MANAGEMENT AND ECONOMICS OF GROUP-FED DAIRY CALVES AND DAIRY STEERS IN AN ORGANIC PRODUCTION SYSTEM

A THESIS

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Finds tongues in trees, books in the running brooks,

Sermons in stones, and good in everything.

William Shakespeare

My eyes have been shown the beauty of all that is good because the following people shared their love with me. To all of you, I dedicate this thesis. My parents, to whom I owe all of my accomplishments, for their continual guidance, lessons, hugs, laughter, faith, encouragement, and wisdom. My brother, who has been my constant companion since I arrived in the world, and who has been my role model since I learned the meaning of admiration. My Grandma Mema, a living saint, to whom I have promised to always remain an original. My Grandpa, who introduced me to the preceding Shakespeare quote, and who continues to find good in everything. My Grandma B, whose love for animals is carried on through her granddaughter. All of my relatives, who have inspired me with their achievements and encouraged me to attain my own. My dearest friends, who have loaned me their ears, given me their hearts, offered me their shoulders to lean on, prayed for me, cheered my successes, and most of all, brought me true happiness. Thank you.

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For I know well the plans I have in mind for you, says the Lord,

plans to give you a future full of hope.

Jeremiah 29:11

With you as my guide, Lord, I am ready for what the future holds.

All glory and praise be to God.

ABSTRACT

The objective of this study was to evaluate the effect of early life feeding duration on calf growth, health, and economics of organic dairy calves fed once per day. Heifer calves born during the spring of 2011 (n = 67) and the spring of 2012 (n = 57) were used to evaluate the effect of weaning age, growth, and profitability of group-fed calves in an organic dairy production system. Calves were assigned to replicate feeding groups of ten in super hutches by birth order, and were born at the University of Minnesota West Central Research and Outreach Center, Morris organic dairy. Breed groups were Holsteins (n = 15) selected for high production (HO), Holsteins (n = 23) maintained at 1964 breed average level (H64), crossbreds (n = 54) including combinations of HO, Montbéliarde, and Swedish Red (HMS), and crossbreds (n = 32) including combinations of HO, Jersey, and Swedish Red (HJS). Groups of calves were weaned at 30 (EW), 60 (MW), or 90 (LW) d of age, and groups were fed 1.5% of birth weight of 13% total solids organic whole milk once daily and weaned when the group of ten calves consumed an average of 0.91 kg starter/calf/day for four consecutive days. Body measurements were recorded at birth, weekly during the pre-weaning period, at weaning, and monthly thereafter, and profitability was estimated as a function of the total cost for organic milk and grain for weaning groups to weaning and to the first 90 days of age. Pre-weaning group performance was weaning age (d), EW (47.6), MW (64.5), LW (93.7); gain per day (kg), EW (0.51), MW (0.63), LW (0.75); and weaning weight (kg), EW (61.8), MW (79.2), LW (108.1). There were no significant differences in body weight (kg) for weaning groups at 90 days of age; however, MW calves had significantly lower 120-d body weight (kg) than LW calves, but EW calves did not differ from either MW or LW calves for 120-d body weight. Total feed costs to weaning were $1,092.97 for EW, $1,871.24 for MW, $2,956.64 for LW groups of calves; however, the cost per kg of gain was significantly higher for the EW ($5.54) group than the MW ($4.60) or LW ($4.14) groups during the pre-weaning period. Total costs and cost per kg of gain for the first 90-d of age were lowest for EW and highest for LW.

(**Key words:** group housing, organic dairy, performance, profitability)

Bull calves (n = 49) were used to compare growth measurements of conventional and organic dairy steers. Calves were assigned to one of three groups at birth; conventional (**CONV**, n = 16), organic (pasture and concentrate, **ORG**, n = 16), and organic-grass only (**GRASS**, n = 17), and were born at the University of Minnesota West Central Research and Outreach Center, Morris from March to May 2011. Breed groups of calves were: Holstein (n = 9), Holsteins (n = 11) maintained at 1964 breed average level, crossbreds (n = 19) that included combinations of Holstein, Montbéliarde, and Swedish Red (HMS), and crossbreds (n = 10) that included combinations of HO, Jersey, Swedish Red, and Normande (HJSN). The CONV steers were fed a diet of 80% concentrate and 20% roughage. The ORG steers were fed a diet of organic corn, organic corn silage, and at least 30% of their diet consisted of organic pasture during the grazing season. The GRASS steers grazed pasture during the grazing season and were fed high quality hay or hay silage during the non-grazing season. Feed intakes were recorded daily with herd management software. A profit function was defined to include revenues and expenses for beef value, feed intake, pasture intake, health cost, and yardage. The GRASS (358.6 kg) steers had significantly lower gain from birth to slaughter than ORG

(429.6 kg) and CONV (534.5 kg) steers. Furthermore, the GRASS (0.61 kg/d) steers had significantly lower average daily gain compared to ORG (0.81 kg/d) and CONV (1.1 kg/d) steers. Both organic steer groups had significantly smaller ribeye area (49.5 cm^2, 65.8 cm^2, respectively) compared to CONV (75.4 cm^2) steers. For profitability, GRASS steers had 25% greater profit per steer, than CONV steers. On the other hand, ORG steers had 169% less profit per steer than CONV steers. The higher cost of production for the ORG steers is due to the extreme high value of organic corn. The results of the current study suggest there may be a potential market for the male offspring of organic dairy cattle in the Midwest.

(**Key words:** organic, dairy beef, pasture, economics)

Holstein and crossbred dairy steers were evaluated for fatty acid profiles, meat quality, sensory attributes, and consumer acceptance of organic dairy-beef compared to conventional dairy-beef. Calves (n=49) were randomly assigned to one of three replicated groups (conventional (CONV), organic (ORG, pasture + concentrates), and grass-fed organic (GRASS)) and were born at the University of Minnesota West Central Research and Outreach Center, Morris, Minnesota from March to May 2011. The CONV steers (n = 16) were fed a diet that contained 80% concentrate and 20% roughage, and ORG steers (n = 16) were fed a diet of organic corn, organic corn silage, and organic protein supplement. Furthermore, ORG steers consumed at least 30% of diet dry matter in high-quality organic pasture during the grazing season. The GRASS steers (n = 17) consumed 100% forage from pasture during the grazing season and high-quality hay or hay silage during the non-grazing season. The ORG (46.9%) steers had fat that was significantly higher in oleic acid (C18:1) than the GRASS (35.7%) and CONV (37.8%) steers. The GRASS steers (22.9%, 1.3%) were significantly lower for monounsaturated and polyunsaturated fat than the ORG (42.9, 2.4%) and CONV (39.4%, 3.1%) steers, respectively. Furthermore, the GRASS steers were significantly higher for omega-3 fat and significantly lower for omega-6 fat than the ORG and CONV steers. Consequently, the GRASS (1.6%) steers had a significantly lower omega-6 to omega-3 fat ratio than the ORG (10.1%) and CONV (13.8%) steers. For sensory attributes, there were no significant differences for ORG (71.3) and CONV (69.2) steers for overall liking; however, the GRASS (56.3) steers had the lowest overall liking among beef consumers. The ORG (73.3) steers had significantly higher flavor liking than the GRASS (56.8) and CONV (69.2) steers. Conversely, the GