier stage of life than other breeds (DeSmet et al., 2004).

Although the concentrations of PUFA consumed with a forage diet is high, the PUFA
content in forage-fed beef is low, averaging only around 5% of the total fatty acids found in the
carcass (Scollan et al., 2006). This is due to forage-finished cattle having lower total fat content
and particularly lower amounts of linoleic acid (Van Elswyk and McNeill, 2014). De Freitas et
al. (2014) found that the average FA concentrations in meat from steers finished on varying
amount of concentrate and pasture amounted to 10% PUFA, 44% MUFA and 46% SFA. Omega-
6 FA and linoleic acids are the primary PUFA found in both grain and forage finished animals
and make up between 60-85% of total PUFA found in the carcass (Van Elswyk and McNeill,
2014). Animals that are grazed on pastures have a lower n6:n3 ratio in their meat as pastures
typically have greater amounts of omega-3 FA than concentrates (French et al., 2000a). While
there are no significant differences in omega-6 FA content between feeding forages and
concentrates, grass-fed beef contains greater concentrations of omega-3 FA which in turn creates
a better n6:n3 ratio for grass-fed beef (Daley et al. 2010). An average n6:n3 ratio between
grain-fed and grass-fed beef was found by Daley et al. (2010) to be 7.65 for grain-fed beef and 1.53 for grass-fed beef. De Freitas et al. (2014) found that the n6:n3 ratio of steers finished on pasture in comparison to steers finished on a 63% grain ration in a feed-lot was 3.6 to 5.8 respectfully. Increasing the amount of concentrates for cattle fed grass-based diets resulted in a linear decrease in the concentrations of n3 FA in the carcass (Daley et al., 2010). This is because cereal based concentrates are dominated by n6 FA which compete for the same enzyme pathways as n3 FA (Mitchell et al. 1991; Crawford et al., 2000). The FA profile will continue to change the longer animals are fed concentrates (De Freitas et al., 2014).

Huuskonen et al. (2010) finished yearling bulls on either pasture or grass silage with each group being supplemented with 4.4 kg of rolled barley daily. They found that the longissimus muscle from pasture finished bulls contained a greater proportion of C 18:3n3, C 18:2 cis-9, trans-11 CLA, C 18:1n7 and C 18:2n6 fatty acids than bulls finished on grass silage (Huuskonen et al., 2010). When comparing FA composition in beef from cattle finished on pasture or grain, pasture-finished steers had greater concentrations of PUFA in their meat than beef from grain-finished cattle (Lorenzen et al., 2007). This diet difference in FA content also continued into the cooked state where cattle from pasture finished regimens have a greater PUFA:SFA ratio than grain finished beef (Lorenzen et al., 2007).

Conjugated fatty acids are also part of the group of FA that make up PUFA. Conjugated linoleic acid is a metabolic end product from biohydrogenation of linoleic acid by rumen microflora. This FA will be absorbed from the gastrointestinal tract and will accumulate in the fat and muscle of ruminants (Van Elswyk and McNeill, 2014). Naturally occurring CLA originates from two sources: bacterial isomerization and/or biohydrogenation of PUFA in the rumen and the desaturation of trans-fatty acids in the adipose tissue and mammary gland.
Griinari et al., 2000; Sehat et al., 1999). Microbial biohydrogenation of linoleic acid and linolenic acid by an anaerobic rumen bacterium, *Butyrivibrio fibrisolvens* is highly dependent on rumen pH (Pariza et al., 2000). Grain consumption decreases rumen pH, creating an acidic environment, and reduces the amounts of *B. fibrisolvens* activity in the rumen (Bessa et al., 2000). Alternatively, grass-based diets do not cause the pH of the rumen to become acidic therefore providing a more favorable rumen environment for subsequent bacterial synthesis (Bessa et al., 2000; Daley et al., 2010). This difference in rumen pH is thought to explain the apparent differences in CLA content between grain and grass-finished beef (Bessa et al., 2000; Daley et al., 2010). One hypothesis for pasture finished animals having more CLA and fatty acids present in the carcass than carcasses from cattle fed high concentrate diets is that the fatty acids in fresh grass have greater protection from biohydrogenation in the rumen than either silages or grains (Alfaia et al., 2009; Fedriksson et al., 2007). A second hypothesis is that while precursors for CLA are present in both grains and lush green forages, forage fed ruminants can produce 2-3 times more CLA in their meat because of the more favourable pH conditions found in the rumen of forage fed animals (Rule et al., 2002; French et al., 2000a; Duckett et al., 1993; Mandell et al., 1997). CLA content is limited in beef due to the high degree of ruminal biohydrogenation of dietary PUFA which leads to the production of SFA in the rumen and subsequent absorption of SFA from the small intestine for tissue deposition of SFA (Warren et al., 2008). So a major challenge to improve the FA content of beef from a human health perspective is to increase the PUFA:SFA ratio while keeping the n-6:n-3 ratio low (Warren et al., 2008).

The most commonly found CLA isomer in forage finished beef is the *cis*-9, *trans*-11 CLA isomer (Van Elswyk and McNeill, 2014). Grain finished beef has a greater carcass fat
content than pasture finished beef. However, according to Van Elswyk and McNeill (2014) the total amount of CLA found in grass finished beef is essentially the same as the amount of CLA found in grain finished beef due to the lower fat content found in the carcass of most forage finished cattle, when comparing grass-fed and grain-fed beef. Results obtained by Dierking et al. (2010) concluded that although FA concentrations in forage from three pasture treatments (tall fescue only, tall fescue and alfalfa or tall fescue and red clover) varied, there were no differences in FA concentrations in the meat across the three. In a study conducted by Dannenberger et al. (2005), pasture feeding significantly increased concentrations of CLA isomers in lipids from *longissimus* muscle as compared to carcasses from bulls fed concentrates. Carcasses from pasture fed bulls in the Dannenberger et al. (2005) study also had greater concentrations of *trans*-10,*cis*-12 18:2 in the lipids of the *longissimus* and up to 14.5 times more *trans*-11,*cis*-13 18:2 (a linoleic isomer) in the tissues and subcutaneous fat than bulls fed a concentrate diet. When comparing grain diets and forage only diets, CLA content increases approximately 1.6-2.9 times in the carcasses of forage fed animals as compared to carcasses from grain-fed cattle (Engle and Spears, 2004; French et al., 2000a; Lorenzen et al., 2007).

Lorenzen et al. (2007) examined FA in cooked meat from cattle on four different dietary treatments: pasture finished on cool season grasses with 30% legumes, pastured and supplemented with soybean hulls, pastured and supplemented with soy oil, or fed in a dry-lot on a diet containing cracked corn and soybean hulls. In the cooked state, the amount of SFA was greatest in meat from cattle finished on pasture supplemented with soyhulls, with the lowest amounts SFA in the beef coming from cattle finished on a feedlot diet of cracked corn and soy hulls; cooked meat from cattle who were pastured with no supplementation contained intermediate amounts of SFA (Lorenzen et al., 2007).
Animal fats contribute approximately 60% of SFA in the average American human diet, most of which is palmitic acid (C16:0) and stearic acid (C18:0) (Daley et al., 2010). French et al. (2000a) found that decreasing the amount of concentrates while steers were on pasture not only increased the amount of grass consumed by cattle but also linearly decreased intramuscular fat SFA concentrations. This decrease in SFA was due primarily to low levels of C 16:0 present in pasture versus silage or concentrates (French et al., 2000a). No other effects of treatment were found for any other intramuscular SFA or total intramuscular MUFA concentration (French et al., 2000a). Noci et al. (2005) found that the proportion of SFA in heifers decreased linearly as the number of days on pasture increased. These results coincide with the French et al. (2000a) study. In the Lorenzen et al. (2007) study, MUFA concentrations were greatest in meat from cattle finished on pasture with supplementation, and in cattle fed the high grain diet as compared to pastured cattle that were not supplemented or were supplemented with soybean oil (Lorenzen et al., 2007). In contrast, PUFA concentrations were greatest in meat from cattle finished on pasture without supplementation. The review conducted by Daley et al. (2010) agreed with the Lorenzen et al. (2007) findings that grain-fed beef consistently contains greater concentrations of MUFA in meat than grass-fed beef.

Work comparing grass to concentrates for finishing steers has found that steers grazed on pasture contained greater concentrations of C 18:0 and various PUFA (C 18:3, C 20:3 and C 20:4) and less SFA including C 16:0 and C 17:0 than beef from concentrate finished steers (French et al., 2000a). When comparing bulls finished on silage or grass, bulls finished on silage had greater proportions of C16:0 and C14:1 than silage finished bulls (Huuskonen et al., 2010). In a review conducted by Daley et al. (2010), grass finished cattle contained lower amounts of total fat in both muscle and IMF than cattle finished on grain but there is no consistent difference
in total SFA content in beef between the two feeding regimes. In terms of human health, SFA including myristic (C14:0) and palmitic (C16:0) are considered to be more detrimental and elevate serum cholesterol levels to a greater extent as compared to PUFA (Daley et al., 2010). Grain-fed beef contains greater concentrations of myristic and palmitic acids than grass-fed beef in 60% of the studies evaluated by Daley et al. (2010). Grass finished meat contains elevated concentrations of stearic acid (C18:0) which is the only SFA with a net neutral impact on blood serum cholesterol in humans (Daley et al., 2010). De Freitas et al. (2014) did not find any effect of finishing diet (63% concentrate vs. pasture) on concentrations of the main FA, 14:0, 16:0 and 18:0 found in intramuscular fat.

2.6 Effects of Grazing on Carcass Traits

2.6.1 Carcass Weight and Fat Cover

Concentrate fed heifers tended (P = 0.08) to produce heavier hot carcass weights (HCW) over grass-fed heifers (Garmyn et al., 2010). McCaughey and Cliplef (1996) found cattle finished on pasture have 3% lower lean meat yields than cattle that were taken from pasture and further fed an alfalfa and barley ration for another 33 or 75 days. These results are also influenced by the fact that alfalfa/barley fed cattle lived another 33 or 75 days longer than their pastured counterparts which would influence carcass weight and corresponding meat yields. The McCaughey and Cliplef (1996) study also found that the cattle on barley grain after pasture had higher carcass grades, and significantly larger longissimus muscle areas. Pavan and Duckett
(2008) found that yield and quality grades were lower for all pasture finished cattle regardless of supplementation with concentrates while on pasture than cattle who were fed a mainly concentrate based diet (Pavan and Duckett, 2008). In terms of kilograms gained, steers on an 85% concentrate diet gained an average of 156 kg more than steers pastured and supplemented with concentrate when fed to the same time end point. Feeding high concentrate diets yielded 64 kg more HCW than pasture supplemented steers and 104 kg more HCW than steers who were finished on only pasture with no supplementation (Pavan and Duckett, 2008).

Carcass weight, backfat thickness and age at slaughter have all been cited as factors that influence meat quality (French et al., 2000b). Cattle who are finished on high grain feedlot rations are fatter than cattle who are fed on other nutritional regimens based on forages as evidenced by increased fat thickness, heavier carcass weights, greater percentages of kidney, pelvic and heart fat, and greater USDA yield and quality grade scores (Lorenzen et al., 2007). Feedlot cattle were also found to be more muscular as evidenced by larger longissimus muscle areas in conventionally fed cattle versus pasture-finished cattle. Pasture finished cattle had the lightest carcass weights and lowest percentage of kidney, pelvic and heart fat when compared to cattle fed high grain rations. Supplementation with soybean hulls or soybean oil did appear to increase the amount of finish on cattle that were finished on forages and supplemented; however this increase was not enough to increase carcass quality grades (Lorenzen et al., 2007). When steers were fed high, medium or low quality alfalfa hay based on ME content of the hay, there was a trend for steers fed high quality hay to be fatter than the other two groups (Ringkob et al., 1982). Cattle fed the low quality alfalfa tended to be the leanest. Fat thickness and longissimus muscle area decreased with the quality of alfalfa hay and resulted in fat thickness being 1.02, 0.89 and 0.72 cm respectively (Ringkob et al., 1982). Due to the greater amount of energy that
concentrate fed cattle consume, extra energy is stored in the animal as fat with intramuscular fat being laid down along with backfat (Leheska et al., 2008). Cattle who are pasture-fed including pastured cattle who are supplemented with concentrates, still tend to have lower amounts of subcutaneous fat and marbling due to the extra energy spent from walking around to gather their food (Huuskonen et al., 2010).

2.6.2 Lean Colour

There are many factors that contribute to a pleasant beef eating experience including tenderness, appearance and flavour. If cooking beef at home, the first step is purchasing beef out of the meat case. Consumers’ selection of a steak to purchase is based on several factors including price, amount of marbling or grade and colour of the lean meat. Grass finished beef tends to have a bad reputation when it comes to these characteristics, as it is known to be darker in colour and tougher than concentrate-finished animals (Priolo et al., 2001). The darker colour of grass-finished beef is associated with greater pH values for the meat and increased myoglobin concentrations in the muscle (Coulon and Priolo, 2002). These traits are normally associated with grass finishing due to the tendency for the cattle to be older in age at the time of slaughter compared to cattle that are concentrate-finished (Coulon and Priolo, 2002). Leheska et al. (2014) conducted a study where 15 producers of grass-fed cattle, across 13 different U.S. states sent in both ground beef and strip loin steaks on three different occasions for testing of fatty acid profile, marbling and fat colour to be compared to ground beef and strip loin steaks from conventionally finished grain-fed cattle. The researchers found no difference in lean meat colour between grass-finished and conventionally-finished beef which is contrary to previous studies (Binder et al.,
Subjective evaluation of colour for strip loin steaks did find that grass finished cattle had a more yellow appearance in their fat colour than conventionally finished beef (Leheska et al., 2008). Ringkob et al. (1982) fed three different qualities of alfalfa hay (based on differences in Mcal/kg ME) to steers for 150 days before slaughter, and kept rib sections from these cattle for meat quality evaluation. The researchers also gathered 12 rib sections from hotels and restaurants for comparison of the meat quality from commercially available ribs to rib sections from the alfalfa hay-fed cattle. No difference in lean colour between high, medium and low quality alfalfa hays were found; however the alfalfa hay finished beef did have more yellow subcutaneous fat than beef from rib sections gathered from hotels and restaurants (Ringkob et al., 1982).

Changing FA composition in meat, particularly PUFA concentrations can affect colour, shelf life and sensory attributes in meat (Scollan et al., 2006). Longissimus muscle colour was found to be darkest in cattle who were slaughtered directly from pasture but became more cherry red the longer cattle were fed grain (McCaughey and Cliplef, 1996). Garmyn et al. (2010) conducted a study which had a trained 6 member panel rating steaks from forage and concentrate finished heifers every 12 hours for 7 days on colour attributes. The steaks were evaluated in simulated store conditions and panelists rated the steaks based on subjective muscle colour, surface discoulouration, and overall appearance at each evaluation time. Overall, finishing diet did not affect instrumental or subjective lean colour evaluation over the 7 days of display. Garmyn et al. (2010) used a HunterLab Miniscan EX Plus Spectrophotometer to measure lean colour and found that L* values (the measure of luminosity) for steaks from concentrate fed heifers were greater than the L* values for steaks from forage finished heifers at the start and end of displaying the steaks. However the change in L* values between the initial and final measures
(156 hours) did not differ between diets. Overall, Garmyn et al. (2010) found no diet effect on initial, final, or overall change in $a^*$ or $b^*$ colour values ($a^*$ being the range from red to green and $b^*$ being the range from yellow to blue) which is in agreement with findings from O’Sullivan (2003). This implies that diet does not affect the colour change in meat as it waits to be consumed. Bjorklund et al. (2014) evaluated colour scores for strip loin steaks from steers that were grass-finished without supplementation, steers who were fed an organic TMR of corn silage, dried distillers dry corn soybean meal and hay along with at least 30% DM pasture and conventionally raised steers fed an 80% concentrate/20% roughage diet with no pasture. $L^*$ and $b^*$ values were not affected by nutritional regimen, but unlike the Garmyn et al. (2010) study, Bjorklund et al. (2014) found $a^*$ values for grass-fed steers to be significantly lower than corresponding values for conventionally finished, grain-fed steers. French et al. (2000b) found no difference in lean colour for $longissimus$ muscle from steers who were finished on grass, silage or concentrate but Huuskonen et al. (2010) found that bulls who were finished on silage had lighter lean meat colour than bulls finished on pasture (Huuskonen et al., 2010; French et al., 2000b).

2.6.3 Fat Colour

Colour of the meat itself is not the only colour attribute that consumers evaluate when deciding which steak to purchase; the colour of the fat is also important. The colour of fat in cattle finished on grass may be affected by dietary concentrations of β-carotene, a precursor for vitamin A (French et al., 2000b; Leheska et al., 2008). β-carotene concentrations are greater in forages than concentrates which lead to higher yellow fat score in grass finished beef (French et
However if the cattle were on pasture prior to finishing, feeding concentrates is not guaranteed to lower the yellow score of fat since fat colour is dependent on how long the cattle were on grain prior to slaughter. Fat colour depends on the degree of carotenoid pigmentation prior to concentrate finishing, the actual finishing diet used, the duration of concentrate finishing and the carotenoid concentration in the roughage used in the finishing diet (French et al., 2000b). The rate of fat deposition can also play a factor in the colour of fat as the faster cattle deposit fat, the faster the carotenoid pool will be diluted (French et al., 2000b). Quality evaluation of beef strip steaks indicate that grass finished beef has more yellow fat and less marbling than grain finished beef (Leheska et al., 2008). Leheska et al. (2008) and Duckett et al. (2013) both reported significant increases in yellow fat colour for grass and forage-finished beef which was related to the 1.5-10 times increase in β-carotene deposition in adipose tissue (Duckett et al., 2009; Duckett et al., 2013).

2.6.4 Muscle pH

While pH is not something consumers take into consideration, or even think about when purchasing beef, it is actually an important contributing factor in the eating experience. Meat colour, tenderness, flavour, juiciness, and shelf life are all influenced by pH (Hofmann, 1988). It has been hypothesised that early post-mortem pH influences the activity of endogenous enzymes which in turn affect meat tenderness (Hofmann, 1988). When comparing animals that were fed just grass, grass and concentrate, silage and concentrate, or concentrate and hay, the cattle that were fed a grass and concentrate diet had the most rapid pH decline post-slaughter (French et al., 2000b). This fact is conducive with the findings of French et al. (2000b) who found that
longissimus dorsi muscle from cattle fed 6 kg of grass DM and 2.5 kg of concentrate had a pH of 6.0 post slaughter while all other experimental treatments had a longissimus dorsi muscle pH of 6.2 post-slaughter (French et al. 2000b). After 24 hours post-slaughter, pH values for longissimus dorsi muscle were similar for all dietary treatments suggesting that pH must be measured immediately post-slaughter to determine if pH is responsible for changes in carcass properties (French et al., 2000b).

2.6.5 Tenderness

When most consumers think of the perfect steak they picture a steak that is juicy and falls apart in their mouth tender. In fact some of the biggest factors that influence consumer perception of meat quality includes tenderness, colour, juiciness and flavour (French et al., 2000b). Postmortem aging of fresh meat improves meat tenderness by allowing for protein degradation to occur (Leheska et al., 2008) and thus post-mortem aging time and toughness are inversely linearly correlated (Brooks et al. 2000). Some research has shown that the longer cattle are finished on grain, the more tender their meat becomes (Leander et al., 1978; Bennett et al., 1995). The quality of forage fed to cattle can also impact beef tenderness. In the study by Ringkob et al. (1982), rib steaks from steers fed high or medium quality alfalfa hay were significantly more tender than rib steaks from steers fed low quality alfalfa hay where quality in hay was distinguished by ME content (Mcal/kg). Some U.S. grass/forage-feeding studies (Hedrick, 1983; Mayet al., 1992; Schroeder et al., 1980; Sitz et al., 2005), but not all (Duckett et al., 2009, 2013; Reagan et al., 1977), report steaks from grass/forage-fed beef to be less tender
than steaks from grain-finished beef while most have found juiciness to be similar between grass/forage- and grain-fed beef.

While meat tenderness can be determined using taste panels, most meat researchers will evaluate meat tenderness using an instrumental measure of tenderness. Warner-Bratzler shear force (WBSF) is an instrumental measure of tenderness often used to mechanically test the amount of force it takes to cut through the muscle fibers of the steak. This test simulates the consumer eating experience as they bite into a steak. In evaluating WBSF values (measured in kg), a low numerical value is associated with low amounts of force needed to bit through the steak, translating into tender beef. High numerical WBSF values are associated with greater force being needed to bite through the steak and as such the beef is considered to be tough.

Wheeler et al., (1997) found that sensory panels associated slightly tender meat with a Warner-Bratzler shear force rating of 4.6 kg or lower. In terms of WBSF values, Bjorklund et al. (2014) evaluated steaks for tenderness from steers fed pasture only, at least 30% pasture on a DM basis and a TMR mix of organic corn, distillers, corn silage and hay or an 80% concentrate ration with no pasture. The researchers found shear force values for steaks were similar between steaks from grass finished steers and steaks from steers that were pastured and fed an organic TMR corn ration (2.6 vs. 2.3 kg WBSF). However, steaks from pasture fed steers tended to have greater shear force values than steaks from cattle fed 80% concentrate (2.6 vs. 2.0 kg WBSF) (Bjorklund et al., 2014). Faucitano et al. (2008) and French et al. (2001) both found no differences in WBSF values between cattle who were grass finished and those who were finished on concentrates. In the study conducted by Garmyn et al. (2010), WBSF values for longissimus muscle steaks from concentrate finished heifers were lower with greater sensory tenderness ratings than longissimus muscle steaks from forage-finished heifers. Garmyn et al. (2010) attributed these results to
increased fat deposition preventing cold shortening or possibly the younger age of the concentrate finished heifers at the time of slaughter. Roberts et al. (2009) and Lorenzen et al. (2007) both found no effect of diet regimen on WBSF values when comparing cattle finished on pasture alone or pasture with grain supplementation.

2.6.6 Juiciness

Meat juiciness plays an important contributing role to the eating quality of meat and plays a role in meat texture (Dransfield et al., 1984; Jowitt, 1974; Hutchings and Illford, 1988). French et al. (2000b) and Muir et al. (1998) concluded there were no detectable differences in beef juiciness between grass-fed and grain-fed cattle when the cattle were compared at similar weights and/or backfat cover. Evaporative cooking losses were found to be greater in cattle that were fed pasture only but interestingly, drip loss upon cooking was greater in cattle fed a TMR mixture of 60% grass silage and 40% barley (Duynisveld et al., 2006). No dietary effects were found in the French et al. (2000b) study for drip loss, cook loss, or juiciness in animals that were finished on grass or concentrates. Longissimus dorsi muscles from lambs that were finished on native grass pasture, ground alfalfa or alfalfa and linseed were found to have no differences in cooking loss versus longissimus dorsi muscles from lambs finished on ground alfalfa or native grass (Perlo et al., 2008). Ringkob et al. (1982) found no differences in cooking loss between cattle who were fed high, medium or low ME hay or rib sections obtained from restaurants from cattle who were finished on a high grain diet. Similarly, Jiang et al. (2010) found no differences in cooking loss of longissimus steaks from cattle fed alfalfa and grain, triticale and ryegrass, triticale and kale or grazing ryegrass, orchard grass and fescue and finished on alfalfa and grain.
2.6.7 Flavour and Overall Acceptability

Each person experiences eating in a different way and eating beef is a complex matter in that every person will experience the same steak in a slightly different way and no two steaks will be alike due to animal to animal differences in the amount of marbling, muscling and myoglobin in carcass after slaughter. Flavour acceptability is generally related to an individual’s preferences and their cultural norms (Van Elswyk and McNeill, 2014). For example, Americans tend to prefer grain-finished beef over grass-finished beef because the majority of beef in the U.S. is grain-finished and this is what consumers have grown to expect (Scollan et al., 2006; Sitz et al., 2005). Individuals tend to prefer eating foods that they grew up eating, making consumer sensory panels more of an art than a science (Sitz et al., 2005). Meat flavour is influenced by a variety of factors including the age of the animal at time of slaughter, cattle genetics, pre-slaughter diet regimen, environment, length of post-slaughter aging and primal cut (Spainer et al., 1990).

Grass-finishing beef cattle alters the fatty acid composition of beef versus the fatty acid profile found in conventionally finished, grain-fed beef, which in turn affects beef aroma and flavour (Daley et al., 2010). Aroma and flavour are directly linked to the chemical makeup of the carcass, and grass-fed beef consumers have come to expect a different flavour and aroma from grass-fed beef (Daley et al., 2010). The flavour of grass-fed beef will vary depending on the type and maturity of the forage the animal was fed, the breed of cattle, the fat content and the marbling score of the animal (Van Elswyk and McNeill, 2014). Beef from grass-finished cattle tends to have a lower lipid content and greater concentration of PUFA than beef from grain-finished cattle (Daley et al., 2010).
In a consumer panel conducted by Bjorklund et al. (2014), dairy steers were raised on one of three diet regimens; 1) grass-fed: where steers grazed cool season grasses or were fed high quality hay or hay silage during the non-grazing season, 2) organic steers: where a minimum of 30% of total DM intake was fed as pasture during the summer with the rest of the diet being made up of organic corn, soybean meal, corn silage and minerals, and 3) a conventional grain-fed treatment: where steers were fed 80% concentrate/20% forage diet with the concentrate consisting of dried distillers grains with soluble, dry corn, soybean meal, and minerals fed with corn silage and grass hay. Means for overall consumer liking were similar for conventional and organic beef; however the grass-fed steaks were rated significantly lower for overall consumer liking than conventional or organic steaks (Bjorklund et al., 2014). The researchers also found that the consumer panel gave greater flavour ratings to the organic beef than the conventional or grass-fed beef. Means for organic and conventional beef were similar for texture, toughness and off flavour. The consumer panel found grass-fed beef to be the toughest with the lowest flavour and juiciness ratings while displaying the most off flavour for the three diet regimens (Bjorklund et al., 2014). U.S. consumers participating in a flavour panel conducted by Melton et al. (1982) described ground beef from grass and forage fed animals to be lacking in beef flavour and accompanied by a soured dairy flavour and/or other off flavours. Due to the fact that ground beef was used by Melton et al. (1982), the fat content was the same between treatments and therefore not responsible for flavour differences that can sometimes be an influencing factor. When using a trained sensory panel, beef from grass-finished cattle was found to lack beef flavour and presented with greater off-flavour scores than beef from grain-finished cattle (Duckett et al. 2013). A suggestion for the greater incidence of off flavour in grass-fed beef is related to the fatty acid profile, where grass-fed beef’s long chain omega-3 FA and linolenic acid contents
increases the likelihood for off-flavours (Melton et al. 1982). Steaks from concentrate (flaked corn and sweet bran) or grass finished (cool season grass and wheat pasture) heifers were found to be similar in juiciness or livery/metallic flavour intensity (Garmyn et al., 2010). However *longissimus* steaks from concentrate-finished heifers had more beef flavour intensity and less grassy/cowy flavour than *longissimus* steaks from forage-finished heifers (Garmyn et al., 2010).

While the flavour of beef plays an important role in the consumer eating experience, it is not the only factor that has to be taken into consideration when evaluating the eating quality of beef. A consumer panel conducted by Lorenzen et al. (2007) found that consumers did not discriminate in their ratings for tenderness with beef from grass-fed cattle. The Faucitano et al. (2008) study found that the trained panel downgraded tenderness ratings for beef from concentrate-fed cattle while panelists in the French et al. (2001) study reported no differences for any sensory traits as affected by the diet fed to cattle. Beef from pasture only, supplemented pasture, or a TMR mix of grass silage and barley were similar in tenderness based on instrumental assessment of tenderness using a Kramer shear press and by a trained taste panel (Duynisveld et al., 2006). In a study conducted by Roberts et al. (2009), steers were pasture-finished on rye grass and supplemented on an as-fed basis with whole corn at 0, 1, 1.5, or 2% BW, or finished in a dry lot on a conventional high concentrate diet. There was a quadratic response for juiciness and tenderness scores based on the amount of grain supplementation. Beef juiciness ranking was the greatest in beef from steers fed the greatest amount of grain as compared to cattle fed grain at 1% and 1.5% BW (Roberts et al., 2009). Beef flavour and intensity of flavour were found to linearly increase as the amount of grain in the diet increased (Roberts et al., 2009). McCaughey and Cliplef (1996), examined palatability attributes for *longissimus* steaks produced by feeding cattle just pasture (with 70% alfalfa in the botanical
composition), pasture followed by 33 days on grain (50:50 alfalfa hay and steamed barley) or pasture followed by 75 days on grain (25:75 alfalfa hay and steamed barley) (McCaughey and Cliplef, 1996). A trained taste panel found no significant differences between treatments for tenderness, juiciness, flavour or over-all acceptance (McCaughey and Cliplef, 1996).

2.7 Conclusion

There are many ways to finish beef cattle and each method has its own benefits and limitations. While there is no right way to finish beef cattle, the method chosen for finishing can impact weight gain and time on feed, HCW, FA profile and palatability. Supplementing grain on pasture dramatically increases the amount of energy provided by the diet and can provide a more cost effective method of finishing beef. The type of forage available in the pasture also plays an important role and producers must take this into consideration when planning their forage finishing strategy, as legumes add crucial protein to the diet. Careful consideration must be taken and the producer’s goals must be evaluated before deciding which finishing method will work the best for their operation. It is hypothesised that supplementing corn to cattle on alfalfa pasture will increase weight gain due to increased energy provided by the diet, alter the fatty acid profile of the carcass and mitigate some of the negative attributes associated with forage finished beef such as decreased carcass finishing and off flavour.
3.0 Effects of Supplementing Corn on Alfalfa Pasture on Growth Performance, Carcass Qualities, Fatty Acid Composition and Palatability Attributes

3.1 Materials and Methods

3.1.1 Acquisition and Management of Cattle

The use and treatment of animals for this study was approved by the University of Guelph Animal Care Committee which follows the regulations of Ontario as well as the Canadian Council of Animal Care regulations (CCAC, 1993).

Fifty yearling black Angus and Angus cross steers were acquired from a sales barn and private cattle dealer in late May, 2015. The cattle were backgrounded in the Bruce Peninsula area before being purchased by the University of Guelph. After the steers were purchased, they were transported to the University of Guelph’s New Liskeard Agricultural Research Station (NLARS) in New Liskeard, ON. Upon arriving at NLARS, the steers were housed in an approximately 10 acre grass pasture until the start of the trial. Steers were weighed shortly after their arrival and averaged 434 ± 37 kg body weight (BW). Steers were then randomly assigned into management regimen groups based on BW such that BW would be similar across management regimens at the start of the study. The management regimens consisted of three groups of steers housed on pasture (n = 38) and one group of steers housed in a drylot (n = 12). The drylot steers were fed a diet consisting of approximately 77% whole shelled corn, 14% chopped dry grass hay, and 8% of a 40% protein pellet containing Rumensin (dry matter basis) (33 ppm Rumensin supplied; Elanco Animal Health, Division of Eli Lilly, Greenfield, IN). The remainder of the steers were housed on alfalfa pasture and were then separated into the three management groups based on
supplementation with varying amounts of whole shelled corn on pasture. These included alfalfa pasture with no further supplementation besides vitamins/minerals (Table 1), alfalfa pasture plus whole shelled corn offered at 0.5% of all steers’ BW (as-fed basis) or whole shelled corn offered at 1.0% of all steers’ BW (as-fed basis). Rumensin was not supplied to the pastured steers in their mineral premix but in a Rumensin bolus.

Seven days prior to the start of the trial, 12 steers were removed from the grass pasture and placed in 1 of 2 outdoor drylot pens equipped with Calan gate feeders. A rope collar was placed around each of the 12 steers’ necks; each collar was equipped with a key to work a Calan gate (American Calan, Northwood, NH). The key placed around the steer’s neck allowed each steer to open a Calan gate that was assigned to them. This Calan gate controlled access to a feed bunk that was available to only one animal for access to feed. Each key only worked on one gate in the drylot allowing for daily feed intakes to be monitored for each steer. After the steers were equipped with a key, they were placed in one of two drylot pens previously mentioned with each drylot measuring approximately 46 meters by 46 meters. Each drylot pen housed 6 animals. Both drylot pens were equipped with six Calan gates opening to individual feed boxes allowing for the collection of feed intake data from each individual steer for the duration of the trial. The Calan gates were powered using Coleman solar panels (Coleman Canada, Brampton, ON) and two deep cell batteries. Gate function and battery levels were checked daily. In the event that the solar panels failed to charge the batteries, a gas generator was used to charge the batteries. To train the steers on how to operate the Calan gates, the gates were tied wide open with a string. The string was then let out in stages allowing the steers to learn how to push on the gates so they would open. At this point the gates were untied and left closed unless opened by the appropriate steer.
The drylot housed steers were fed alfalfa silage during a 7 day training period before being transferred to a corn step up program. The corn step up program was used to gradually adjust the cattle to the 85.76% concentrate diet based on whole corn. Free choice salt and minerals (Table 1) were available for the steers and no shade was provided for either drylot pen.

Steers were stepped up gradually on the amount of corn in their diet over a 20 day period before reaching their final 85.76% concentrate ration (Table 2) on July 1, 2015. During the step up process, each ingredient in the diet was individually measured out for each steer and all steers received the same amount. The final diet was mixed in a Calan Data Ranger equipped with a scale. The total mixed ration (TMR) was weighed out and delivered to the drylot pens using large Rubbermaid bins marked with each steer’s Calan gate number. Fresh feed was added daily throughout the trial. After the step up program was completed, steers were fed ad libitum. The amount of refusals was checked each morning and the amount of feed for the day was adjusted accordingly. Orts were cleaned out and weighed back once weekly with the weight of the orts being recorded before the steers received new feed for the day.

The remaining 38 steers on the grass pasture were introduced to a poloxalene based, anti-bloat product called Alfasure (8Rafter Products, Calgary, AB), one week prior to the start of the trial. Alfasure was distributed to the cattle in their water supply using a Dosatron (Dosatron International Inc., Dallas TX) that automatically dosed the water the steers were consuming. The dosatron mixed the Alfasure solution in a 1:100 ratio of Alfasure solution to plain water. Due to the fact that Alfasure is a concentrated product, it was mixed with water prior to going through the dosatron to dilute the bloat preventative to an appropriate concentration depending on the bloat risk factors presented by the pasture, as well as how much water the steers were consuming. As per label instructions, the Alfasure solution was kept out of direct sunlight, and
the diluted Alfasure mix was made in batches that would last a maximum of three days. The level of Alfasure solution was checked each morning when the steers were checked. Alfasure was provided only to the pastured steers. This was done as a secondary preventative measure to ensure that bloat would not occur in the pastured steers if the Rumensin bolus ran out before the end of the trial.

To obtain a true start of trial weight without fasting, all steers were weighed on two consecutive days the day prior to the start of the trial. The start of trial body weight of the steers was 447 ± 37.0 kg. In order to reduce the number of times cattle had to go through the handling system, steers on pasture received their Rumensin bolus on the first day of weighing. All steers were closely monitored for 45 minutes after being given the Rumensin bolus to ensure the bolus stayed in the rumen and was not regurgitated. Bolus serial numbers were recorded along with ear tag numbers in the event that a steer did regurgitate his bolus. Boluses were used as a secondary bloat preventative measure and to help promote growth.

All steers in the trial underwent ultrasound scans on the second weigh day to determine body composition at the start of the trial, including subcutaneous backfat thickness, *longissimus* muscle area, and *longissimus* intramuscular fat content. An Aloka 500 (Hitachi Aloka America, Wallingford, CT, USA) with a 17 cm transducer was used for the ultrasound procedure. The transducer was placed parallel between the 12th and 13th ribs to measure subcutaneous backfat thickness and *longissimus* muscle area. The transducer was placed perpendicular across ribs 12 and 13 to measure *longissimus* intramuscular fat content. The ultrasound images were saved on a Dell laptop to be eventually evaluated for the respective body composition traits using Cattle Performance Enhancement Company (CPEC) software (CPEC, Oakley, KS, USA). Ultrasound
measurements were repeated at the midpoint of the trial on all steers and at the end of the trial on the 5 steers not sent to slaughter.

Due to an electrical storm, it was decided to wait until the morning after the second weight was taken to allocate the alfalfa pasture steers into their treatment groups and start the trial. The pasture trial started on June 11, 2015. The 38 steers on the alfalfa pasture were allocated to the following management regimens: 13 steers on alfalfa pasture with no grain supplementation, 12 steers on alfalfa pasture with whole shelled corn offered at 0.5% BW (as-fed basis) of all steers in that regimen, and 13 steers on alfalfa pasture with whole shelled corn offered at 1.0% BW (as-fed basis) of all steers in that regimen. All steers were given a free choice vitamin/mineral mix and salt on the pasture (Table 1). The whole shelled corn was fed in troughs to the appropriate steers in the morning during morning cattle checks. Ten days after the start of the trial, a 13th steer was added to the 0.5% supplementation regimen group. This steer was disqualified from another forage study taking place at the station due to failing to acclimatize to the use of Calan gates. Due to biosecurity, he could not be taken to the cow-calf farm owned by the station to be grazed until the end of the trial. Therefore he was put on Alfasure and turned out with the 0.5% supplementation regimen to even out their numbers. Growth and carcass data from this steer were not used for this study.

The two alfalfa pastures used for the trial consisted of 10.3 and 9.9 acres that were subdivided to contain three smaller paddocks of approximately just over 3 acres each. The two pastures had been seeded down the previous year with 117.9 kg/acre of a 92% Survivor Alfalfa and 8% Timothy mix along with 45.4 kg/acre of Fleet Meadow Brome Grass. Some volunteer vetch was also growing in the pasture throughout the trial.
All fencing used was electrical fencing commonly found in livestock production. Strip grazing was used to move the pastured steers through each 3 acre paddock. The amount of new forage given to the steers was adjusted daily depending on how much forage was left from the day before. Mineral feeders, water troughs and feed troughs were moved with the steers as they moved through the paddocks. Steers in the pastures were not provided with shade. A back fence was also used to prevent steers from re-grazing pasture they had just been on and to allow for regrowth on previously grazed pastures. The front and back fences were moved directly after lunch each day to ensure morning dew had burned off the alfalfa. The steers were rotated between paddocks approximately every 14 days to avoid confounds of one paddock having a greater amount of forage or a greater variety of forage species than another. Steers were moved to a fresh pasture when one pasture regimen group finished their paddock. The rotation of the steers in the paddocks coincided with weigh days to cut down on stress to the steers. All steers were weighed every 14 days for the duration of the trial to track performance. Steers were also closely monitored for any signs of bloating throughout the trial.

In late summer (Aug 27, 2015), pasture re-growth was slower than it had been previously so the steers were pulled from the pastures and put on green feed. The green feed consisted of primarily alfalfa forage that was harvested from another field not previously used in this trial. The alfalfa was freshly cut and baled each day and given to the steers in round bale feeders each afternoon directly after lunch. The steers were fed green feed for 8 days before being moved back onto pasture. This was repeated at the end of the trial (Sept 23, 2015) as again, pasture was slow to re-grow. Moving to green feed also allowed the pasture some time to recover for next year as it was now into the critical period for the alfalfa and further grazing would only damage the viability of the stand for next year’s trial.
Forage samples were taken weekly using a metal quadrat bracket measuring 30 cm x 100 cm. Forage samples were taken from fresh pasture that had not yet been grazed and from pasture that the steers had just been moved off of. Samples were taken to be tested for forage quality throughout the trial and to determine how much biomass the steers were leaving behind. Samples were cut using a Black & Decker (Stanley Black & Decker INC, Towson, MD, USA) battery operated hedge clipper and placed in labeled brown paper bags for weighing and drying. All samples were weighed on a Denver Instrument scale (Denver Instrument, Bohemia, NY, USA) before being placed in either an electric or a gas dryer for a minimum of three days to dry. The dry matter (DM) content was determined on up to a 700-g fresh sample of forage, which was dried at 55°C to a constant weight (Goering and Van Soest, 1970). Samples were weighed again once they were dried and then were ground to pass through a 1 mm screen in a Thomas Wiley Mill (Model 3; Arthur H Thomas, Philadelphia, PA) for preparing samples for chemical analysis. Samples were pooled within treatment for every weigh period and analyzed at Université du Québec en Abitibi-Témiscamingue (UQUAT) in Notre-Dame, Quebec for dry matter, ash, neutral detergent fiber (NDF), acid detergent fiber (ADF), and acid detergent fiber lignin (ADL). Cell wall fractions (NDF, ADF, ADL) were measured in oven-dried samples according to Van Soest et al. (1991) using the ANKOM apparatus. The NDF procedure was conducted with the inclusion of heat stable alpha-amylase to digest starch. Subsamples of forage were ashed at 600°C for 2 h in a muffle furnace (method 942.05 in AOAC, 2006). Water soluble carbohydrates were measured colorimetrically (Dubois et al. 1956) on a 1 mL water extract using 0.1 g of forage soaked in 50 mL of deionised water and agitated for 1 h on a rotary shaker.
The pasture samples were then shipped to the University of Guelph where they were further pooled within treatment and sent to A&L Canada Laboratories (London, ON) for mineral and protein analyses.

Several calculations were made at the end of trial using the final body weights of the steers and the intake data from the dry lot steers. Average daily gain for each steers was calculated by the following formula: 

$$\text{ADG} = \frac{\text{final body weight} - \text{initial body weight}}{\text{number of days on trial}}$$

Dry matter intake was calculated for each of the steers in the dry lot using the formula:

$$\text{DMI} = \frac{\text{feed offered} - \text{feed refused}}{\text{number of days on trial}}$$

To calculate the gain:feed ratio for the steers in the drylot the following formula was used: 

$$\text{G:F} = \frac{\text{total weight gain for trial}}{(\text{kg of feed offered} - \text{kg of feed refused})}$$

Out of the original 50 steers, 45 were sent to Cargill Meat Solutions beef packing plant in Guelph, ON for harvesting. The remaining 5 steers were too light in BW at the end of the trial and it was decided that it would be best not to send undesirable cattle to the Cargill plant. The animals were resold at the Keady Livestock Market. Two steers from the high grain regimen and three from the pasture only regimen were resold.
Table 1. Chemical Composition of Mineral Fed to All Steers

<table>
<thead>
<tr>
<th>Component</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dry Matter (%)</td>
<td>97.89</td>
</tr>
<tr>
<td>Crude Protein (%)</td>
<td>0.26</td>
</tr>
<tr>
<td>Total Ash (%)</td>
<td>83.76</td>
</tr>
<tr>
<td>Mineral Oil (%)</td>
<td>1.10</td>
</tr>
<tr>
<td><strong>Macro Minerals</strong></td>
<td></td>
</tr>
<tr>
<td>Calcium (%)</td>
<td>17.61</td>
</tr>
<tr>
<td>Phosphorus (%)</td>
<td>12.00</td>
</tr>
<tr>
<td>Sodium Chloride (salt) (%)</td>
<td>12.50</td>
</tr>
<tr>
<td>Sodium (%)</td>
<td>5.02</td>
</tr>
<tr>
<td>Potassium (%)</td>
<td>0.12</td>
</tr>
<tr>
<td>Chloride (%)</td>
<td>7.63</td>
</tr>
<tr>
<td>Magnesium (%)</td>
<td>3.99</td>
</tr>
<tr>
<td>Sulphur (%)</td>
<td>1.00</td>
</tr>
<tr>
<td><strong>Trace Minerals</strong></td>
<td></td>
</tr>
<tr>
<td>Fluorine (mg/kg)</td>
<td>1128.94</td>
</tr>
<tr>
<td>Manganese (mg/kg)</td>
<td>3004.67</td>
</tr>
<tr>
<td>Zinc (mg/kg)</td>
<td>3573.46</td>
</tr>
<tr>
<td>Iron (mg/kg)</td>
<td>7033.73</td>
</tr>
<tr>
<td>Copper (mg/kg)</td>
<td>1009.26</td>
</tr>
<tr>
<td>Selenium (mg/kg)</td>
<td>90.00</td>
</tr>
<tr>
<td>Cobalt (mg/kg)</td>
<td>41.40</td>
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<tr>
<td>Iodine (mg/kg)</td>
<td>41.92</td>
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<tr>
<td>Vitamin A (KIU/kg)</td>
<td>600.50</td>
</tr>
<tr>
<td>Vitamin D (KIU/kg)</td>
<td>87.40</td>
</tr>
<tr>
<td>Vitamin E (KIU/kg)</td>
<td>5002.60</td>
</tr>
</tbody>
</table>

*Masterfeeds manufactures the mineral mix. It is veterinary prescribed custom mix to increase levels of vitamin E and selenium in the diet due to selenium deficiency of the soil.
<table>
<thead>
<tr>
<th>Nutritional Composition of High Grain TMR (% DM basis) Used in Drylot</th>
<th>Drylot TMR&lt;sup&gt;z&lt;/sup&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>High grain</td>
<td>87.7</td>
</tr>
<tr>
<td>Dry Matter (%)</td>
<td>87.7</td>
</tr>
<tr>
<td>Net Energy Maintenance (Mcal/kg)</td>
<td>2.1</td>
</tr>
<tr>
<td>Net Energy Gain (Mcal/kg)</td>
<td>1.35</td>
</tr>
<tr>
<td>TDN (%)</td>
<td>81.4</td>
</tr>
<tr>
<td>Crude Protein (% DM)</td>
<td>5.1</td>
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<tr>
<td>UIP (% DM)</td>
<td>24.0</td>
</tr>
<tr>
<td>NDF (% DM)</td>
<td>24.1</td>
</tr>
<tr>
<td>ADF (% DM)</td>
<td>10.1</td>
</tr>
<tr>
<td>Ca (% DM)</td>
<td>0.62</td>
</tr>
<tr>
<td>P (% DM)</td>
<td>0.37</td>
</tr>
</tbody>
</table>

<sup>z</sup>Values were calculated based on nutrient analysis of individual components for the TMR diet which contains 77.63% whole shelled corn, 14.25% hay and 8.13% pellets on a dry matter basis. For cattle fed corn at 0.5% and 1% BW, no estimates of pasture intakes are available so nutrient composition of alfalfa and corn are presented separately.
3.1.2 Cattle and Carcass Processing

The remaining 45 steers from the pasture trial were shipped from New Liskeard to the Cargill Meat Solutions plant in Guelph, ON the night before their harvesting date. This included 10 steers from the alfalfa pasture management regimen with no corn supplementation, 12 from the alfalfa pasture management regimen with corn supplementation at 0.5% BW, 13 from the alfalfa pasture management regimen with corn supplementation based at 1% BW and 11 steers from the high grain regimen. All steers were processed on October 1, 2015. Cattle were harvested at Cargill Meat Solutions in accordance with commercial industry standards which include captive bolt stunning before exsanguination. The order of kill was recorded at the plant by recording the ear tag numbers of individual steers at the station on the kill line where dentition is checked to determine animal age before the hide is removed. Ear tag numbers were recorded to enable identification of individual carcasses once head, hide, organs and limbs were removed. Each carcass was identified by affixing several numbered parcel tags to the right half of the carcass before and immediately after entry into the chill cooler in order to identify individual carcasses for subsequent procurement of muscle cuts. One carcass from the corn supplemented at 1% regimen was held at Cargill for further testing and therefore was omitted from data collection. At approximately 3 days post-mortem (PM), carcasses were assessed by an experienced carcass evaluator from the Canadian Beef Grading Agency (CBGA) to determine quality and yield grades following the Livestock and Poultry Carcass Grading Regulations (Canada Agricultural Products Act, 1992). Carcass data were collected from a commercial vision image analysis based system used to evaluate the carcass at the grading site, the split interface of muscle, bone, and fat between the 12th/13th ribs. This included longissimus muscle area (LMA), longissimus intramuscular fat content or marbling, a measure of subcutaneous backfat (grade fat,
the minimum measure of subcutaneous fat in mm measured in the last quadrant over the
longissimus muscle at the 12\(^{th}\)/13\(^{th}\) rib interface), and the determination of estimated lean yield
for each steer. The CBGA also provided hot carcass weight (HCW), yield grade (YG), and
quality grade (QG) data for each animal. At 4 days PM, a primal rib section (3 x 4 with chine
bone on) from 44 of the test cattle were removed from the right side of each carcass by Cargill
workers. This rib section includes all the lean, fat and bones from ribs 6 to 12 with the
predominant muscle being the longissimus et thoracis. The primal rib sections were collected
from the line by University of Guelph staff before being packaged and shipped to the University
of Guelph Meat Laboratory for further analysis.

At 7 days PM, the primal rib sections were processed at the University of Guelph Meat
Laboratory. Rib sections were cut into 6 longissimus steaks starting at the 12\(^{th}\)/13\(^{th}\) rib interface.
All six steaks were dissected into lean, fat, and bone components (Lunt et al., 1985) with each
component being weighed with values recorded to determine carcass composition. Fat was
partitioned into body cavity fat, subcutaneous fat (backfat) and internal fat deposits with data
recorded. Boneless longissimus muscle steaks were allocated for the following purposes: Steak
1: determination of lean colour, pH, temperature, chemical fat content, fatty acid composition;
Steaks 2 and 3 were aged for 14 days and used for assessing palatability traits (juiciness,
tenderness, flavour attributes) by a trained taste panel; Steak 4: 7 day aged steak for Warner
Bratzler shear force (WBSF) and cook loss determinations; Steak 5: 14 day aged steaks for
WBSF and cook loss determinations; Steak 6: 21 day aged steaks for WBSF and cook loss
determinations. All steaks were individually identified by placing labelled parcel tags in the
plastic vacuum seal bag before the bags were sealed and placed in a \(\leq 4^\circ\)C cooler to be aged for
the appropriate amount of time. Once steaks were aged for the correct amount of time, they were placed in a freezer and frozen at -22°C.

3.1.3 Meat Quality Evaluation

Colour and pH

Steak 1 was processed to evaluate pH, temperature, colour, chemical fat and fatty acid data from each steer for the assessment of meat quality. Colour, temperature and pH data were collected on *longissimus* muscle steaks 1 on the same day the ribs were processed at the University of Guelph Meat Lab. Steak 1 was scraped using the flat side of a knife to rid it of any debris (extraneous fat particles and/or bone dust) and placed on brown butcher paper to bloom for a minimum of 30 minutes. This was performed in order to enhance colour development prior to lean colour evaluation. A Hanna spear-tipped pH electrode (Hanna Instruments, Mississauga, ON) with thermocouple connected to an Accumet A71 pH meter (Fisher Scientific, Toronto, ON) was used for pH and temperature determinations. Prior to the data measurements, the pH meter was placed in the processing room to equilibrate with room temperatures which cannot exceed 10°C and then was calibrated using buffer solutions at a pH of 4 and 7. In order to determine muscle pH, the electrode and thermocouple were inserted into three different locations in the muscle with all three measurements being recorded and then averaged for a final determination. Lean colour was measured using a hand held Konica Minolta Chroma Meter (Model CR-400; Konica Minolta Sensing Inc., Ramsey, NJ) with illuminant D65 and 0 degree viewing angle. Prior to the start of lean colour evaluation, the chroma meter was calibrated using
a white ceramic tile with the specifications of \( Y = 92.7, \ x = 0.3134, \) and \( y = 0.3196. \) The chroma colour meter was placed on the lean at six different locations for each steak with \( L^*, \ a^*, \) and \( b^* \) readings recorded for each location. The six readings would later be averaged to determine the final colour reading for each steak. Colour data were recorded in accordance with the Commission International de l’Eclairge (CIE, 1976) with \( L^*, \ a^*, \) and \( b^* \) measurements determined using the device. \( L^* \) is a measure of luminosity, \( a^* \) is a measure of the range from red to green and \( b^* \) is a measure of the range from yellow to blue. In regards to luminosity, a higher value is indicative of a lighter colour where as for \( a^* \) and \( b^* \), higher values indicate higher levels of red and yellow, respectively. The lower the values for \( a^* \) and \( b^* \) correspond to greater the levels of green and blue, respectively. Hue angle was determined as the distance between the true colour axis of CIE model and is measured in degrees using the following formula: 

\[
\text{Hue angle}_{ab} = \left( \frac{\arctan(b^*/a^*)}{180/\pi} \right)
\]  

(Jones, 1995; Kelly, 2015). As the Hue angle increases, colours of the visible spectrum (red, blue, green, yellow) are encountered (Jones, 1995). Chroma was determined as the saturation or intensity of a colour compared to a neutral grey of the same \( L^* \) value (Jones, 1995). Chroma is calculated using the colour variables \( a^* \) and \( b^* \) in the following formula: 

\[
\text{Chroma} = \left( a^{*2} + b^{*2} \right)^{0.5}
\]  

(Kelly, 2015). After colour, temperature and pH measurements were completed, the steaks were vacuum-sealed and frozen at -22°C to be later used for the determination of chemical intramuscular fat content and fatty acid profile as described later.

**Warner Bratzler Shear Force Determinations**

*Longissimus* muscle steaks designated for Warner Bratzler shear force (WBSF) evaluations were removed from the freezer and placed in a cooler at \( \leq 4^\circ C \) to thaw for
approximately 48 hours prior to cooking of the steaks. Steaks from each animal had previously been aged for 7, 14 or 21 days before being frozen. After a 48 hour thawing period, raw steaks were trimmed of excess fat before being weighed individually prior to grilling. A Garland Grill (ED-30B; Garland Commercial Ranges Ltd., Mississauga, ON) was preheated and sprayed with a light coat of cooking oil prior to the steaks being placed on the grill. Steaks were cooked in batches of no more than 6 at a time in a systematic approach to ensure no steak was misidentified. The raw steaks were weighed with values recorded and then the steaks were placed on the grill; a thermocouple was immediately inserted into the geometric center of the steak to determine the initial temperature of the steak. The thermocouple remained in the steak for the duration of the cooking period to track the internal temperature of the steak. Once steaks reached 40°C, they were flipped over. When an internal temperature of 74°C was achieved, steaks were removed promptly from the grill. Steaks were again weighed straight after being removed from the grill. Weight of the cooked steak and approximate cooking time were all recorded. After weighing the cooked steaks, they were bagged and placed into a cooler filled with ice water to end the cooking process. The temperature of the ice water was also monitored and more ice was added to the chest cooler as necessary. Steaks were removed from the chest cooler after no less than 15 minutes and were moved to a cooler ≤ 4°C and left for approximately 24 hours. Cooking losses were calculated using the ratio of the raw and cooked weights of the steak. The equation used was (Percent Cooking Loss = [(Raw weight - Cook weight)/raw weight] * 100).

Approximately 24 hours after the steaks were placed in the cooler post-cooking, they were removed from the cooler to be prepared for WBSF evaluation. The steaks were cored using a drill press (Mastercraft 10 inch drill press) mounted corer with a core diameter of 1.3 cm. Six to
eight cores were taken from each steak across its entirety in order to get an accurate representation of beef tenderness from across the muscle. All cores were taken along the grain of the muscle fibers. Once the steak was cored, the cores were cut perpendicular to the muscle fibres using a Warner-Bratzler blade attached to a TA-XT Plus Texture Analyzer (Texture Technologies Corp., Scarsdale, NY) with a blade speed of 3.3 mm/s. This machine measures the force required (in kg) to shear the sample in half across the muscle fibers. Using a custom pre-programmed macro in Sun Microsystems Texture Exponent program software for Windows XP, a peak shear force value was determined and recorded for each core sample. The shear force values were then averaged in order to determine a mean shear force value for each steak.

Chemical Determination of Intramuscular Fat Content

A chemical fat analysis was conducted on steak 1 which was aged for 7 days prior to freezing. Steaks were partially thawed before being cut into chunks, placed into aluminium trays and freeze dried. Once samples were freeze dried, they were ground in a coffee grinder to make a fine powder. The powder from each steak was weighed out into 1.5-1.7 g increments and placed into Ankom Xt4 bags (Ankom, Macedon, NY) that were then heat sealed. The bags were thoroughly dried in an electric Hotpack oven (Waterloo, Ont) at 100°C for 24 hours and re-weighed to record the moisture lost in the drying process. The dried bags were then placed into an Ankom XT20 Fat Analyzer (Ankom, Macedon, NY) that used petroleum ether extraction to determine the amount of intramuscular fat present in the muscle. The bags were weighed again after ether extraction to determine the amount of lipids lost. The percentage of chemical fat was
determined using the following formula; percentage chemical fat = ((Initial weight- Post 
extraction weight)/Initial weight)*100 (Kelly, 2015).

**Fatty Acid Determination**

Freeze dried muscle samples from *longissimus* muscle steak 1 were used for fatty acid 
determination. These freeze-dried samples were ground in a coffee grinder before being 
measured out into 16-mm x 125-mm screw cap Pyrex culture tubes. One mL of internal standard 
C 13:0 (0.5 mg mL\(^{-1}\) in methanol), 0.7 mL of 10 N KOH and 5.3 mL methanol were added to 
each tube. Tubes were capped, vortexed and incubated at 55 °C for 1.5 hours before being cooled 
below room temperature using cold tap water. 0.58 mL of 24 N H\(_2\)SO\(_4\) were then added to each 
tube before the tubes were vortexed a second time and placed into a 55°C water bath for 1.5 
hours. Tubes were cooled once again using cold tap water, and 3.0 mL of hexane were added to 
the tube prior to hand mixing and vortexing the tubes. All tubes were centrifuged for 5 minutes 
with the hexane layer transferred to a gas chromatograph vial that was stored at -20°C until 
further analysis with a gas chromatograph could be performed (Berthiaume, 2015). Fatty acid 
methyl esters were determined using a Shimadzu 2014 gas chromatograph equipped with a 
Shimadzu AOC-20 auto sampler and a 120-m x 0.25-mm x 0.25-µm BPX-70 capillary column 
(Mandel Scientific, Guelph, ON). The carrier gas used was helium with a 20:1 split ratio. The 
temperature of the injector was 250°C while the temperature of the flame ionization detector 
(FID) was 280°C. The initial temperature of the oven was 150°C, which was held for 1 minute 
before being increased to 180°C at a rate of 10°C minute\(^{-1}\), from 180°C to 200°C at 2°C minute\(^{-1}\) 
and from 200°C to 240°C at 1°C minute\(^{-1}\) where it was held for 2 minutes. Fatty acid methyl 
esters of each sample were identified by comparison of retention times to that of GC reference
standards (Nu-Check-Prep, Elysian, MN). Chromatograms were integrated using Shimadzu GC solutions software (Berthiaume, 2015). A legend of the fatty acids with common and chemical names is presented in Table 3.
<table>
<thead>
<tr>
<th>Short-Hand Name</th>
<th>Common Name</th>
<th>Chemical Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>C14:0</td>
<td>Myristic Acid</td>
<td>Tetradecanoic Acid</td>
</tr>
<tr>
<td>C16:0</td>
<td>Palmitic Acid</td>
<td>Hexadecanoic Acid</td>
</tr>
<tr>
<td>C16:1</td>
<td>Palmitoleic Acid</td>
<td>(Z)-9-hexadecanoic Acid</td>
</tr>
<tr>
<td>C17:0</td>
<td>Margaric Acid</td>
<td>Heptadecanoic Acid</td>
</tr>
<tr>
<td>C18:0</td>
<td>Stearic Acid</td>
<td>Octadecanoic Acid</td>
</tr>
<tr>
<td>C18:1tv</td>
<td>Trans-vaccenic Acid</td>
<td>(E)-11-octadecenoic Acid</td>
</tr>
<tr>
<td>C18:1o</td>
<td>Oleic Acid</td>
<td>9-octadecenoic Acid</td>
</tr>
<tr>
<td>C18:2</td>
<td>Linoleic Acid</td>
<td>All-cis-9,12-octadecadienoic Acid</td>
</tr>
<tr>
<td>C18:3g</td>
<td>Gamma-Linolenic Acid</td>
<td>All-cis-6,9,12 octadecadienoic Acid</td>
</tr>
<tr>
<td>C18:3a</td>
<td>Alpha-Linolenic Acid</td>
<td>All-cis-9,12,15 octadecadienoic Acid</td>
</tr>
<tr>
<td>C20:0</td>
<td>Arachidic Acid</td>
<td>Eicosanoic Acid</td>
</tr>
<tr>
<td>CLA cis-9,trans-11</td>
<td></td>
<td>Cis-9, trans-11 Conjugated Linoleic Acid</td>
</tr>
<tr>
<td>CLA trans-10,cis-2</td>
<td></td>
<td>Trans-10, cis-12 Conjugated Linoleic Acid</td>
</tr>
<tr>
<td>C20:1</td>
<td>Eicosenoic Acid</td>
<td>11-eicosenoic Acid</td>
</tr>
<tr>
<td>C20:2</td>
<td>Eicosadienoic Acid</td>
<td>All-cis-11,14 eicosenoic Acid</td>
</tr>
<tr>
<td>C20:3</td>
<td>Dihomo-gamma-linolenic Acid</td>
<td>All-cis-8,11,14- eicosatrienoic Acid</td>
</tr>
<tr>
<td>C20:4</td>
<td>Eicosatetraenoic Acid</td>
<td>All-cis-8,11,14,17-eicosatetraenoic Acid</td>
</tr>
<tr>
<td>C20:5</td>
<td>Eicosopentaenoic Acid</td>
<td>All-cis-5,8,11,14,17-eicosapentaenoic Acid</td>
</tr>
<tr>
<td>C20:6</td>
<td>Adrenic Acid</td>
<td>All-cis-7,10,13,16-docosatetraenoic Acid</td>
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<tr>
<td>C22:0</td>
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<td>Docosanoic Acid</td>
</tr>
<tr>
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<td>Docosopentaenoic Acid</td>
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<tr>
<td>C22:5</td>
<td>Docosohexaenoic Acid</td>
<td>All-cis-4,7,10,13,16,19-docosahexaenoic Acid</td>
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<tr>
<td>SFA</td>
<td>Saturated Fatty Acids</td>
<td></td>
</tr>
<tr>
<td>MUFA</td>
<td>Monounsaturated Fatty Acids</td>
<td></td>
</tr>
<tr>
<td>PUFA</td>
<td>Polyunsaturated Fatty Acids</td>
<td></td>
</tr>
<tr>
<td>n-6 fatty acids</td>
<td>Omega 6 Fatty Acids</td>
<td></td>
</tr>
<tr>
<td>n-3 fatty acids</td>
<td>Omega 3 Fatty Acids</td>
<td></td>
</tr>
<tr>
<td>n-6:n-3 ratio</td>
<td>Ratio of Omega 6 to Omega Fatty Acids</td>
<td></td>
</tr>
<tr>
<td>PUFA:SFA ratio</td>
<td>Ratio of Poly-unsaturated Fatty Acids to Saturated Fatty Acids</td>
<td></td>
</tr>
</tbody>
</table>

SFA, MUFA and PUFA consists of:
Saturated Fatty Acids = (C10:0 + C12:0 + C14:0 + C16:0 + C18:0 + C20:0 + C24:0);
Monounsaturated Fatty Acids = (C16:1 + C18:1 cis9 + C18:1 cis11 + C18:1 trans 11 + C20:1);
Polyunsaturated Fatty Acids = (C18:2n6 + C18:3n6 + C18:3n3 + C18:2 cis 9 trans 11 + C18:2 trans 10 cis 12 + C20:2n6 + C20:3n6 + C20:3n3 + C20:4n6 + C20:5n3 + C22:3n3 + C22:4n6 + C22:5n3 + C22:6n3).

n6 and n3 fatty acids are comprised of:
n6 fatty acids = (C18:2n6 + C18:3n6 + C20:2n6 + C20:3n6 + C20:4n6 + C22:4n6 + C22:2n6);
n3 fatty acids = (C18:3n3 + C20:5n3 + C20:5n3 + C22:5n3 + C22:6n3 + C20:3n3).
3.1.4 Trained Taste Panel Assessment of Beef Palatability Attributes

Screening of Panelists

A trained taste panel was used to determine important palatability attributes (tenderness, juiciness, flavour and off flavour) for longissimus steaks from the trial cattle. Steaks 2 and 3 were aged for 14 days and used in the taste panel. All requirements from the University of Guelph’s Research Ethics Board to involve human participants in research were met before the trained taste panel could be conducted. E-mails were sent out to graduate secretaries from several departments across the University of Guelph on September 30, 2015 for circulation to graduate students and interested employees. The e-mail asked for participants who had no food allergies, ate beef regularly and were available from 12 P.M. – 1 P.M. starting in October until late November, 2015. Students who replied to the e-mail were asked to complete two screening days and were directed to a discrete doodle poll to book a time to complete the screening process. The screening took place on October 15\textsuperscript{th} and 16\textsuperscript{th} 2015. Screening days were designed to test participant’s abilities to detect basic flavours, smells, and texture differences. A total of 32 participants completed both screening days. Screening day 1 consisted of four tests which examined basic olfactory function by identifying smells, detection of basic flavour intensities, detection of basic tastes, ranking of saltiness, and completing a paired comparison for softness.

For test 1, eight common odours (lemon juice, cinnamon, vinegar, coconut, vanilla extract, cloves, coffee and garlic) were prepared and placed in individual, non-transparent brown coloured capped containers. Cotton balls were placed in the top of each container to prevent the participants from looking into the container to identify the source of the odour. All bottles were
labelled with a random three digit code with all the same odours having the same code. Participants were asked to uncap the bottles and take a quick sniff before re-capping the bottles. They were instructed to then write down what the odour was or to describe what the odour reminded them of on a test sheet. There were eight identical bottles placed in front of each participant so that all eight odours were given to the participants at once. If they could not identify the odour after smelling the bottle twice they were asked to recap the bottle and to try again later. This measure was taken to prevent fatiguing the sensory capabilities of the nose. The odour test was included as the olfactory senses play a crucial role in a person’s ability to perceive flavour. Not having a full range of odour identification can limit a participant’s tasting experience. A panelist with limited olfactory function can have a different perception of flavour than a panelist who has full olfactory function.

Test 2 was a basic taste test. Participants were asked to sample five colourless solutions and identify which of the four basic tastes were in the solution; bitter, sour, sweet, salty or no flavour (water). Each colourless and odourless solution was then presented to the panelist in a cup labelled with a random three digit code. Each cup contained the same amount of solution (approximately 150 ml). Participants were only provided with water to cleanse their palate and were instructed to cleanse their palate between each solution. Participants were asked to sip each solution and then write down on the test sheet the three digit code associated with the specific basic taste attribute.

Test 3 was a ranking test which assessed the ability of each participant to rank the saltiness of a solution. Filtered water was mixed in clean juice jugs with increasing amounts of salt, producing odourless and colourless salt solutions that varied in intensity. These different salt solutions were presented to the panelists in random order in opaque plastic cups labelled with
random three digit codes. Each cup contained the same amount of solution (approximately 150 ml). The participants were asked to sample each of the solutions and rank in order the four salt solutions from least intense (1) to most intense (4) salt flavour. Water was provided and the participants were instructed to cleanse their pallets between tasting each salt solution.

Test 4 was a paired comparison test to evaluate two types of white coloured cheese; cheddar and mozzarella. This test was conducted in order to evaluate the participant’s ability to differentiate compression needed to bite through a piece of food. The cheese was presented to the participants as approximately 1 cm$^2$ cubes in small plastic serving cups labeled with three digit codes. Participants were asked to sample each of the cheeses and identify which of the samples was the softer sample. Participants were also asked to cleanse their pallet with water between samples. Cheese samples were kept in the fridge until the time of testing in order to eliminate any temperature effects on the properties of the cheeses.

After completion of the tests on the first day, score sheets from each panelist were collected and marked.

The second day of screening consisted of five different tests.

The first test on the second day of screening was another ranking test to evaluate the sour taste of solutions. Filtered water was mixed with citric acid in clean juice jugs in increasing amounts to produce odourless and colourless solutions that varied in intensity for sour flavour. Participants were presented with four odourless and colourless sour solutions in opaque plastic cups labelled with random three digit codes. They were then asked to sip the solutions, and rank the solutions from the most sour (1) to the least sour (4). Participants were also instructed to cleanse their pallets with water between each solution. Ranking the solutions from most to least
sour also allowed the researcher to determine how well panelists followed instructions as the solutions were ranked in opposite order on the first day of screening when participants were ranking salt solutions.

Test two on the second day of screening was a paired comparison test to evaluate the texture of regular sized marshmallows based on freshness. Marshmallows were cut in half and left out in ambient air temperatures for approximately 24 hours the day before testing in order to harden the marshmallows. Participants were given the two samples of marshmallows (soft and hard) in small serving cups labelled with a random three digit code. Each participant received half a marshmallow in the serving cup. Participants were asked to try both samples and identify which sample was harder. Participants were also asked to cleanse their pallets with water between each sample.

Test three on the second day of testing was a triangle test. Participants were given three identical pieces of meat in individual small plastic serving cups labelled with a random three digit code. Two of the pieces of meat were from *semitendinosus* steak with a high WBSF value, indicative of tough meat, while the third piece of meat was from a *psoas* major steak with a low WBSF value which indicated tender meat. Participants were asked to taste the three samples and identify which of the three samples was different in tenderness.

The fourth test on the second day of screening was another paired comparison test to evaluate differences in chewy texture. Panelists were presented with identical, halved chocolate chip cookies in serving cups labelled with a random three digit code. Both types of cookies were Chips Ahoy! (Christie Brown & Co., Mississauga, ON) chocolate chip cookies, with one being
of the chewy variety and one being the regular variety. Participants had to correctly identify which of the two cookie samples was more chewy.

The fifth test on the second day of screening was another paired comparison test. This test required participants to evaluate two different brands of hamburgers and choose which burger was juicier. The difference in juiciness was due to varying fat content in the burgers. The burgers were cut into identical cubes and presented to the participants in small serving cups labelled with a three digit code. The participants were asked to try the President’s Choice Blue Menu Lean Beef Burgers (Loblaws Inc., Brampton, ON) containing 22% fat and the Butcher’s Choice Original Beef Burgers (Loblaws Inc., Toronto, ON) containing 46% fat, and identify which burger piece was juicier.

The second day of screening focused on texture profiles that would be closer to what trained panelists would be expected to encounter during the actual taste panel. Therefore more weight was given to the second day of screening for assessing the participants for selection to be on the taste panel. Any participant that answered a question wrong regarding the texture questions was excluded from being considered as a panelist. A total of 32 people completed both days of screening.

In addition to the two days of screening, participants were asked to fill out a three page questionnaire. The questionnaire helped the participants and researcher assess how available they were to participate in the panel, if they could commit to the time requirement for the panel, how much meat they ate and how much of it was red meat, their ratings of their own tasting and olfactory abilities and to describe flavours associated with eating beef. Participants were also asked about their preferred degree of doneness when eating steak, as all steaks were cooked to a
uniform 72°C during the taste panel. If participants did not enjoy steak at this level of doneness, then they were not eligible to participate in the trained panel. Participants were paid $12/day for their participation in the screening process.

Training of the Panelists for the Taste Panel

After the two days of screening were completed, 11 individuals were identified as suitable for the taste panel and were asked to participate in the panel. One panelist dropped out before training began. Training and testing took place in the Human Nutraceuticals Research Unit located at the University of Guelph.

Panelists were trained for a total of 2 weeks on what each palatability attribute was and where it should be placed on a line scale described in Appendix 1. Training sessions were approximately 30 minutes long and ran daily from Monday to Thursday. Structure for training was based on teaching proper evaluation of each palatability attribute that was used to evaluate the beef samples and the definition for each attribute. Training was developed based on the FOOD*3700 Sensory Evaluation of Foods Course offered by the University of Guelph. The palatability attributes evaluated were: softness, tenderness, initial juiciness, flavour, off flavour, chewiness, overall juiciness and rate of breakdown. Panelists were instructed during training and evaluations to place the steak cube in their mouth with the grill marks not touching their teeth for better attribute determination. Each panelist was given 2 steak cubes from each steak throughout the training and evaluation periods.

The palatability attributes and instructions for the panelists are defined as follows:
**Softness**: The force needed to break apart the sample with their teeth.

Panelists were asked to evaluate this attribute on the first chew of cube 1 and place their determinations on the 10 cm line scale with the anchors being 1 = firm and 10 = soft.

**Tenderness**: Overall impression of the breakdown of the product which includes a combination of cohesiveness, chewiness, softness and juiciness (Peachey, Purchas and Duizer, 2002).

Panelists were asked to evaluate tenderness on the third chew of the first cube.

Cohesiveness was explained as how well the steak cube sticks together when being chewed. The other attributes that make up tenderness are explained below. The panelists were instructed to place their determinations for tenderness for each sample on the 10 cm line scale with 1 = tough and 10 = tender.

**Initial Juiciness**: How much juice is expressed as you bite down on the sample when it is placed between your back molars, excluding saliva.

This attribute was evaluated on the fifth chew. The line scale ranged from 1 = small amounts of juice to 10 = extensive amounts of juice expressed.

**Flavour**: The amount of full meaty flavour present in the sample.

The panelists were asked to evaluate the flavour on the 8th chew of the first cube.

Appendix 2 describes the lexicon used to explain the definition of beef flavour to panelists. Flavour was rated on a 10 cm scale with 1 = weak beef flavour 10 = intense beef flavour.

**Chewiness**: How many chews does it take to prepare the sample for swallowing.
Panelists were asked to evaluate the chewiness of each sample on the 9th chew of the second beef cube. Panelists were instructed to write down their evaluations on the 10 cm line scale with 1 = not chewy and 10 = chewy.

**Overall Juiciness:** How much juice is expressed over the entire chewing process, excluding saliva.

Panelists were asked to evaluate overall juiciness at 10 chews of the second beef cube and mark down where the sample ranked on the 10 cm line scale with 1 = small amounts of juice to 10 = extensive amounts of juice expressed.

**Rate of breakdown:** The rate at which the sample disintegrates during the mastication process in preparation for swallowing.

Panelists were asked to evaluate rate of breakdown at the end of their second cube of steak on a 10 cm line scale. The anchors on the scale were 1 = slow and 10 = rapid.

**Off Flavours:** Flavours not associated with a pleasant beef eating experience.

Panelists were asked to rate the amount of off flavour in the overall sample on a 10 cm line scale with the scale being 0 = no off flavours 10 = major off flavours; major defect in the steak. A full breakdown of off flavour rankings is presented in Appendix 3.

Panelists were trained on two palatability attributes per day. To start the training, the panellists were asked to describe the attributes in their own words before they were given the definition of each term (as stated above) and were given a brief explanation about what the anchors meant for each trait. Panelists were then given samples of beef to rate on a 10 cm line scale. The line scale contained the same anchors that were discussed at the start of the session.
The panellist’s evaluations of the sample were marked against a trained beef technician’s evaluations of the same cuts of meat. The beef used for the training was meant to represent the anchors on the line scale as well as a sample which was more conservative and would be closer to what the panelists would encounter during the panel. Appendix 4 includes a description of the full list of beef cuts used during training. Feedback was given to the panelists the next day and they were able to compare their rankings with ratings from the beef technician.

For the second week of training, panelists were moved into individual sensory testing booths. The booths were located in an enclosed room with positive air pressure. Each booth was equipped with a red light to mask appearance differences in the steaks. Each booth also had a computer running the program Compusense 5 (Compusense INC, Guelph, ON). This is a program specifically designed for sensory evaluation and sensory analysis of food products. The program generated 10 cm line scales with the same anchors used during the first week of training for the panelists to evaluate their training samples. During this second week of training, feedback was given immediately by Compusense 5 to the panelists showing a range of where their evaluations should fall. The range was created by having the beef technician sample and evaluate all of the beef cuts before the panelists arrived to the session. The beef technician’s evaluation of where the beef should fall on the line scale was then expanded by 1.5 cm on each side to create a range of 3 cm. This 3 cm range appeared on the screen after the panelists had inputted their evaluation to immediately show the panelists where their evaluations of the sample should be on the line scale.

An analysis of variance test was run by the Compusense 5 program on the results from the panelists to show how effective their training was. Near the end of the second week of
training, it was found the panelists were assessing palatability attributes within an acceptable standard deviation level (below 2) and the panel could proceed.

A total of forty-four, 14 day aged *longissimus* steaks were evaluated by the panel including 10 steaks from cattle on the high grain management regimen, 10 steaks from the pastured cattle with no grain supplementation regimen, 12 steaks from the pastured cattle fed corn at 0.5% BW and 11 steaks from pastured cattle fed corn at 1.0% BW. All steaks were from different animals and panelists evaluated no more than six steaks per day. The steaks were randomized by management regimen and 2 cubes from each steak were presented to the panelists in opaque cups with lids and labelled with three digit codes. The Compusense 5 program randomized the order each panelist would receive each sample. The panel took place in the same booths used during the second week of panelist training in the Human Nutraceuticals Research Unit.

The steaks were prepared by removing them from the freezer and thawing in a cooler at ≤ 4°C for approximately 48 hours prior to the steak being prepared for the taste panel. Steaks were cooked on a grooved double sided grill (Silesia CG2-C Double Grooved High Speed Contact Grill) (Silesia Grill Machines, Oakville, ON) at the University of Guelph Meat Laboratory. A non-flavoured vegetable cooking shortening was used to prevent the steaks from sticking to the grill. The Silesia grill was used instead of the Garland grill previously used for shear force evaluations. The Garland grill was not used as it tends to fry the meat and uses a flavoured cooking oil in its cooking process. There is concern that the frying process and the use of flavoured cooking oil may influence the panelist’s evaluation of the palatability attributes. Steaks were trimmed of external fat and connective tissue before a type K thermocouple (Fisher Scientific, Toronto, ON) was inserted into the geometric center of the steak while it was cooked.
in order to monitor steak temperature during cooking. Steaks were cooked until an internal
temperature of 40°C was reached before they were flipped over to continue cooking. When the
internal temperature of the steak reached 72°C, the steak was removed from the grill and placed
in glass Pyrex containers. The glass containers were then placed into a chest cooler to stay warm
until they could be transported to the Human Nutraceutical Research Unit located next to the
Animal & Poultry Science Building where the steaks were cooked. During training, aluminum
trays were used to transport the steaks. This was discontinued as the aluminum trays allowed the
steaks to continue to cook during transport of the steaks and added a slight metallic flavour to the
steaks. To replace the aluminum containers, glass Tupperware baking dishes were used for the
duration of the taste panel.

Once in the kitchen at the Human Nutraceutical Research Unit, steaks were cut into
uniform cubes (1 cm x 1 cm x 2.5 cm in dimension) and 2 cubes were placed into opaque cups
with lids that were labelled with a random three digit code. Any cubes containing gristle or large
amounts of fat were not used for the taste panel. The prepared cubes were then placed by the
booths until serving time which was no longer than 30 minutes from the time the steaks were cut
into cubes. Panelists had to log into the Compusense 5 program using their individual
identification number, and the program then randomly assigned samples to the panelists. Each
panelist was presented with one sample at a time. Unsalted soda crackers and bottled water were
given to the panelist to cleanse their pallets between each sample. The Compusense 5 program
tracked all the responses from the panelists and compiled them in the program.

Once panelists had completed the taste panel for the day, Compusense 5 would compile
the results into an Excel spreadsheet. The spreadsheet from the program was transferred to the
researcher’s computer and the results were statistically analysed.
3.1.5 Statistical Methods

All production, carcass and meat quality, fatty acid, and taste panel data were analyzed using a least means squares model within the PROC MIXED procedure of SAS 9.4 Foundation Software (SAS Institute Inc., 2013) using a completely randomized design based on the four management regimens evaluated. Due to lack of paddock replication in the pasture management regimens, no random effects could be used in the model. Individual animal was used as the experimental unit. Start of trial body weight was used as a covariate for growth performance data; grade fat (mm) from Cargill camera data was used as a covariate for specific carcass trait data. Intramuscular fat content was used as a covariate for sensory attribute data. Covariates were kept in the final model when significant at P < 0.05. Statistical analysis of the carcass data included converting longissimus muscle area data into cm²/100 kg HCW and converting current quality grades into a numeric form (A = 4, AA = 3, AAA = 2, Prime = 1). In order to determine yields of dissectible lean, fat and bone as a percent of rib weight, dissected rib component weights (lean, fat and bone) were divided by total rib weight. In the case of fat partitioning data, subcutaneous, intermuscular and body cavity fat deposits were dissected and weighed individually to determine the percentage of each as well as to determine the overall percentage of fat in the carcass.

Statistical analysis of taste panel data was conducted using a modification to the previously described model for analyzing growth performance. Panelist was included in the model as a fixed effect while intramuscular fat content was run in the model as a covariate for taste panel data and was kept in the model when a significance level of P < 0.05 was reached. Again due to lack of paddock replication, a random statement could not be used.
The effects of post-mortem aging on Warner-Bratzler shear force evaluations and cooking losses were analysed using a model that included the main effects of management regimen, days of post-mortem aging and the management regimen x post-mortem aging interaction. Intramuscular fat was included as a covariate and was kept in the model when it reached a significance level of P < 0.05.

Orthogonal contrasts were used to separate means from the different management regimens (Table 4) (Steele and Torrie, 1960). Orthogonal contrasts included:

1) The comparison of cattle fed no corn on pasture vs. all cattle fed corn (corn supplementation on pasture or high grain diet),

2) The comparison of cattle supplemented on pasture with corn at 0.5% BW vs. the average of cattle supplemented on pasture with corn at 1% BW and cattle fed the high grain diet,

3) The comparison of cattle supplemented on pasture with corn at 1% BW vs. cattle fed the high grain diet.

Linear and quadratic functions were also run on the pasture treatments to examine if the amount of corn supplemented on pasture had linear or quadratic effects on collected data.

Orthogonal contrasts were also used for means separation of post-mortem aging (7, 14 or 21 days) on shear force and cooking loss data. Orthogonal contrasts (Table 5) included:

1) The comparison of 7 day aged steaks vs. the average of 14 and 21 day aged steaks,

2) The comparison of 14 day aged steaks vs. 21 day aged steaks.
### Table 4. Contrast Coefficients Used for Least Square Means Separation for Management Regimens

<table>
<thead>
<tr>
<th>Management Regimens</th>
<th>Amount of Corn Supplemented on Pasture (based on % BW on as-fed Basis)</th>
<th>Drylot</th>
</tr>
</thead>
<tbody>
<tr>
<td>Contrast</td>
<td>0%</td>
<td>0.5%</td>
</tr>
<tr>
<td>1</td>
<td>3</td>
<td>-1</td>
</tr>
<tr>
<td>2</td>
<td>0</td>
<td>2</td>
</tr>
<tr>
<td>3</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

Contrast 1 = cattle fed no corn on pasture vs. cattle fed corn (on pasture or in drylot).
Contrast 2 = pastured cattle fed corn at 0.5% BW vs. cattle fed high corn (pastured cattle fed at 1% BW and cattle in drylot).
Contrast 3 = pastured cattle fed corn at 1% BW vs. drylot cattle fed a high grain diet.
Table 5. Contrast Coefficients Used for Least Square Means Separation for Postmortem Days of Ageing

<table>
<thead>
<tr>
<th>Contrasts</th>
<th>7</th>
<th>14</th>
<th>21</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2</td>
<td>-1</td>
<td>-1</td>
</tr>
<tr>
<td>2</td>
<td>0</td>
<td>1</td>
<td>-1</td>
</tr>
</tbody>
</table>

Contrast 1 = 7 day aged *longissimus* steaks vs. 14 and 21 day aged *longissimus* steaks.
Contrast 2 = 14 days aged *longissimus* steaks vs. 21 day aged *longissimus* steaks.
3.2 Results and Discussion

3.2.1 Diets

The nutritional composition of the four diets is presented in Table 6 while the pasture nutritional composition is presented in Table 7.

The crude protein (CP) concentrations were consistent across the study for cattle fed the high concentrate diet due to the use of stored feed ingredients (corn and hay) as well as a commercially prepared 40% protein supplement (Appendix 5). However, CP levels in the pasture regimens fluctuated by 8.8% throughout the grazing season (Table 7). Types of forage available and stage of growth can be attributed to the change in CP content. Grasses are known to contain less CP than legumes while alfalfa that is grazed regularly and kept at a more immature stage of growth has higher protein levels than mature alfalfa (Schlegel et al., 2000). In a previous study conducted by Yari et al. (2012), CP content in alfalfa increased when the plant was kept in a vegetative state, which would agree with the current study. The lowest numerical CP content for the pastures occurred in July. This drop in CP content was not surprising as the alfalfa that was grazed in July had flowered and was more mature than the alfalfa grazed for the remainder of the trial.

The maturity of the plants was evaluated by visual inspection; this is further supported by the increased levels of NDF, ADF and ADL present in the chemical analysis of the July samples as compared to samples collected during the other months of the study. As plants mature, NDF, ADF and ADL concentrations increase due to the increase in fiber and the fiber components. There is a negative relationship between the amount of lignin in the plant (ADL) and feed
degradation rate. The cell wall portion limits feed intake and digestibility as NDF is negatively related to intake potential of a forage and ADF (along with ADL) is negatively related to digestibility (Buxton, 1996). In July the NDF, ADF and ADL values were all numerically higher than any other month during the trial.

The net energy maintenance and gain values for the pasture also differed slightly between pasture regimens. The experimental protocol attempted to minimize these differences in pasture nutrient concentrations by rotating the pastured management regimens through different pastures so no pasture regimen was in the same pasture for more than 2 weeks. The differences in net energy values may be caused by differing amounts/species of grass available in each pasture. The net energy maintenance never differed more than 0.14 Mcal/kg between the pasture treatments in any given month.

Undegradable intake protein (UIP) differed by 4.9% across pasture regimens, throughout the duration of the experiment. There is some evidence that more mature forages contain greater amounts of UIP than more immature forages which may be an explanation for the variation in UIP content of the pastures for the current study (Merchen and Bourquin, 1994).
<table>
<thead>
<tr>
<th>Management Regimen</th>
<th>Amount of Corn Supplemented on Pasture managed Cattle (% BW as-fed Basis)</th>
<th>Drylot</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0%</td>
<td>0.5%</td>
</tr>
<tr>
<td>Dry Matter (%)</td>
<td>Alfalfa 25.0</td>
<td>Alfalfa 25.3</td>
</tr>
<tr>
<td>Net Energy Gain (Mcal/kg)</td>
<td>0.82</td>
<td>0.83</td>
</tr>
<tr>
<td>Net Energy Maintenance (Mcal/kg)</td>
<td>1.54</td>
<td>1.56</td>
</tr>
<tr>
<td>TDN (%)</td>
<td>61.9</td>
<td>63.7</td>
</tr>
<tr>
<td>Crude Protein (% DM)</td>
<td>21.6</td>
<td>21.7</td>
</tr>
<tr>
<td>UIP (% DM)</td>
<td>22.9</td>
<td>23.2</td>
</tr>
<tr>
<td>NDF (% DM)‡</td>
<td>39.0</td>
<td>38.1</td>
</tr>
<tr>
<td>ADF (% DM)‡</td>
<td>37.3</td>
<td>36.4</td>
</tr>
<tr>
<td>Ca (% DM)</td>
<td>1.60</td>
<td>1.61</td>
</tr>
<tr>
<td>P (% DM)</td>
<td>0.28</td>
<td>0.28</td>
</tr>
</tbody>
</table>

*DM content determined by oven drying at University of Guelph.

†Values were calculated based on nutrient analysis of individual components for the TMR diet which contains 77.63% whole shelled corn, 14.25% hay and 8.13% pellets on a dry matter basis. For cattle fed corn at 0.5% and 1% BW, no estimates of pasture intakes are available so nutrient composition of alfalfa and corn are presented separately.

‡NDF and ADF for alfalfa determined at UQAT.
<table>
<thead>
<tr>
<th>Management Regimen(^y)</th>
<th>0%</th>
<th>0.5%</th>
<th>1%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Amount of Corn Supplemented on Pasture (% BW on an as-fed Basis)</td>
<td>June</td>
<td>July</td>
<td>August</td>
</tr>
<tr>
<td>Ash (% DM)</td>
<td>8.5</td>
<td>8.4</td>
<td>9.6</td>
</tr>
<tr>
<td>NE Maintenance (Mcal/kg(^z))(DM)</td>
<td>1.46</td>
<td>1.51</td>
<td>1.53</td>
</tr>
<tr>
<td>NE Gain (Mcal/kg(^w))(DM)</td>
<td>0.79</td>
<td>0.79</td>
<td>0.89</td>
</tr>
<tr>
<td>NDF (% DM)</td>
<td>39.4</td>
<td>41.8</td>
<td>38.6</td>
</tr>
<tr>
<td>ADF (% DM)</td>
<td>36.7</td>
<td>40.1</td>
<td>35.1</td>
</tr>
<tr>
<td>ADL (% DM)</td>
<td>8.4</td>
<td>10.0</td>
<td>8.2</td>
</tr>
<tr>
<td>Crude Protein (% DM)</td>
<td>20.0</td>
<td>20.0</td>
<td>25.5</td>
</tr>
<tr>
<td>UIP (% DM)</td>
<td>22.5</td>
<td>24.1</td>
<td>23.6</td>
</tr>
<tr>
<td>Ca (% DM)</td>
<td>1.47</td>
<td>1.62</td>
<td>1.93</td>
</tr>
<tr>
<td>P (% DM)</td>
<td>0.28</td>
<td>0.26</td>
<td>0.31</td>
</tr>
</tbody>
</table>

\(^z\)Sampling Date: Pastures were sampled weekly in 4 places using a 100 cm x 30 cm quadrat. These samples were then weighed, dried and ground to pass through 1 mm screen before being composited into monthly samples.

\(^y\)Management Regimen includes: 0% Corn = cattle on alfalfa pasture only and were not fed corn; 0.5% Corn = cattle on alfalfa pasture fed whole grain corn at 0.5% BW (as-fed basis); 1% Corn = cattle on alfalfa pasture fed whole corn grain at 1% BW (as-fed basis); High Grain = cattle fed high grain diet in drylot.

\(^x\)Calculation used by A&L to determine NE Gain: 2.205 x (0.01318 x % Total Digestible Nutrients - 0.132).

\(^w\)Calculation used by A&L to determine NE Maintenance: 2.205 x (0.01318 x % Total Digestible Nutrients - 0.459).
3.2.2 Growth performance

Management regimen effects on growth performance are presented in Table 8. There were no differences (P > 0.56) in starting weight (447 ± 37 kg) of the steers across management regimens due to cattle allocation which was based to have similar body weights across management regimens at the start of trial.

Start of trial body weight (SOTBW) was used as a covariate in the statistical analysis of growth performance data to account for variation in body weights at the start of the trial and was kept in the model when a significance of P < 0.05 was reached (Table 8). There were management regimen differences for final body weight, total gain and average daily gain (P < 0.0001). Final body weight, total gain and ADG increased with the addition of corn to the diet (P < 0.0001; Contrast 1). Steers fed corn at 0.5% BW had lower final body weights and gains than steers fed greater amounts of corn (P < 0.0001; Contrast 2). Steers fed the high grain diet had greater final body weights and gains than steers fed corn at 1% BW (P < 0.0001; Contrast 3). As corn was increased in the pasture regimens, final body weight (P < 0.02; Linear contrast) and gains linearly increased (P < 0.001; Linear contrast). Roberts et al. (2009) found that supplementing steers on rye grass pasture with whole shelled corn also resulted in a linear increase in ADG as the amount of corn in diet increased with gains ranging from 0.95 kg to 1.27 kg per day. These results are comparable to the results achieved in the current study of 1.13 kg to 1.28 kg per day respectively. Pavan and Duckett (2008) found that supplementing tall fescue pasture with either corn oil or soybean hulls or corn grain also increased ADG from 0.76 kg to 1 kg per day. The added weight gained from corn supplementation is attributed to the increased energy value of corn versus pasture. Corn grain in the current study contained approximately 0.65 more Mcal/kg of net energy gain than the alfalfa pasture. In past studies, gains of 0.93 to 1.2
kg/d have been reported for cattle grazing alfalfa with no corn supplementation (Herman et al., 2002; Lauriault et al., 2005; Butler et al., 2012; Shepherd, 2013). These values are greater than the 0.88 kg/d ADG in the present study for cattle grazing alfalfa only. When comparing Shepherd (2013) and the current study, the difference in ADG of steers grazing alfalfa only (1.14 vs. 0.88 kg/day respectively) could be attributed to higher levels of ADF and lower net energy gain for the alfalfa pasture in the current study. The increase in the ADG for the steers supplemented with corn on pasture is due to the increase in starch and energy that the corn grain provides over that of the alfalfa pasture alone. The increase in dietary energy provided by the corn not only increased the gains in the pasture regimens but provided the current study with high gains when fed in the high concentrate ration to the dry lot regimen cattle. Steers on the high grain ration had the greatest ADG for all management regimens in the current study. Cruz et al. (2013) reported gains of 1.34 kg/d in steers fed an 80% cracked corn diet while Shepherd (2013) fed a high grain diet similar to the one provided in the current study where steers gained 1.83 kg/d. Drylot cattle in the present study gained 1.73 kg/d which is comparable to the results reported by Shepherd (2013). Cattle in the two studies consumed similar amounts of feed with DMI of 11.6 kg/d as compared to DMI of 11.2 kg/d reported by Shepherd (2013) for cattle fed a similar high concentrate diet as in the present study. The gain to feed of 0.15 for cattle fed the high grain diet in the current study is similar to the gain to feed of 0.16 calculated from the data of Shepherd (2013).
Table 8. Management Regimen Effects on Growth Performance for Cattle Fed in Drylot or on Pasture

<table>
<thead>
<tr>
<th>Management Regimen</th>
<th>Amount of Corn Supplemented on Pasture (% BW as-fed Basis)</th>
<th>Drylot</th>
<th>High Grain</th>
<th>SE</th>
<th>P-value</th>
<th>P-value for Contrasts</th>
</tr>
</thead>
<tbody>
<tr>
<td>Trait</td>
<td>Covariate</td>
<td>0%</td>
<td>0.5%</td>
<td>1%</td>
<td>SE</td>
<td>1</td>
</tr>
<tr>
<td>Starting Body Weight (kg)</td>
<td>N/A</td>
<td>448.5</td>
<td>451.7</td>
<td>453.2</td>
<td>434.1</td>
<td>0.569</td>
</tr>
<tr>
<td>Final Body Weight (kg)</td>
<td>SOTBW</td>
<td>544.5</td>
<td>572.7</td>
<td>589.1</td>
<td>638.5</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Total Gain (kg)</td>
<td>N/A</td>
<td>97.5</td>
<td>125.7</td>
<td>142.1</td>
<td>191.5</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>ADG (kg)</td>
<td>N/A</td>
<td>0.88</td>
<td>1.13</td>
<td>1.28</td>
<td>1.73</td>
<td>&lt;0.0001</td>
</tr>
</tbody>
</table>

Management Regimen includes: 0% Corn = cattle on alfalfa pasture only and were not fed corn; 0.5% Corn = cattle on alfalfa pasture fed whole grain corn at 0.5% BW (as-fed basis); 1% Corn = cattle on alfalfa pasture fed whole corn grain at 1% BW (as-fed basis); High Grain = cattle fed high grain diet in drylot.

Contrasts include: 1 = cattle fed no corn on pasture vs. cattle fed corn (on pasture or in drylot); 2 = corn fed at 0.5% BW vs. cattle fed greater amounts of corn; 3 = pastured cattle fed corn at 1% BW vs. drylot cattle fed a high grain diet; Linear (L) and Quadratic (Q) examines the linear and quadratic effects respectively of increasing the amount of corn offered on pasture.

Traits include: Starting and Final Body Weights (body weights of steers at the start and end of trial as measured on two consecutive days), Total Gain (body weight gained in kg over the 111 day trial), Average Daily Gain (average weight gained per day in kg), Dry Matter Intake (amount of dry matter steers on high grain diet consumed over the course of the trial), Gain to Feed (the ratio of weight gained in kg compared to the amount of dry matter steers consumed while on high grain diet).

Body weight at the start of the trial (SOTBW) was included in the model as a covariate and was retained in the final model when significant at P < 0.05. If the covariate was not found to be significant, the cell is labeled N/A for not applicable or not appropriate for the specific trait.
3.2.3 Carcass Traits

Management regimen effects on carcass traits are presented in Table 9. Grade fat was used as a covariate in the statistical analysis for most carcass traits to account for differing amounts of back fat across management regimens and was kept in the model when the covariate was significant at $P < 0.05$ (Table 9).

There were significant differences in hot carcass weight (HCW) for the steers across management regimens ($P < 0.02$). HCW was greater with the addition of corn to the diet ($P < 0.02$; Contrast 1). As the amount of corn in the diet increased, the effect on HCW lessened and providing corn at greater than 0.5% BW only tended to increase HCW ($P < 0.06$; Contrast 2). Providing corn at 1% BW to pastured cattle did not affect HCW when compared to steers fed the high grain diet ($P > 0.15$; Contrast 3). Roberts et al. (2009) showed that as the amount of corn supplementation on ryegrass pasture increased, the effect on HCW slowed to the point where there was no significant differences found in HCW between high concentrate fed cattle, and cattle supplemented with corn at 2% and 1.5% BW which agrees with current findings. There was a linear trend for HCW to increase as the amount of corn supplemented on pasture increased ($P = 0.07$; Linear contrast). This agrees with previous studies which found that HCW increased with increasing supplementation on pasture (Lorenzen et al., 2007; Faucitano et al., 2008; Pavan and Duckett., 2008; Roberts et al., 2009; Garmyn et al., 2010). Based on results from the current study, producers may be able to supplement corn on pasture without sacrificing HCW values when compared to HCW for cattle fed high grain diets.

Grade fat and longissimus muscle area (LMA) values were similar across management regimens ($P > 0.32$) regardless if grain was supplemented on pasture or if cattle were fed a high
grain diet. The current findings for grade fat (the amount of back fat in the last quadrant over the
*longissimus*) contradicts Duynisveld et al. (2006), where as supplementation on pasture
decreased, so did the amount of grade fat (back fat). Bidner et al. (1981) found steers that were
supplemented with corn grain on bermuda grass pasture contained greater amounts of back fat
than steers who were fed a high concentrate diet for 70 days prior to slaughter. In the current
study, cattle were on feed for 111 days and the similar amounts of grade fat across management
regimen may be due to the use of Angus genetics and their ability to deposit fat when fed high
quality pasture with (and without) grain supplementation. Another explanation is limited
accuracy of the camera used at the Cargill plant to measure grade fat at the grading site. This
could not be prevented as researchers from the University of Guelph were not allowed access
to the carcass while hanging to take our own carcass measurements at the packing plant. In
addition, taking carcass measures on rib sections would also be inaccurate due to handling of the
rib sections and the effects of transport. Previous studies (Bidner et al., 1981; McLaughrey et al.,
1999; Garmyn et al., 2010) concur with the current study that management regimen has no effect
on LMA but there is a slight discrepancy as Lorenzen et al. (2007) found that cattle finished on
high grain rations had larger LMA and were more muscular than cattle finished on pasture. Time
of slaughter may have affected the LMA in these past studies. Garmyn et al. (2010) and
McLaughrey et al. (1999) and the current study slaughtered all cattle on the same day. In contrast,
the Lorenzen et al. (2007) study slaughtered cattle only when they reached a target BW of 500 kg
with a backfat thickness of 0.76 cm. However some pastured cattle in the Lorenzen et al. (2007)
study were sent for slaughter before these targets were met due to a shortage of available pasture
caused by drought. These drought conditions may have lead to pastured cattle developing smaller
LMA due to lack of energy.
Adjusted *longissimus* muscle area (cm²/100 kg HCW) differed across management regimens (P < 0.03). Providing corn at greater than 0.5% BW decreased adjusted LMA (P = 0.003; Contrast 2). This is due in part to the fact that the 1% supplemented steers and the high concentrate steers had similar HCW and LMA where the 0.5% supplemented steers had lower HCW and larger LMA. There was a significant quadratic effect found with the addition of corn to pastured cattle (P < 0.02; Quadratic contrast) with adjusted LMA being greater for carcasses from cattle fed corn at 0.5% BW. This quadratic effect for adjusted LMA agrees with Roberts et al., (2009) who found a quadratic effect with LMA relating to the amount of corn supplemented on pasture. The authors found that cattle receiving the greatest amount of supplementation (corn fed at 1.5 and 2% BW) had the same LMA as control, non-supplemented cattle, with the largest LMA in cattle receiving intermediate amounts of corn.

Body composition was determined by dissecting the ribs into lean, fat and bone components and then presenting each component as a percentage. Lean content differed across management regimens (P < 0.01). Percentage of lean was lower in cattle fed corn (P < 0.01; Contrast 1) than cattle fed pasture only. Lean content was greater in steers fed corn at 1% BW as compared to steers fed the high grain diet (P < 0.02; Contrast 3). The amount of lean present in the rib dissections agrees with previous work (Duckett et al., 2007; Duckett et al., 2013) where steers fed only pasture contained more lean muscle than concentrate finished steers. The greater amount of lean in the pasture regiment cattle can be attributed to the lack of fat in the rib dissections when compared to steers fed corn.

Fat content also differed across management regimens and is inversely related to the amount of lean in the rib dissections (P < 0.0001). Steers fed corn in their diet had significantly more fat in their carcass (P < 0.01; Contrast 1) than cattle finished on alfalfa pasture alone. Steers
supplemented with corn at 0.5% BW had significantly less fat than steers fed corn at 1% BW or the high grain diet (P < 0.01; Contrast 2). Steers fed 1% BW corn had significantly less body fat than steers finished on the high grain regimen (P < 0.01; Contrast 3). There was a linear increase in the amount of body fat as the amount of corn supplemented on pasture increased (P = 0.01; Linear contrast). Previous research agrees that cattle either supplemented with grain on pasture or fed a high concentrate diet contain more fat in the carcass versus cattle fed only forage (Duckett et al., 2007; Scaglia et al., 2012; Duckett et al., 2013). It could be inferred that the increase in body fat in the grain finished and corn supplemented cattle is a result of greater amounts of dietary net energy gain for these cattle over cattle finished on pasture alone which has also been responsible for management regimen differences in ADG (Table 6).

The percentage of bone in rib dissections differed across management regimens (P < 0.001). Steers on the pasture only regimen had significantly more bone than steers fed corn (P < 0.01; Contrast 1). Steers fed corn at 0.5% BW had more bone than steers fed greater amounts of corn in their diet (P < 0.01; Contrast 2). Providing corn at 1% BW resulted in greater amounts of bone than feeding the high grain diet (P < 0.02; Contrast 3). Greater amounts of bone in pasture vs. concentrate fed steers agrees with previous work (Mandell et al., 1998; Duckett et al., 2007; Duckett et al., 2013). The increase in bone can be associated with lower amounts of fat in the rib section of forage finished animals. As the fat decreases the bone present in the rib section represents more of the rib section, therefore increasing the amount of bone present.

Fat that was dissected from the rib sections was further divided into body cavity, subcutaneous, and intermuscular fat deposits to examine fat partitioning in the carcass. The amount of subcutaneous fat in the carcass differed across management regimens (P < 0.05). Steers fed corn at 0.5% BW had less subcutaneous fat than steers fed 1% BW corn or the high
grain diet (P < 0.01; Contrast 2). This agrees with previous research where pasture finished cattle had less subcutaneous fat than drylot cattle regardless of if they were supplemented with concentrates while on pasture (Binder et al. 1981; Huuskonen et al., 2010). Body Cavity and Intermuscular fat were not affected (P > 0.22) by diet regimen.

Marbling score did not differ across management regimens (P > 0.26). Roberts et al. (2009) also found no difference in marbling score across treatments when supplementing differing amounts of corn to cattle on ryegrass pasture. Duynisveld et al. (2006) supplemented barley or whole roasted soy beans on pasture and found only small differences in marbling score between the supplement treatments and pasture only or TMR confinement feeding. Pavan and Duckett (2008) reported a significant increase in marbling score between carcasses from concentrate finished and pasture supplemented cattle. However these authors found that the type of supplement on pasture (soybean hulls covered in corn oil or corn grain) did not affect the marbling score when compared to cattle grazing pasture only. Other studies (Bidner et al., 1981; Huuskonen et al., 2010) found that marbling score increased when pastured cattle were supplemented with grain. In contrast to the current study, marbling scores in cattle finished primarily on a grain diet were greater than marbling scores for pasture finished cattle (Reagan et al., 1981; Crouse et al., 1984; Bidner et al., 1986). In these studies, increased marbling is attributed to increased fatness in grain-finished cattle. The results of the current study in regards to marbling may be caused by the lack of difference in grade fat across management regimens (P > 0.3). The similar marbling scores across regimens in the present study is most likely responsible for nonsignificant differences in CBGA quality grade across management regimens (P > 0.59) as marbling score is a major determinant of quality grade (Moon et al., 2003). Despite nonsignificant differences in marbling score across management regimens, intramuscular fat
content was lower in cattle fed corn at 0.5% BW than steers fed corn at 1% BW or the high grain diet (P < 0.03; Contrast 2).

Canadian Beef Grading Agency (CBGA) lean yield percentage and grade class significantly differed across management regimens (P < 0.04). Carcasses from steers fed corn at 0.5% BW had significantly greater lean yield percentages than carcasses from cattle fed greater amounts of corn (P < 0.04; Contrast 2). Carcasses from steers supplemented with corn at 1% BW had greater lean yield percentages and lean yield grade class than carcasses from steers fed the high grain diet (P < 0.04; Contrast 3). The greater lean yields may be the result of pastured regimen cattle depositing more lean whereas the high grain steers deposited more fat. This is supported by past studies (Pavan and Duckett., 2008; Lorenzen et al., 2006) while Roberts et al. (2009) found that as concentrate levels on pasture increased so did yield grade. These results indicate that supplementing corn on pasture may be a way for producers to decrease the amount of lean cattle deposit.
### Table 9: Management Regimen Effects on Carcass Traits for Cattle Fed in Drylot or on Pasture

<table>
<thead>
<tr>
<th>Management Regimen</th>
<th>Amount of Corn Supplemented on Pasture (% BW as-fed Basis)</th>
<th>Drylot</th>
<th>P-value for Contrasts y</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0%</td>
<td>0.5%</td>
<td>1%</td>
</tr>
<tr>
<td>HCW (kg)</td>
<td>Grade Fat</td>
<td>309.1</td>
<td>319.0</td>
</tr>
<tr>
<td>Grade Fat (mm)</td>
<td>N/A</td>
<td>9.9</td>
<td>10.7</td>
</tr>
<tr>
<td>LMA (cm²)</td>
<td>Grade Fat</td>
<td>77.2</td>
<td>79.0</td>
</tr>
<tr>
<td>LMA (cm²/100kg HCW)</td>
<td>N/A</td>
<td>24.0</td>
<td>24.2</td>
</tr>
<tr>
<td>Body Composition</td>
<td>Lean</td>
<td>52.9</td>
<td>51.0</td>
</tr>
<tr>
<td>via Rib Dissection</td>
<td>N/A</td>
<td>22.9</td>
<td>25.8</td>
</tr>
<tr>
<td>Fat</td>
<td>N/A</td>
<td>24.3</td>
<td>23.2</td>
</tr>
<tr>
<td>Bone</td>
<td>N/A</td>
<td>42.5</td>
<td>45.2</td>
</tr>
<tr>
<td>Fat Partitioning</td>
<td>Body Cavity</td>
<td>41.1</td>
<td>38.2</td>
</tr>
<tr>
<td>via Rib Dissection</td>
<td>Subcutaneous</td>
<td>N/A</td>
<td>9.9</td>
</tr>
<tr>
<td>Fat</td>
<td>N/A</td>
<td>42.5</td>
<td>45.2</td>
</tr>
<tr>
<td>Fat Partitioning</td>
<td>Intermuscular</td>
<td>N/A</td>
<td>41.1</td>
</tr>
<tr>
<td>Marbling</td>
<td>Grade Fat</td>
<td>398.6</td>
<td>366.8</td>
</tr>
<tr>
<td>Intramuscular Fat Content for Longissimus, %</td>
<td>N/A</td>
<td>3.6</td>
<td>3.1</td>
</tr>
<tr>
<td>CBGA Lean Yield %</td>
<td>N/A</td>
<td>61.4</td>
<td>61.3</td>
</tr>
<tr>
<td>CBGA Lean Grade Class</td>
<td>N/A</td>
<td>1.1</td>
<td>1.2</td>
</tr>
<tr>
<td>CBGA Quality Grade</td>
<td>N/A</td>
<td>2.7</td>
<td>2.7</td>
</tr>
</tbody>
</table>

Management Regimen includes: 0% Corn = cattle on alfalfa pasture only and were not fed corn; 0.5% Corn = cattle on alfalfa pasture fed whole grain corn at 0.5% BW (as-fed basis); 1% Corn = cattle on alfalfa pasture fed whole corn grain at 1% BW (as-fed basis); High Grain = cattle fed high grain diet in drylot.

Contrasts include: 1 = cattle fed no corn on pasture vs. cattle fed corn (on pasture or in drylot); 2 = corn fed at 0.5% BW vs. cattle fed greater amounts of corn; 3 = pastured cattle fed corn at 1% BW vs. drylot cattle fed a high grain diet; Linear and Quadratic examines the linear and quadratic effects respectively of increasing the amount of corn offered on pasture.

Traits include HCW (hot carcass weight), LMA (longissimus muscle Area) as cm² or cm²/100 kg HCW, Body Composition and Fat Partitioning via Rib Dissection, Marbling (degree of marbling where: practically devoid = 200 to 299, traces = 300 to 399, slight = 400 to 499; small = 500 to 599; modest = 600 to 699), Intramuscular Fat Content for longissimus, % determined via fat extraction, Canadian Beef Grading Agency (CBGA) Lean Yield, Yield Grade Class, and Quality grade. CBGA Yield Grade (YG) data were coded before statistical analysis was conducted as follows: YG1 = > 59% lean yield, YG 2 = 54-58% lean yield; YG 3 = < 53% lean yield. CBGA Quality Grade data were coded before statistical analysis as follows: Prime = 1, AAA = 2, AA = 3, A = 4.

Grade fat was included in the model as a covariate and was retained in the final model when significant at P < 0.05. If the covariate was not found to be significant, the cell is labeled N/A for not applicable or not appropriate for specific trait.
3.2.4 Meat Quality Evaluation

Management regimen effects on meat quality are presented in Table 10. *Longissimus* muscle (LM) pH was not affected by management regimen ($P > 0.21$). While there was a linear decrease in pH as corn was increased in the diet for pastured cattle ($P < 0.05$; Linear contrast), the biological significance of this effect is questionable as all pH values in the LM are associated with values typical for the conversion of muscle to meat (Immonen et al., 2000). The absence of a management regimen effect on pH is supported by previous studies (Duyisveld et al. 2006; French et al. 2000b) where there were no differences in muscle pH across diet regimens.

Lean colour is important to consumers as it is one of the only characteristics that consumers can appraise before deciding which steak to buy in the grocery store. Subjective lean colour evaluation is also part of the grading process so the nonsignificant differences in CBGA Quality Grade (Table 9) implies that lean colour was acceptable for all carcasses across management regimens to the CBGA grader. The Minolta colourimeter was used for an objective evaluation of lean colour. The lack of significant differences in $L^*$ (luminosity or lightness) values ($P > 0.17$) for Contrasts 1 and 2 are supported by nonsignificant differences in CBGA Quality Grade in which the CBGA grader found that lean colour for LM from all management regimens was acceptable based on subjective evaluation. However, $L^*$ values were greater for LM from cattle fed corn at 1% BW in comparison to LM from cattle fed the high grain diet ($P < 0.03$; Contrast 3). Previous research counters the current study, as there were no differences found in $L^*$ values as the result of dietary regimens (French et al., 2000a; Garmyn et al., 2010; Bjorklund et al., 2014) where cattle where fed pasture only, pasture plus concentrate or a high concentrate diet.
Objective measures of a* (the range from red to green) and b* (range from yellow to blue) were not affected by management regimen (P > 0.14). The findings for a* in the present study agrees with past work conducted by Garmyn et al. (2010) and O’Sullivan et al. (2003); however, Bjorklund et al. (2014) found a* values to be lower in strip loin steaks from grass fed steers versus steaks from cattle fed an 80% concentrate ration. There was a management regimen effect for b*, in which b* values for LM from cattle fed corn at 1% BW were greater than b* values for LM from cattle fed the high grain diet, indicating a higher degree of yellowness in the steaks from cattle on the pasture regimen (P < 0.04; Contrast 3). Duckett et al. (2007) found a correlation between total lipid content and b* values, where b* values were greater in muscles with greater amounts of fat. However the current study contradicts this as the steers supplemented with corn at 1% BW had higher b* values (indicating more yellowness) while containing less intramuscular fat than the steers on the high grain diet. Findings from past studies (O’Sullivan et al., 2003; Garmyn et al., 2010; Bjorklund et al., 2014) found that diet regimen had no effect on b* values for longissimus dorsi muscle when cattle were fed grass pasture alone, a concentrate diet, or grass pasture supplemented with varying amounts of concentrate, which would agree with the current study.

While the overall hue (how close the colour is to red, green, blue or yellow on the colour wheel) as affected by management regimen, was not significant (P > 0.11), hue values were greater for LM from cattle fed corn at 1% BW than from cattle fed the high grain diet (P< 0.04; Contrast 3). This indicates more true colour in steaks from cattle on pasture fed corn at 1% BW. The pH values of a carcass can also have an effect on meat colour. The higher the muscle pH, the darker the meat tends to be (Duckett et al., 2007). There was no difference in chroma across
management regimens in the current study (P > 0.62) which may help explain the general consistency in muscle colour across management regimens.

Warner-Bratzler shear force (WBSF), an instrumental measure of beef tenderness differed (P < 0.05) across management regimens. There were no differences in shear force values when cattle were finished exclusively on pasture in comparison to cattle fed corn on pasture or in drylot, (P > 0.64; Contrast 1). Previous studies have found that diet has no effect on WBSF values when comparing cattle who were fed pasture only, high concentrate diets or pasture with concentrate supplementation (McCaughey et al., 1999; French et al., 2001; Duynisveld et al., 2006; Lorenzen et al., 2007; Roberts et al., 2009; Duckett et al., 2013). However, shear force values for LM from steers fed corn at 1% BW were lower than steers fed the high grain diet (P < 0.01; Contrast 3), indicating that LM from pastured cattle supplemented with corn at 1% BW was more tender than LM from steers fed the high grain diet. This is contrary to some previous studies (Garmyn et al., 2010; Bjorklund et al., 2014) who found longissimus dorsi muscle from concentrate fed animals to have lower WBSF values than longissimus dorsi muscle from pasture finished cattle. However, French et al. (2000b) found that pastured cattle supplemented with 2.5 kg of a concentrate pellet had lower WBSF values than all other treatments including, a high concentrate diet, and a pasture only diet. In the past, no differences in WBSF values across diet regimens were found in studies where cattle were slaughtered at similar time (McCaughey et al., 1999; Duckett et al., 2007; Jiang et al., 2010; Duckett et al., 2013), body weight (Bidner et al., 1981) or back fat (Lorenzen et al., 2007; Roberts et al., 2009). Garmyn et al. (2010) found concentrate fed cattle to be significantly more tender with a lower WBSF rating than pasture fed cattle; however, pasture-finished animals were older at time of slaughter than the concentrate finished cattle which is a confounding factor.
Cooking losses were determined when cooking steaks for shear force evaluation. Cook loss is important as it is related to the juiciness of the product, as generally lower cook loss means greater water retention in the muscle which leads to a juicer cut of meat. While the overall P-value for cooking losses as affected by management regimen was not significant (P > 0.26), cooking losses for LM steaks from cattle finished exclusively on pasture were greater than cooking losses for LM steaks from cattle fed corn on pasture or in dry lot (P < 0.05; Contrast 1). In the past, previous studies (French et al., 2000b; Duynisveld et al., 2006; Jiang et al., 2010) have found that cooking losses were not affected by diet regimen when cattle were fed grass pasture alone, grass pasture plus concentrate supplement or a high concentrate diet.
Table 10. Management Regimen Effects on *Longissimus* Muscle Colour, Cooking Losses, and Warner Bratzler Shear Force

<table>
<thead>
<tr>
<th>Management Regimen²</th>
<th>Amount of Corn Supplemented on Pasture (% BW as-fed Basis)</th>
<th>Drylot</th>
<th>P-value for Contrast²y</th>
</tr>
</thead>
<tbody>
<tr>
<td>Trait</td>
<td>0%</td>
<td>0.5%</td>
<td>1%</td>
</tr>
<tr>
<td>pH</td>
<td>5.49</td>
<td>5.48</td>
<td>5.45</td>
</tr>
<tr>
<td>L*</td>
<td>36.5</td>
<td>35.8</td>
<td>37.3</td>
</tr>
<tr>
<td>a*</td>
<td>20.3</td>
<td>20.4</td>
<td>20.4</td>
</tr>
<tr>
<td>b*</td>
<td>5.6</td>
<td>5.4</td>
<td>6.1</td>
</tr>
<tr>
<td>Chroma</td>
<td>21.1</td>
<td>21.1</td>
<td>21.3</td>
</tr>
<tr>
<td>Hue</td>
<td>15.4</td>
<td>14.8</td>
<td>16.7</td>
</tr>
<tr>
<td>Warner Bratzler Shear Force (kg²)</td>
<td>3.1</td>
<td>3.0</td>
<td>2.9</td>
</tr>
<tr>
<td>Cooking Losses (%)</td>
<td>23.7</td>
<td>22.5</td>
<td>22.4</td>
</tr>
</tbody>
</table>

²Management Regimen includes: 0% Corn = cattle on alfalfa pasture only and were not fed corn; 0.5% Corn = cattle on alfalfa pasture fed whole grain corn at 0.5% BW (as-fed basis); 1% Corn = cattle on alfalfa pasture fed whole corn grain at 1% BW (as-fed basis); High Grain = cattle fed high grain diet in drylot.

²Contrasts include: 1 = cattle fed no corn on pasture vs. cattle fed corn (on pasture or in drylot); 2 = corn fed at 0.5% BW vs. cattle fed greater amounts of corn; 3 = pastured cattle fed corn at 1% BW vs. drylot cattle fed a high grain diet; Linear (L) and Quadratic (Q) examines the linear and quadratic effects respectively of increasing the amount of corn offered on pasture.
3.2.5 Postmortem Aging Effects on Shear Force and Cooking Losses

The effects of postmortem aging on Warner-Bratzler shear force and cooking loss values are presented in Table 11. There were no management regimen x postmortem aging interactions (P > 0.2) for either trait (data not presented).

Shear force differed significantly by the days of aging (P < 0.0001). *Longissimus* steaks aged for 7 days were significantly less tender than steaks aged either 14 or 21 days (P < 0.0001; Contrast 1). There was no statistical difference in tenderness between steaks aged 14 or 21 days (P > 0.76; Contrast 2). It has been documented in previous studies (Smith et al., 1978; Koohmaraie, 1996; Gruber et al., 2006) that postmortem aging positively impacts tenderness of beef with steaks aged 11 days reaching the optimum level of tenderness; aging after 11 days showed no increases in tenderness. The WBSF values linearly decreased (P < 0.0001) as days of aging increased which is to be expected as the proteolysis of myofibrillar proteins takes time postmortem to aid in the tenderization of meat (Koohmaraie, 1996). In agreement with the current study, Duckett et al. (2007; 2013) aged LM steaks from forage finished for 14 or 28 days but found no affect of aging on WBSF values while Berthiaume et al. (2015) aged forage finished *longissimus* thoracis steaks for 10, 14 or 21 days and found that the steaks aged 14 or 21 days had a significantly lower WBSF value than *longissimus* thoracis steaks aged 10 days. Shepherd (2013) aged LM steaks from forage finished cattle for 7, 14 and 21 days and found that WBSF values were significantly higher in LM steaks aged 7 days than LM steaks aged 14 or 21 days, and that LM steaks aged 14 days had greater WBSF than LM steaks aged for 21 days.

Cooking losses for LM steaks differed across days of aging (P < 0.0001). Steaks aged 14 days had greater cooking losses than steaks aged 21 days (P < 0.0001; Contrast 2). There was a
quadratic effect on cook losses by days of aging with LM steak aged for 14 days having the greatest cook loss versus LM steaks aged 7 or 21 days (P < 0.0001; Quadratic contrast).

Berthiaume et al. (2015) found that aging LM steak for longer than 10 days reduced the cooking loss values contrary to the current study. However, the cooking losses observed by Berthiaume et al. (2015) were not consistent over days of aging when examining different muscle cuts as Semimembranosus muscle showed a similar quadratic affect to the current study with the 14 day aged muscle producing the greatest cook loss.
Table 11. Postmortem Ageing Effects on Shear Force (WBSF) and Cooking Loss Values for Longissimus Muscle from Steers Fed on Drylot or Pasture

<table>
<thead>
<tr>
<th>Trait</th>
<th>Postmortem Ageing (days)$^z$</th>
<th>SE</th>
<th>P-value</th>
<th>P-value for Contrasts$^y$</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>7</td>
<td>14</td>
<td>21</td>
<td></td>
</tr>
<tr>
<td>WBSF (kg)</td>
<td>3.6</td>
<td>2.9</td>
<td>2.8</td>
<td>0.081</td>
</tr>
<tr>
<td>Cooking Losses (%)</td>
<td>22.2</td>
<td>24.7</td>
<td>21.4</td>
<td>0.381</td>
</tr>
</tbody>
</table>

$^z$Longissimus steaks were aged for 7, 14, and 21 days postmortem.
$^y$Contrasts 1 = 7 d aged longissimus steak vs. 14 and 21 d aged longissimus steaks; 2 = 14 d aged longissimus steak vs. 21 d aged longissimus steaks; Linear (L) and Quadratic (Q) examines the linear and quadratic effects respectively of varying the time that steaks are aged postmortem.
3.2.6 Fatty Acid Profile of the Pasture

FA composition of the pasture forages is presented in Table 12. The FA profile of the pasture in the current study is comparable to the FA profile of alfalfa from previous work with variations of no more than 2% in any FA that was presented in those studies (Boufaied et al., 2003; Ribeiro et al., 2005). The three primary FA in the pasture were C16:0 (palmitic acid), C18:2n6 (linoleic acid) and C18:3n3 (α-linolenic acid).
<table>
<thead>
<tr>
<th>Fatty Acid</th>
<th>Short-Hand Names</th>
<th>June</th>
<th>July</th>
<th>August</th>
<th>September</th>
<th>SEM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Myristic</td>
<td>14:0</td>
<td>1.60</td>
<td>1.66</td>
<td>1.95</td>
<td>2.22</td>
<td>0.062</td>
</tr>
<tr>
<td>Palmitic</td>
<td>16:0</td>
<td>22.17</td>
<td>24.29</td>
<td>22.81</td>
<td>21.45</td>
<td>0.394</td>
</tr>
<tr>
<td>Palmitoleic</td>
<td>16:1</td>
<td>1.99</td>
<td>2.12</td>
<td>2.39</td>
<td>2.19</td>
<td>0.096</td>
</tr>
<tr>
<td>Heptadecanoic</td>
<td>17:0</td>
<td>0.416</td>
<td>0.648</td>
<td>0.516</td>
<td>0.436</td>
<td>0.027</td>
</tr>
<tr>
<td>Stearic</td>
<td>18:0</td>
<td>3.13</td>
<td>3.85</td>
<td>3.53</td>
<td>3.24</td>
<td>0.091</td>
</tr>
<tr>
<td>Oleic cis-9</td>
<td>18:1</td>
<td>2.74</td>
<td>3.26</td>
<td>2.79</td>
<td>2.08</td>
<td>0.166</td>
</tr>
<tr>
<td>Vaccenic cis-11</td>
<td>18:1</td>
<td>0.472</td>
<td>0.503</td>
<td>0.431</td>
<td>0.353</td>
<td>0.029</td>
</tr>
<tr>
<td>Linoleic</td>
<td>18:2 n-6</td>
<td>21.72</td>
<td>21.89</td>
<td>20.16</td>
<td>18.83</td>
<td>0.382</td>
</tr>
<tr>
<td>γLinolenic</td>
<td>18:3 n-6</td>
<td>0.203</td>
<td>0.234</td>
<td>0.261</td>
<td>0.246</td>
<td>0.011</td>
</tr>
<tr>
<td>α-Linolenic</td>
<td>18:3 n-3</td>
<td>40.91</td>
<td>37.11</td>
<td>42.28</td>
<td>46.41</td>
<td>0.855</td>
</tr>
<tr>
<td>Eicosatrienoic cis-11, 14, 17</td>
<td>20:3 n-3</td>
<td>0.104</td>
<td>0.128</td>
<td>0.088</td>
<td>0.083</td>
<td>0.006</td>
</tr>
<tr>
<td>Eicosapentaenoic cis-5, 8 11,14, 17 (EPA)</td>
<td>20:5</td>
<td>1.91</td>
<td>1.48</td>
<td>1.08</td>
<td>0.904</td>
<td>0.179</td>
</tr>
<tr>
<td>Docosatrienoic cis 13,16,19</td>
<td>22:3</td>
<td>0.495</td>
<td>0.604</td>
<td>0.417</td>
<td>0.375</td>
<td>0.025</td>
</tr>
<tr>
<td>Docosatetraenoic cis 7,10,13,16</td>
<td>22:4</td>
<td>1.19</td>
<td>1.30</td>
<td>0.955</td>
<td>0.793</td>
<td>0.051</td>
</tr>
<tr>
<td>Tetracosanoic</td>
<td>24</td>
<td>0.297</td>
<td>0.501</td>
<td>0.329</td>
<td>0.216</td>
<td>0.026</td>
</tr>
<tr>
<td>Docosaheaxaenoic cis- 4,7,10,13,16,19 (DHA)</td>
<td>22:6</td>
<td>0.168</td>
<td>0.197</td>
<td>0.119</td>
<td>0.086</td>
<td>0.010</td>
</tr>
</tbody>
</table>
3.2.7 Fatty Acids in Longissimus Muscle

Fatty acid (FA) composition of longissimus muscle (LM) is presented in Table 13.

Management regimen did not affect concentrations of C10:0, C12:0, C14:0, C16:1, C17:0, C18:1v, C18:3n6, C20:0, C20:3n3, C20:4n6, and C22:3n3 (P ≥ 0.21). The present findings contrast to Duckett et al. (2013) who found concentrations of C14:0, C16:1 and C18:1 cis-11 to be greater in concentrate versus pasture fed cattle. The pasture in the Duckett et al. (2013) study included a mixture of grass and legumes before cattle were put on either alfalfa, pearl millet or mixed pasture for the last 40 days before slaughter, while the concentrate steers were fed a diet containing approximately 82% concentrate plus corn silage. Concentrations of C17:0 and C20:4n-6 in the Duckett et al. (2013) study were not affected by diet regimen, agreeing with the current study. These study-to-study differences in FA concentrations could be due to the increased level of corn through the use of corn silage in the Duckett et al. (2013) study compared to the current study.

C16:0 and C18:0 concentrations in LM were not different among management regimens (P > 0.19). In agreement with the current study, de Freitas et al. (2014) found no difference in C16:0 or C18:0 concentrations in longissimus muscle from pasture or concentrate fed steers while Leheska et al. (2008) found no difference in C16:0 concentrations in LM when cattle were fed 100% grasses or forages. However French et al. (2000a) found increased amounts of C16:0 in the LM of grain fed cattle compared to the LM of cattle on pasture which contrasts with the current findings. French et al. (2000a) fed cattle a high concentrate diet, pasture only, or pasture (6 kg DM or 12 kg DM) supplemented with a concentrate pellet (5 kg or 2.5 kg). The concentrate diet was greater in C16:0 leading the researchers to believe this caused the increase in C16:0 in
the LM from concentrate fed cattle. Leheska et al. (2008) found C18:0 concentrations to be no different in the LM of cattle fed a concentrate versus a pasture diet.

C18:1 tv was significantly greater in LM from steers with no corn in their diet (P = 0.03; Contrast 1). Fincham et al. (2009) took ruminal, serum and adipose tissue samples from cattle grazing a mixture of grass and legumes (including alfalfa) or fed a high concentrate corn diet over a 140 day period. These researchers found C18:1 tv concentrations to be consistently greater in pastured cattle compared to concentrate fed cattle.

Steers fed corn at 0.5% BW had lower amounts of C18:1o (oleic acid) than steers fed greater amounts of corn in their diet (P < 0.02; Contrast 2). Leheska et al. (2008) also found longissimus dorsi from conventionally raised cattle to contain greater amounts of C18:1o than cattle finished on strictly forage or grass. The beef from the Leheska et al. (2008) study was sourced from across the U.S. from forage or grass finishing beef operations while the conventional beef was sourced from high end restaurants. However French et al. (2000a) found no difference in the amount of oleic acid present in the LM of cattle fed concentrates, pasture or pasture with concentrate supplementation.

Management regimen differed in the amounts of the low order omega-3 FA, C18:3n3 in LM as the amount of corn in the diet varied (P < 0.0001). Steers with no corn in their diet had significantly greater levels of C18:3n3 than steers with corn in their diet (P < 0.0001; Contrast 1). Steers fed corn at 0.5% BW had greater amounts of C18:3n3 than steers with greater amounts of corn in their diet (P < 0.0001; Contrast 2). Steers fed corn at 1% BW had almost four times more C18:3n3 than high grain fed steers (P < 0.0001; Contrast 3) showing that even with supplementation on pasture, providing pasture to cattle results in increased amounts of C18:3n3.
Leheska et al. (2008) compared fatty acid concentrations in *longissimus dorsi* in forage or grass raised and finished cattle versus muscle FA concentrations from conventionally finished, grain-fed cattle and found elevated levels of C18:3n3 in the forage finished beef. De Freitas et al. (2014) also found elevated levels of C18:3n3 in beef that was pasture finished when compared to cattle fed high grain rations, agreeing with the current study. There is a consensus among researchers that higher C18:3 levels in the meat of pasture fed animals is the result of greater C18:3n3 levels in fresh forage (de Freitas et al., 2014).

The current study found similar concentrations of CLA 1 or CLA 2 in LM across management regimen (P > 0.27). It should be noted that CLA 2 co-elutes with CLA 1 which could be a contributing factor to the low levels of CLA 2 in the current study (French et al., 2000a). However, concentrations of CLA 1 also did not differ across management regimens (P > 0.27). This finding differs from past studies (French et al., 2000a; Engle and Spears, 2004; Dannenberger et al., 2005; Lorenzen et al., 2007; Fincham et al., 2009) where decreasing grain in the ration correlated with increased levels of CLA cis-9 trans-11 in the muscle. In agreement with the current study, Dierking et al. (2010) found no difference in CLA concentrations between cattle fed tall fescue, alfalfa/tall fescue or red clover/tall fescue pasture; however no concentrates were fed in the Dierking et al. (2010) study. In the previously cited studies that have examined concentrations of CLA in pasture-fed cattle, none of them contained as much alfalfa as the current study, which may be a contributing factor for the nonsignificant differences in CLA concentration for the current study. Ribeiro et al. (2005) found that when using culture fermenters with rumen fluid as a model for cattle digestive systems, fresh alfalfa had greater flow of all intermediates of biohydrogenation except for CLA. It could be inferred that lower flow of
CLA intermediates could lead to lower CLA concentrations in muscle of animals finished on alfalfa pasture.

C20:1 was lower in steers fed corn at 0.5% BW than steers fed greater amounts of corn in their diet (P < 0.03; Contrast 2). Contrary to the current study, French et al. (2000a) fed a high concentrate diet, pasture only or differing levels of pasture (6 kg DM or 12 kg DM) with concentrate supplementation (5 kg or 2.5 kg), and found that cattle fed 6 kg DM pasture supplemented with 5 kg concentrate diet contained the greatest amount of C20:1 in the LM than cattle fed the other diets. The current study tended to have a quadratic response in C20:1 to supplementation on pasture with LM from pastured cattle fed no corn supplement and corn supplemented at 1% BW having the highest levels of C20:1.

Steers fed corn at 0.5% BW had greater amounts of C20:2n6 in LM than steers fed greater amounts of corn in their diet (P < 0.04; Contrast 2). Jiang et al. (2010) finished cattle on a concentrate diet of 71.2% alfalfa and 15.5% cracked corn, a diet of mixed grass pasture before being transitioned to the concentrate diet for finishing, or mixed pasture of triticale and ryegrass. They found no difference in the amount of C20:2n6 in the triceps muscle in cattle finished on any of these diet regimens.

*Longissimus* muscle from cattle only fed pasture, contained more C20:3n6 in LM than cattle fed corn (P < 0.02; Contrast 1). Contrary to the current study, de Freitas et al. (2014) found no difference in the amounts of C20:3n6 in *longissimus dorsi* between concentrate and pasture fed beef. Jiang et al. (2010) also found no difference in C20:3n6 in ground beef when comparing cattle fed different levels of alfalfa and concentrate or grass pasture. In the current study there...
was a linear response to increasing corn supplementation on pasture (P < 0.05; Linear contrast) with the pasture only treatment possessing the greatest level of C20:3n6.

C20:5n3, C22:2n6 and C22:5n3 all differed amongst management regimens (P < 0.0001). All were present in greater amounts in cattle only fed pasture (P < 0.0001; Contrast 1) and were greater in cattle fed corn at 0.5% BW than steers fed greater amounts of corn in their diet (P < 0.0001; Contrast 2). Steers fed corn at 1% BW had double the amounts of C20:5n3 and C22:2n6 and greater amounts of C22:5n3 than steers fed the high grain diet (P < 0.0001; Contrast 3). Concentrations of C20:5n3, C22:5n3 and C22:2n6 linearly decreased as corn supplementation on pasture increased (P < 0.01; Linear contrast). Contrary to the current study, de Freitas et al. (2014) found no difference in concentrations of C20:5n3 and C22:2n6 in the longissimus dorsi of pasture or concentrate finished beef. Findings from Jiang et al. (2010) agree with the current study as cattle finished on a mixed pasture of triticale and ryegrass contained more C22:2n6 in ground beef than ground beef from cattle finished using a 71.2% alfalfa/15.5% cracked corn diet. Also in agreement with the current study, Duckett et al. (2013) found that concentrations of C20:5n3 and C22:5n3 were significantly greater in the LM of pasture finished over concentrate finished cattle. Although the use of alfalfa pasture produced FA concentrations that were numerically greater than the other pasture forage treatments (mixed pasture or pearl millet), the FA concentrations of C20:5n3 and C22:5n3 were not statistically significant. In the present study, the biological significance of these differences is questionable regarding consumption of the two higher order omega-3 FA.

Concentrations of C22:4n6 differed between management regimens (P < 0.0001). LM from steers fed only pasture contained less C22:4n6 then LM from steers fed corn in their diet (P < 0.0001; Contrast 1). Steers fed corn at 0.5% BW contained lower amounts of C22:4n6 in their
LM than LM from steers fed greater amounts of corn (P < 0.001; Contrast 2). Steers fed the high grain diet had greater amounts of C22:4n6 in LM than LM from cattle fed corn at 1% BW (P < 0.0001; Contrast 3). Concentrations of C22:6n3 in LM were greater in cattle fed corn at 0.5% BW than cattle fed greater amounts of corn (P < 0.04; Contrast 2). Concentrations of C22:4n6 increased linearly as the amount of corn supplemented on pasture increased (P < 0.03; Linear contrast). Contrary to the current study, Jiang et al. (2010) found no difference in concentrations of C22:4n6 in ground beef from cattle fed 71.2% alfalfa/ 15.5% cracked corn, grazed on triticale/rye grass pasture or pastured before being finished on the alfalfa/cracked corn diet.

Concentrations of saturated fatty acids (SFA) were similar across management regimens (P > 0.19). Scientific studies from the 1980’s (Melton et al., 1982; Marmer et al., 1984) reported concentrations of SFA in grass finished cattle were greater than concentrations of SFA in grain finished beef. However, more recent studies (French et al., 2000a; Yang et al., 2002; Noci et al., 2005) have found that grass finished beef has less SFA than grain fed beef. Findings from de Freitas et al. (2014) agree with the current study as they also found no difference in SFA between steers finished on natural pastures containing legumes or cattle finished on high concentrate diets containing sorghum grain and corn silage. Findings from the current study are also supported by Duckett et al. (2013) where SFA concentrations were similar in LM between cattle finished on shelled corn/soybean meal mix or finished on a pasture of alfalfa, pearl millet or mixed grass.

Concentrations of Monounsaturated fatty acids (MUFA) were significantly lower in LM from steers fed corn at 0.5% BW versus MUFA concentrations in LM from cattle fed greater amounts of corn (P < 0.03; Contrast 2). This agrees with previous research (Leheska et al., 2007; Daley et al., 2010; Duckett et al., 2013) where concentrate feeding increased MUFA concentrations in longissimus muscle. In contrast, de Freitas et al. (2014) found there was no
difference in MUFA concentrations when comparing cattle finished on natural pasture improved with legumes versus cattle finished on a concentrate ration consisting mainly of sorghum grain. Steers fed only pasture contained significantly more polyunsaturated fatty acids (PUFA) in LM (P ≤ 0.002; Contrast 1) than LM from cattle fed corn in their diets. As corn supplementation on pasture increased, PUFA levels in LM linearly decreased (P = 0.03; Linear contrast). Findings from French et al. (2000) are in agreement with the current study as they found supplementing a concentrate consisting of barley and beet pulp decreased PUFA levels in LM. However other studies (Leheska et al., 2007; de Freitas et al., 2014) found no difference of PUFA levels in *longissimus dorsi* between cattle that were pastured versus fed concentrate. Duynisveld et al. (2006) found that supplementing pasture with whole roasted soybeans actually increased PUFA levels in *longissimus thoracis* over PUFA concentrations in *longissimus thoracis* of cattle fed pasture alone or pasture plus barley supplement. Dierking et al. (2006) examined PUFA levels in *longissimus dorsi* between cattle fed tall fescue, tall fescue/alfalfa mix or tall fescue/red clover mix and found that although the *longissimus dorsi* of cattle fed the alfalfa mix had the highest numerical PUFA level, the PUFA levels in the *longissimus dorsi* were not statistically different from each other due to diet regimen.

Omega-6 (n6) fatty acid concentrations in LM tended to be greater in pastured cattle (P > 0.07). In past studies, (French et al., 2000a; Noci et al., 2005; Leheska et al., 2008; Duckett et al., 2013; de Freitas et al., 2014) found n6 FA concentrations in muscle were not affected by diet regimen. In contrast to only a trend for differences in n6 FA across management regimens, the omega-3 (n3) FA concentrations in LM varied greatly amongst management regimens (P < 0.0001). LM from steers fed only pasture contained greater levels of omega-3 FA than LM from cattle fed corn in their diet (P < 0.0001; Contrast 1). Cattle fed corn at 0.5% BW contained
greater levels of n3 FA than steers fed greater amounts of corn (P < 0.0001; Contrast 2). Steers fed corn at 1% BW had over double the amount of n3 FA found in the LM than cattle fed the high grain diet (P < 0.0001; Contrast 3). As corn supplementation on pasture increased, n3 levels in the LM were found to linearly decrease (P < 0.0001; Linear contrast). These findings are not surprising based on past studies (French et al., 2000a; Noci et al., 2005; Leheska et al., 2008; Daley et al., 2010; de Freitas et al., 2014) which have found greater concentrations of n3 FA in muscle from cattle finished on forages compared to n3 FA concentrations in muscle from grain finished cattle. However, the current study has found that use of grain supplementation on pasture to increase gains, can also dramatically increase the n3 FA concentration in beef as compared to feeding the traditional high concentrate diet to cattle. This approach of supplementing pastured cattle was found to alter the omega-6:omega-3 FA ratio (P < 0.0001). Cattle fed only pasture or corn at 0.5% BW had lower omega-6:omega-3 FA ratios in LM than cattle fed greater amounts of corn (P < 0.0001; Contrasts 1 and 2). Steers fed corn at 1% BW also had lower omega-6:omega-3 FA ratios in LM than cattle fed the high grain diet (P < 0.0001; Contrast 3). As corn supplementation increased on pasture, the omega-6:omega-3 FA ratio in LM linearly increased (P < 0.001; Linear contrast). The lower omega-6:omega-3 FA ratio in all the cattle fed on pasture is due to increased amounts of n3 FA in muscle (Daley et al., 2010). The lower omega-6:omega-3 FA ratio in LM with pasture fed cattle is in agreement with past studies (French et al., 2000a; Leheska et al., 2008; Daley et al., 2010; Duckett et al., 2013; de Freitas et al., 2014) comparing intramuscular FA concentrations in forage and grain finished cattle.

Humans evolved with an omega-6:omega-3 FA ratio of approximately 1:1; however today’s western diet contains a ratio closer to 16:1 (Simopoulos, 2002). This has negative effects on human health. The recommended omega-6:omega-3 FA ratio in the diet is dependent on what
disease one is trying to fight but generally the lower the ratio is, the healthier the diet (Simopoulos, 2002). While management regimen affected omega-6:omega-3 FA ratio in the current study, management regimen did not affect the PUFA:SFA ratio in LM ($P > 0.10$) which agrees with Leheska et al. (2008). However, Duynisveld et al. (2006) found that cattle fed pasture supplemented with whole roasted soybeans had greater PUFA:SFA ratios in longissimus thoracis than cattle on pasture alone or pasture supplemented with barley. French et al. (2000a) found that the highest PUFA:SFA ratios in LM belonged to cattle who were fed mixed grass pasture with no supplementation than LM in cattle fed pasture with grain supplementation, or cattle fed a high concentrate diet.
Table 13. Management Regimen Effects on Fatty Acid Composition (% Total Fatty Acids) in *Longissimus* Muscle from Cattle Fed in Drylot or on Alfalfa Pasture

<table>
<thead>
<tr>
<th>Fatty Acid</th>
<th>0%</th>
<th>0.5%</th>
<th>1%</th>
<th>High Grain</th>
<th>SE</th>
<th>P-value</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>L</th>
<th>Q</th>
</tr>
</thead>
<tbody>
<tr>
<td>C10:0</td>
<td>0.03</td>
<td>0.02</td>
<td>0.02</td>
<td>0.03</td>
<td>0.003</td>
<td>0.538</td>
<td>0.794</td>
<td>0.385</td>
<td>0.252</td>
<td>0.602</td>
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<tr>
<td>C12:0</td>
<td>0.04</td>
<td>0.04</td>
<td>0.04</td>
<td>0.04</td>
<td>0.004</td>
<td>0.842</td>
<td>0.460</td>
<td>0.942</td>
<td>0.606</td>
<td>0.403</td>
<td>0.881</td>
</tr>
<tr>
<td>C14:0</td>
<td>1.57</td>
<td>1.51</td>
<td>1.71</td>
<td>2.06</td>
<td>0.417</td>
<td>0.320</td>
<td>0.112</td>
<td>0.457</td>
<td>0.551</td>
<td>0.271</td>
<td>0.278</td>
</tr>
<tr>
<td>C16:0</td>
<td>17.61</td>
<td>15.20</td>
<td>18.33</td>
<td>21.16</td>
<td>2.012</td>
<td>0.197</td>
<td>0.791</td>
<td>0.058</td>
<td>0.313</td>
<td>0.805</td>
<td>0.259</td>
</tr>
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<td>C16:1</td>
<td>1.08</td>
<td>1.01</td>
<td>1.03</td>
<td>0.99</td>
<td>0.064</td>
<td>0.795</td>
<td>0.372</td>
<td>0.988</td>
<td>0.648</td>
<td>0.622</td>
<td>0.567</td>
</tr>
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<td>0.63</td>
<td>0.51</td>
<td>0.60</td>
<td>0.62</td>
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<td>0.535</td>
<td>0.473</td>
<td>0.218</td>
<td>0.760</td>
<td>0.685</td>
<td>0.197</td>
</tr>
<tr>
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<td>10.31</td>
<td>8.82</td>
<td>10.82</td>
<td>12.11</td>
<td>1.123</td>
<td>0.220</td>
<td>0.839</td>
<td>0.055</td>
<td>0.420</td>
<td>0.754</td>
<td>0.200</td>
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<tr>
<td>C 18:1 tv</td>
<td>2.16</td>
<td>1.67</td>
<td>1.64</td>
<td>1.65</td>
<td>0.186</td>
<td>0.182</td>
<td>0.030</td>
<td>0.919</td>
<td>0.967</td>
<td>0.089</td>
<td>0.353</td>
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<td>C 18:1 o</td>
<td>23.98</td>
<td>20.98</td>
<td>27.65</td>
<td>32.59</td>
<td>3.066</td>
<td>0.049</td>
<td>0.393</td>
<td>0.014</td>
<td>0.252</td>
<td>0.398</td>
<td>0.184</td>
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<td>0.16</td>
<td>0.14</td>
<td>0.13</td>
<td>0.07</td>
<td>0.042</td>
<td>0.520</td>
<td>0.402</td>
<td>0.399</td>
<td>0.354</td>
<td>0.660</td>
<td>0.995</td>
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<td>2.16</td>
<td>2.34</td>
<td>2.53</td>
<td>0.134</td>
<td>0.100</td>
<td>0.127</td>
<td>0.085</td>
<td>0.319</td>
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<td>0.05</td>
<td>0.05</td>
<td>0.05</td>
<td>0.007</td>
<td>0.689</td>
<td>0.235</td>
<td>0.943</td>
<td>0.873</td>
<td>0.313</td>
<td>0.647</td>
</tr>
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<td>C 18:3n3</td>
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<td>0.51</td>
<td>0.41</td>
<td>0.11</td>
<td>0.030</td>
<td>&lt;0.0001</td>
<td>&lt;0.0001</td>
<td>&lt;0.0001</td>
<td>&lt;0.0001</td>
<td>0.0001</td>
<td>0.825</td>
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<td>0.11</td>
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<td>0.278</td>
<td>0.453</td>
<td>0.714</td>
<td>0.622</td>
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<td>0.276</td>
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<td>0.996</td>
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<td>0.03</td>
<td>0.03</td>
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<td>0.712</td>
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<td>0.14</td>
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<td>0.113</td>
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<td>0.304</td>
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<td>0.02</td>
<td>0.01</td>
<td>0.01</td>
<td>0.003</td>
<td>0.049</td>
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<td>&lt;0.0001</td>
<td>&lt;0.0001</td>
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<td>C 22:4n6</td>
<td>C 24</td>
<td>C 22:5n3</td>
<td>C 22:6n3</td>
<td>SFA %</td>
<td>MUFA %</td>
<td>PUFA %</td>
<td>n6 fatty acids %</td>
<td>n3 fatty acids %</td>
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<td>0.005</td>
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<td>0.026</td>
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<td>0.887</td>
<td>0.514</td>
<td>0.064</td>
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<td></td>
<td>0.008</td>
<td>0.192</td>
<td>0.0001</td>
<td>0.986</td>
<td>0.0001</td>
<td>0.947</td>
<td>0.996</td>
<td>0.016</td>
<td>0.064</td>
<td>0.983</td>
<td>0.663</td>
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</table>

*Management Regimen includes: 0% Corn = cattle on alfalfa pasture only and were not fed corn; 0.5% Corn = cattle on alfalfa pasture fed whole grain corn at 0.5% BW (as-fed basis); 1% Corn = cattle on alfalfa pasture fed whole corn grain at 1% BW (as-fed basis); High Grain = cattle fed high grain diet in drylot.*

*Contrasts include: 1 = cattle fed no corn on pasture vs. cattle fed corn (on pasture or in drylot); 2 = corn fed at 0.5% BW vs. cattle fed greater amounts of corn; 3 = pastured cattle fed corn at 1% BW vs. drylot cattle fed a high grain diet; Linear and Quadratic examines the linear and quadratic effects respectively of increasing the amount of corn offered on pasture.*

*SFA, MUFA and PUFA consists of:
- Saturated Fatty Acids = (C10:0 + C12:0 + C14:0 + C16:0 + C18:0 + C20:0 + C24:0);
- Monounsaturated Fatty Acids = (C16:1 + C18:1 cis9 + C18:1 cis11 + C18:1 trans11 + C20:1);
- Polynsaturated Fatty Acids = (C18:2n6 + C18:3n6 + C18:3n3 + C18:2 cis 9, trans11 + C18:2 trans10, cis 12 + C20:2n6 + C20:3n6 + C20:4n6 + C20:5n3 + C22:3n3 + C22:4n6 + C22:5n3 + C22:6n3).

*n6 and n3 fatty acids are comprised of:
- n6 fatty acids = (C18:2n6 + C18:3n6 + C20:2n6 + C20:3n6 + C20:4n6 + C22:4n6 + C22:2n6);
- n3 fatty acids = (C18:3n3 + C20:5n3 + C20:5n3 + C22:5n3 + C22:6n3 + C20:3n3).

*CLA 1 = Conjugated linoleic acid cis-9 trans-11 or C18:2 cis-9 trans-11.
*CLA 2 = Conjugated linoleic acid trans 10 cis 12 or C18:2 trans 10 cis 12.
3.2.8 Palatability Attributes of *Longissimus* Muscle as Determined by a Trained Taste Panel

Intramuscular fat (IMF) content was used as a covariate in the statistical analysis of taste panel data to account for differing amounts of IMF across management regimens. IMF was significant as a covariate (*P* < 0.05) for all palatability attributes except beef flavour and off flavours for the palatability attribute data presented in Table 14.

Four measures of “tenderness” were assessed by trained taste panel including softness, tenderness, chewiness and rate of breakdown. While the trained taste panel found no differences in softness, tenderness, chewiness and rate of breakdown in LM from pastured cattle with no corn in their diet as compared to cattle fed corn in their diet (*P* > 0.44; Contrast 1), LM from cattle fed corn at 1% BW was found to be softer and more tender with a faster rate of breakdown than LM from cattle fed the high grain diet (*P* < 0.03; Contrast 3). These results are confirmed by many past studies in the literature (Reagan et al., 1977; Duynisveld et al., 2006; Faucitano et al., 2008; Duckett et al., 2009; Roberts et al., 2009; Duckett et al., 2013;) which found no effect of diet on the tenderness ratings of beef from forage or concentrate finished cattle when slaughtered at similar time points. Others (Mandell et al., 1998; Realini et al., 2004; Duckett et al., 2009b) have found no differences in tenderness when forage or concentrate finished cattle are finished to an equal age. However, there are past studies (Garmyn et al., 2010; Hedrick, 1983; May et al., 1992; Schroeder et al., 1980; Sitz et al., 2005) which found that forage finishing decreases tenderness scores as compared to grain finished beef.
No management regimen effect was found for overall juiciness (P > 0.27). Previous studies (Muir et al., 1998; French et al., 2000a; Duynisveld et al., 2006) also found that juiciness was not affected if cattle were forage or grain finished.

Beef flavour and off flavour were not affected by management regimen (P > 0.05). This contradicts previous research as the scientific literature (Roberts et al., 2009; Duckett et al., 2013; Bjorklund et al., 2014) has stated beef flavour is more intense with less off flavours in beef from grain finished cattle when compared to forage finished beef. However, findings from Duynisveld et al. (2006) agree with the current study as they also found no difference in beef flavour between cattle that were fed pasture only, pasture plus a barley or whole roasted soybean supplement or fed a TMR. McCaughey and Cliplef (1996) grazed steers on pasture containing alfalfa, meadow brome and wild rye before putting them on a barley concentrate diet for 0, 33 or 75 days before slaughter. A trained taste panel found there was no difference in beef flavour for LM between these diet treatments (McCaughey and Cliplef, 1996).

There were no linear or quadratic effects of varying the amount of corn supplemented on pasture for any palatability attribute (P > 0.12) which indicated that supplementing corn on pasture is a viable option to increase gains on grass fed cattle while not affecting palatability attributes.
Table 14. Management Regimen Effects on Palatability Attributes of *Longissimus* Muscle Steaks from Cattle Fed in Drylot or on Pasture$^z$

<table>
<thead>
<tr>
<th>Trait</th>
<th>Covariate</th>
<th>0%</th>
<th>0.5%</th>
<th>1%</th>
<th>High Grain</th>
<th>SE</th>
<th>P-value</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>L</th>
<th>Q</th>
</tr>
</thead>
<tbody>
<tr>
<td>Softness</td>
<td>IMF</td>
<td>6.0</td>
<td>6.3</td>
<td>6.3</td>
<td>5.6</td>
<td>0.22</td>
<td>0.079</td>
<td>0.873</td>
<td>0.219</td>
<td>0.021</td>
<td>0.338</td>
<td>0.625</td>
</tr>
<tr>
<td>Tenderness</td>
<td>IMF</td>
<td>6.1</td>
<td>6.6</td>
<td>6.5</td>
<td>5.8</td>
<td>0.22</td>
<td>0.040</td>
<td>0.446</td>
<td>0.087</td>
<td>0.027</td>
<td>0.158</td>
<td>0.224</td>
</tr>
<tr>
<td>Initial Juiciness</td>
<td>IMF</td>
<td>4.8</td>
<td>4.6</td>
<td>4.7</td>
<td>5.3</td>
<td>0.22</td>
<td>0.119</td>
<td>0.764</td>
<td>0.135</td>
<td>0.053</td>
<td>0.749</td>
<td>0.603</td>
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<tr>
<td>Beef Flavour</td>
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<td>5.2</td>
<td>5.5</td>
<td>5.4</td>
<td>0.19</td>
<td>0.800</td>
<td>0.740</td>
<td>0.386</td>
<td>0.699</td>
<td>0.541</td>
<td>0.441</td>
</tr>
<tr>
<td>Chewiness</td>
<td>IMF</td>
<td>4.6</td>
<td>4.3</td>
<td>4.2</td>
<td>5.0</td>
<td>0.22</td>
<td>0.058</td>
<td>0.728</td>
<td>0.309</td>
<td>0.011</td>
<td>0.125</td>
<td>0.903</td>
</tr>
<tr>
<td>Overall Juiciness</td>
<td>IMF</td>
<td>4.7</td>
<td>4.7</td>
<td>4.8</td>
<td>5.2</td>
<td>0.21</td>
<td>0.275</td>
<td>0.433</td>
<td>0.183</td>
<td>0.193</td>
<td>0.829</td>
<td>0.765</td>
</tr>
<tr>
<td>Rate of Breakdown</td>
<td>IMF</td>
<td>5.4</td>
<td>5.9</td>
<td>5.6</td>
<td>4.8</td>
<td>0.25</td>
<td>0.021</td>
<td>0.956</td>
<td>0.025</td>
<td>0.025</td>
<td>0.369</td>
<td>0.319</td>
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<tr>
<td>Off Flavour</td>
<td>N/A</td>
<td>1.5</td>
<td>1.3</td>
<td>1.1</td>
<td>1.1</td>
<td>0.17</td>
<td>0.508</td>
<td>0.189</td>
<td>0.402</td>
<td>0.956</td>
<td>0.243</td>
<td>0.973</td>
</tr>
</tbody>
</table>

$^z$Taste panel data were collected using a 10 cm line scale with 1 equaling a negative attribute and 10 equaling a positive attribute.

$^y$Management Regimen includes: 0% Corn = cattle on alfalfa pasture only and were not fed corn; 0.5% Corn = cattle on alfalfa pasture fed whole grain corn at 0.5% BW (as-fed basis); 1% Corn = cattle on alfalfa pasture fed whole corn grain at 1% BW (as-fed basis); High Grain = cattle fed high grain diet in drylot.

$^x$Contrasts include: 1 = cattle fed no corn on pasture vs. cattle fed corn (on pasture or in drylot); 2 = corn fed at 0.5% BW vs. cattle fed greater amounts of corn; 3 = pastured cattle fed corn at 1% BW vs. drylot cattle fed a high grain diet; Linear and Quadratic examines the linear and quadratic effects respectively of increasing the amount of corn offered on pasture.

$^w$Intramuscular fat content was included in the model as a covariate and was included in the final model when significant at $P < 0.05$. If the covariate was not found to be significant, the cell is labeled N/A for not applicable. Intramuscular fat content determined using ether extraction.
3.3 Conclusion and Implications

Supplementing corn to cattle on pasture can increase average daily gains, HCW and fat deposition while maintaining a fatty acid profile in LM that contains more omega-3 FA and therefore a better omega-6:omega-3 FA ratio than conventionally grain finished beef. The improved gains and heavier carcasses are beneficial to producers due to less time on feed and more product to market than traditional production of grass-fed beef. While omega-3 concentrations do decrease when supplementing corn on pasture, FA concentrations exceed concentrations in conventional, grain-finished beef and can help consumers to satisfy daily omega-3 FA recommendations. Supplementing corn on pasture did not negatively affect lean colour in the carcass, ensuring an attractive appearance for consumers who seek out cherry red beef as an indicator of freshness and quality. Supplementing corn on alfalfa pasture did not affect WBSF values, an instrumental measure of tenderness or palatability attributes for LM steaks produced by pasture regimen steers. Thus consumers are not sacrificing on eating quality (tenderness, juiciness, flavour) with beef from pastured cattle supplemented with corn if they seek a beef product that has a nutrient composition more beneficial to human health than grain-finished beef. Regardless of the feeding regimen used in beef cattle finishing, beef is nutrient dense and is regarded as an important source of essential amino acids, fatty acids, vitamins A, B6, B12, D,E and minerals including iron, zinc, and selenium (Daley et al., 2010).
3.4 Appendix

3.4.1 Appendix 1: Line Scale

Line scales used during the 2 week training process. Panelists were trained for 2 weeks on what each palatability trait was and where it should be placed on a line scale.

<table>
<thead>
<tr>
<th>Trait</th>
<th>Scale</th>
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<tr>
<td><strong>Softness</strong></td>
<td>firm</td>
</tr>
<tr>
<td></td>
<td>soft</td>
</tr>
<tr>
<td><strong>Tenderness</strong></td>
<td>tough</td>
</tr>
<tr>
<td></td>
<td>tender</td>
</tr>
<tr>
<td><strong>Initial Juiciness</strong></td>
<td>little</td>
</tr>
<tr>
<td></td>
<td>much</td>
</tr>
<tr>
<td><strong>Flavour</strong></td>
<td>weak</td>
</tr>
<tr>
<td></td>
<td>intense</td>
</tr>
<tr>
<td><strong>Chewiness</strong></td>
<td>not chewy</td>
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<tr>
<td></td>
<td>chewy</td>
</tr>
<tr>
<td><strong>Overall Juiciness</strong></td>
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<td></td>
<td>much</td>
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<td><strong>Rate of Breakdown</strong></td>
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</tr>
<tr>
<td></td>
<td>rapid</td>
</tr>
<tr>
<td><strong>Off Flavour</strong></td>
<td>none</td>
</tr>
<tr>
<td></td>
<td>intense</td>
</tr>
</tbody>
</table>
3.4.2 Appendix 2: Lexicon for Beef Flavour

Flavour: The amount of fully meaty flavour present in the sample.

The panelists were asked to evaluate the flavour on the 8th chew of the first cube. The lexicon used to explain the definition of beef flavour to panelists is based on Maughan (2011) where beef flavour can contain elements that are astringent, barny, bloody, brothy, browned, gamey, grassy, juicy, fatty, livery, metallic, oxidized, roast beef, bitter, sweet, sour, umami, and rancid. However not all of these descriptors are considered positive flavour attributes. The panellists discussed and decided that barny, bitter, sour, and rancid should be considered as off flavours if detected in the sample. Flavour was rated on a 10 cm scale with 1 = weak beef flavour and 10 = intense beef flavour.

3.4.3 Appendix 3: Ranking of Off Flavour

Description of the Ranking of Off Flavour

0 = no off flavour

2 = very slight off flavour, only a trained panelist would detect the presence of any off flavour, still acceptable

4 = slight but definite off flavours

6 = moderate off-flavours

8 = strong off flavours, unacceptable beef flavour

10 = very strong off flavours, major defect such that product would be discarded
3.4.4 Appendix 4: Meat Cuts Used for Panel Training

Description of Beef Cuts Used During Training

Beef Flavor and Juiciness Description

Training day 1: Flavour and Juiciness

Training Day 1, Test 1: Ranking beef broth on level of beef flavour

1. Beef broth-stock solution 100%
2. Beef broth-(800 ml stock/200ml water) 80%
3. Beef broth-(600ml stock/400 ml water) 60%
4. Beef broth-(400 ml stock/600 ml water) 40%
5. Beef broth-(200 ml stock/800 ml water) 20%

Training Day 1, Test 2: Evaluate 3 samples of beef and rate beef flavour

Cow *Psoas major* (tenderloin) (28 day aged); shear force (SF) = 3.396

*Longissimus et thoracis* (Rib eye) steak; SF = 4.472

*Longissimus et thoracis* (Rib eye) steak; SF = 4.871

Training Day 1, Test 3: Evaluate samples for juiciness

Juicy high fat burgers (juicy)

*Longissimus et thoracis* (Rib eye) steak (intermediate) (striploins 14 day aged)

*Semitendinous* (not juicy)

Training Day 2: Tenderness and Softness

Training Day 2, Test 1: Evaluate tenderness

*Longissimus et lumborum* (Strip loin) roasts aged 28 days (tender); SF = 2.346

*Longissimus et thoracis* (Rib eye) steak (intermediate); SF = 3.605

*Longissimus et thoracis* (Rib eye) steak (tough); SF = 6.173

Training Day 2, Test 2: Evaluate softness

*Longissimus et lumborum* (Strip loin) roasts aged 28 days (soft)

*Longissimus et thoracis* (Rib eye) steak- (intermediate)

*Semitendinous* steaks (hard)
Training Day 2 Test 3: Evaluate both tenderness and softness

*Longissimus et thoracis* (rib eye) steak from steer 3A (intermediate in tenderness); SF = 3.621
*Longissimus et thoracis* (rib eye) steak from steer 24A (intermediate in tenderness); SF = 4.267
*Longissimus et lumborum* (Strip loin) roasts (tender); SF = 2.9

Training Day 3: Chewiness and Rate of Breakdown

Training Day 3, Test 1: Evaluate chewiness

*Semitendinous* steaks (very chewy)
*Longissimus et thoracis* Ribeye steak (intermediate)
*Longissimus et lumborum* Striploin Roast aged 28 days (not chewy)

Training Day 3, Test 2: Evaluate chewiness

*Longissimus et lumborum* Striploin Roast aged 28 days (not chewy)
*Longissimus et thoracis* Ribeye steak (intermediate)
*Longissimus et thoracis* Ribeye Steak (tough and chewy)

Training Day 3, Test 3: Evaluate rate of breakdown

*Longissimus et thoracis* (Rib eye) steak (intermediate); SF = 3.657
*Longissimus et thoracis* (Rib eye) steak (intermediate); SF = 4.641
*Longissimus et lumborum* (Strip loin) (tough); SF = 7.062

Training day 4: Evaluate Tenderness, Juiciness and Flavour on line scale

Training day 4 Test 1: Evaluate Tenderness
*Longissimus et thoracis* (Rib eye) steaks (tender); SF = 2.296
*Longissimus et lumborum* (Strip loin) (intermediate); SF = 4.081 or 4.115
*Longissimus et thoracis* (Rib eye) steak (tough); SF = 6.004
Training Day 4 Test 2: Evaluate Juiciness

Cow *psoas* major (tenderloin) steaks; SF = 3.396  
*Longissimus et thoracis* (Ribeye) steak; SF = 3.233  
*Longissimus et lumborum* (Strip loin); SF = 7.577

Training Day 4 Test 3: Evaluate flavour

Cow *Psoas major* (tenderloin) steaks  
*Longissimus et thoracis* (Ribeye) steak; SF = 3.233  
*Longissimus et lumborum* (Strip loin); SF = 7.577

Mock Trial day 1

*Longissimus et thoracis* (Ribeye); SF = 1.929  
*Longissimus et lumborum* (Strip loin); SF = 7.689  
*Longissimus et lumborum* (Strip loin); SF = 5.479  
*Longissimus et thoracis* (Ribeye); SF = 3.457  
*Longissimus et thoracis* (Ribeye); SF = 5.017  
*Longissimus et lumborum* (Strip loin); SF = 4.579

Training Day 5: Off flavour training and mock trial for all attributes

Training Day 5 Test 1: Off flavour

Steaks marinated in citric acid  
Hamburger (50/50) with venison  
Hamburger (80/20) with venison

Mock Trial day 2

*Longissimus et thoracis* (Ribeye); SF = 5.736  
*Longissimus et thoracis* (Ribeye); SF = 2.823  
*Longissimus et thoracis* (Ribeye); SF = 2.489  
Rounds; SF = 6.092  
*Longissimus et thoracis* (Ribeye); SF = 3.434  
*Longissimus et thoracis* (Ribeye); SF = 4.7
Mock Trial Day 3
Longissimus et thoracis (Ribeye); SF = 2.794
Longissimus et lumborum (Strip loin); SF = 4.115
Longissimus et thoracis (Ribeye); SF = 2.987
Longissimus et thoracis (Ribeye); SF = 3.349
Longissimus et lumborum (Strip loin); SF = 3.548
Longissimus et lumborum (Strip loin); SF = 6.829

Mock Trial Day 4
Longissimus et lumborum (Strip loin); SF = 5.479
Longissimus et thoracis (Ribeye); SF = 2.584
Longissimus et thoracis (Ribeye); SF = 2.655
Longissimus et lumborum (Strip loin); SF = 4.532
Longissimus et lumborum (Strip loin); SF = 5.924
Longissimus et thoracis (Ribeye); SF = 2.99

Mock Trial Day 5
Roast Round
Roast Round
Roast Round
Roast Round
Roast Round
Roast Round
3.4.5 Appendix 5: Crude Protein in High Grain Diet

<table>
<thead>
<tr>
<th>Sample #</th>
<th>Corn (g/kg)</th>
<th>Hay (g/kg)</th>
<th>Pellets (g/kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>8.74</td>
<td>10.67</td>
<td>45.16</td>
</tr>
<tr>
<td>2</td>
<td>8.61</td>
<td>11.37</td>
<td>43.19</td>
</tr>
<tr>
<td>3</td>
<td>9.00</td>
<td>13.46</td>
<td>N/A</td>
</tr>
<tr>
<td>4</td>
<td>N/A</td>
<td>7.20</td>
<td>N/A</td>
</tr>
</tbody>
</table>

*Individual ingredients were sampled when a new hay bale was chopped, corn bin was re-filled from larger corn bin or when a new tote of pellet was delivered from feed mill.*
### 3.4.6. Appendix 6: Weather for Duration of the Trial

#### Weather Summary for New Liskeard Agricultural Research Station (Summer, 2015)

<table>
<thead>
<tr>
<th>Month</th>
<th>Average °C</th>
<th>Minimum °C</th>
<th>Maximum °C</th>
<th>Precipitation (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>May</td>
<td>13</td>
<td>-5</td>
<td>30</td>
<td>48</td>
</tr>
<tr>
<td>June</td>
<td>15</td>
<td>0</td>
<td>26</td>
<td>39</td>
</tr>
<tr>
<td>July</td>
<td>18</td>
<td>5</td>
<td>33</td>
<td>38</td>
</tr>
<tr>
<td>August</td>
<td>18</td>
<td>8</td>
<td>30</td>
<td>91</td>
</tr>
<tr>
<td>September</td>
<td>15</td>
<td>-1</td>
<td>28</td>
<td>68</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td></td>
<td></td>
<td>284</td>
</tr>
</tbody>
</table>

Weather data were collected by the agronomy unit staff. Weather data equipment was located on the research station.
### 3.4.7 Appendix 7: Management Regimen Effects on Growth Performance for Cattle Fed in Drylot or on Pasture with No Covariate

<table>
<thead>
<tr>
<th>Trait^w</th>
<th>0%</th>
<th>0.5%</th>
<th>1%</th>
<th>High Grain</th>
<th>SE</th>
<th>P-value</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>L</th>
<th>Q</th>
</tr>
</thead>
<tbody>
<tr>
<td>Starting Body Weight (kg)</td>
<td>448.5</td>
<td>451.7</td>
<td>453.2</td>
<td>434.1</td>
<td>10.48</td>
<td>0.569</td>
<td>0.854</td>
<td>0.541</td>
<td>0.203</td>
<td>0.757</td>
<td>0.954</td>
</tr>
<tr>
<td>Final Body Weight (kg)</td>
<td>546.3</td>
<td>578.2</td>
<td>596.4</td>
<td>623.3</td>
<td>14.04</td>
<td>0.003</td>
<td>0.002</td>
<td>0.076</td>
<td>0.183</td>
<td>0.012</td>
<td>0.686</td>
</tr>
<tr>
<td>Total Gain (kg)</td>
<td>97.7</td>
<td>126.5</td>
<td>143.2</td>
<td>189.2</td>
<td>6.95</td>
<td>&lt;0.0001</td>
<td>&lt;0.0001</td>
<td>&lt;0.0001</td>
<td>&lt;0.0001</td>
<td>&lt;0.0001</td>
<td>0.394</td>
</tr>
<tr>
<td>ADG (kg)</td>
<td>0.88</td>
<td>1.14</td>
<td>1.29</td>
<td>1.70</td>
<td>0.06</td>
<td>&lt;0.0001</td>
<td>&lt;0.0001</td>
<td>&lt;0.0001</td>
<td>&lt;0.0001</td>
<td>&lt;0.0001</td>
<td>0.394</td>
</tr>
</tbody>
</table>

^Management Regimen includes: 0% Corn = cattle on alfalfa pasture only and were not fed corn; 0.5% Corn = cattle on alfalfa pasture fed whole grain corn at 0.5% BW (as-fed basis); 1% Corn = cattle on alfalfa pasture fed whole corn grain at 1% BW (as-fed basis); High Grain = cattle fed high grain diet in drylot.

^Contrasts include: 1 = cattle fed no corn on pasture vs. cattle fed corn (on pasture or in drylot); 2 = corn fed at 0.5% BW vs. cattle fed greater amounts of corn; 3 = pastured cattle fed corn at 1% BW vs. drylot cattle fed a high grain diet; Linear (L) and Quadratic (Q) examines the linear and quadratic effects respectively of increasing the amount of corn offered on pasture.

^xBody weight at the start of the trial (SOTBW) was included in the model as a covariate and was retained in the final model when significant at P<0.05. If the covariate was not found to be significant, the cell is labeled N/A for not applicable or not appropriate for the specific trait.

^wTraits include: Starting and Final Body Weights (body weights of steers at the start and end of trial as measured on two consecutive days), Total Gain (body weight gained in kg over the 111 day trial), Average Daily Gain (average weight gained per day in kg).
3.4.8. Appendix 8: Management Regiment Effects on Carcass Traits for Cattle Fed in Drylot or on Pasture with No Covariate

<table>
<thead>
<tr>
<th>Trait</th>
<th>Management Regimen(^{a})</th>
<th>Amount of Corn Supplemented on Pasture (% BW as-fed Basis)</th>
<th>Drylot</th>
<th></th>
<th>P-value for Contrasts(^{a})</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>0%</td>
<td>0.5%</td>
<td>1%</td>
<td>High Grain</td>
</tr>
<tr>
<td>HCW (kg)</td>
<td></td>
<td>304.2</td>
<td>316.5</td>
<td>331.5</td>
<td>347.3</td>
</tr>
<tr>
<td>Grade Fat (mm)</td>
<td></td>
<td>9.9</td>
<td>10.7</td>
<td>11.8</td>
<td>13.5</td>
</tr>
<tr>
<td>LMA (cm(^2))</td>
<td></td>
<td>75.6</td>
<td>78.2</td>
<td>77.8</td>
<td>77.4</td>
</tr>
<tr>
<td>LMA (cm(^2)/100kg HCW)</td>
<td></td>
<td>24.0</td>
<td>24.2</td>
<td>23.9</td>
<td>23.8</td>
</tr>
<tr>
<td>Body Composition via Rib Dissection (%)</td>
<td>Lean</td>
<td>53.0</td>
<td>51.0</td>
<td>50.6</td>
<td>47.3</td>
</tr>
<tr>
<td></td>
<td>Fat</td>
<td>22.9</td>
<td>25.7</td>
<td>27.0</td>
<td>32.1</td>
</tr>
<tr>
<td></td>
<td>Bone</td>
<td>24.3</td>
<td>23.2</td>
<td>22.4</td>
<td>20.1</td>
</tr>
<tr>
<td>Fat Partitioning via Rib Dissection (%)</td>
<td>Body Cavity</td>
<td>0.178</td>
<td>0.212</td>
<td>0.231</td>
<td>0.249</td>
</tr>
<tr>
<td></td>
<td>Subcutaneous</td>
<td>0.5</td>
<td>0.6</td>
<td>0.6</td>
<td>0.8</td>
</tr>
<tr>
<td></td>
<td>Intermuscular</td>
<td>0.5</td>
<td>0.5</td>
<td>0.6</td>
<td>0.8</td>
</tr>
<tr>
<td>Marbling</td>
<td></td>
<td>389.1</td>
<td>362.1</td>
<td>374.9</td>
<td>434.5</td>
</tr>
<tr>
<td>Intramuscular Fat Content for Longissimus, %</td>
<td></td>
<td>3.63</td>
<td>3.09</td>
<td>4.1</td>
<td>4.4</td>
</tr>
<tr>
<td>CBGA Lean Yield %</td>
<td></td>
<td>61.4</td>
<td>61.3</td>
<td>60.5</td>
<td>58.6</td>
</tr>
<tr>
<td>CBGA Lean Yield Grade Class</td>
<td></td>
<td>1.1</td>
<td>1.2</td>
<td>1.2</td>
<td>1.2</td>
</tr>
<tr>
<td>CBGA Quality Grade</td>
<td></td>
<td>2.7</td>
<td>2.7</td>
<td>2.6</td>
<td>2.4</td>
</tr>
</tbody>
</table>

\(^{a}\)Traits include HCW (hot carcass weight), LMA (longissimus muscle Area) as cm\(^2\) or cm\(^2\)/100 kg HCW, Body Composition and Fat Partitioning via Rib Dissection, Marbling (degree of marbling where: practically devoid = 200 to 299, traces = 300 to 399, slight = 400 to 499; small = 500 to 599; modest = 600 to 699), Intramuscular Fat Content for Longissimus, % determined via fat extraction, Canadian Beef Grading Agency (CBGA) Lean Yield, Yield Grade Class, and Quality grade. CBGA Yield Grade (YG) data were coded before statistical analysis was conducted as follows: YG1 = > 59% lean yield, YG 2 = 54-58% lean yield; YG 3 = < 53% lean yield. CBGA Quality Grade data were coded before statistical analysis as follows: Prime = 1, AAA = 2, AA = 3, A = 4.

\(^{b}\)Management Regimen includes: 0% Corn = cattle on alfalfa pasture only and were not fed corn; 0.5% Corn = cattle on alfalfa pasture fed whole grain corn at 0.5% BW (as-fed basis); 1% Corn = cattle on alfalfa pasture fed whole corn grain at 1% BW (as-fed basis); High Grain = cattle fed high grain diet in drylot.

\(^{c}\)Contrasts include: 1 = cattle fed no corn on pasture vs. cattle fed corn (on pasture or in drylot); 2 = corn fed at 0.5% BW vs. cattle fed greater amounts of corn; 3 = pastured cattle fed corn at 1% BW vs. drylot cattle fed a high grain diet; Linear (L) and Quadratic (Q) examines the linear and quadratic effects respectively of increasing the amount of corn offered on pasture.
### 3.4.9 Appendix 9: Management Regimen Effects on Sensory Attributes of *Longissimus* Muscle Steaks from Cattle Fed in Drylot or on Pasture with No Covariate

<table>
<thead>
<tr>
<th>Trait</th>
<th>Management Regimen</th>
<th>Amount of Corn Supplemented on Pasture (% BW as-fed Basis)</th>
<th>P-value for Contrast</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Drylot</td>
<td>High Grain</td>
<td>1%</td>
</tr>
<tr>
<td>Softness</td>
<td></td>
<td>5.7</td>
<td>6.4</td>
</tr>
<tr>
<td>Tenderness</td>
<td></td>
<td>5.9</td>
<td>6.5</td>
</tr>
<tr>
<td>Initial Juiciness</td>
<td></td>
<td>5.4</td>
<td>4.8</td>
</tr>
<tr>
<td>Beef Flavour</td>
<td></td>
<td>5.4</td>
<td>5.5</td>
</tr>
<tr>
<td>Chewiness</td>
<td></td>
<td>4.9</td>
<td>4.1</td>
</tr>
<tr>
<td>Overall Juiciness</td>
<td></td>
<td>5.4</td>
<td>4.9</td>
</tr>
<tr>
<td>Rate of Breakdown</td>
<td></td>
<td>4.9</td>
<td>5.7</td>
</tr>
<tr>
<td>Off Flavour</td>
<td></td>
<td>1.1</td>
<td>1.1</td>
</tr>
</tbody>
</table>

Management Regimen includes: High Grain = cattle fed high grain diet in drylot; 1% Corn = cattle on alfalfa pasture fed whole corn grain at 1% BW (as-fed basis); 0.5% Corn = cattle on alfalfa pasture fed whole grain corn at 0.5% BW (as-fed basis); 0% Corn = cattle on alfalfa pasture only and were not fed corn.

Contrasts include: 1 = cattle fed no corn on pasture vs. cattle fed corn (on pasture or in drylot); 2 = pastured cattle fed corn at 0.5% BW vs. cattle fed high corn (pastured cattle fed at 1% BW and cattle in drylot); 3 = pastured cattle fed corn at 1% BW vs. drylot cattle fed a high grain diet.
3.5 Works Cited


Shepherd, L.M.K. 2013. The effects of method of forage-finishing and cattle breed on growth performance, carcass characteristics, meat quality and fatty acid composition. Thesis from the University of Guelph. atrium.lib.uoguelph.ca/xmlui/handle/10214/7575


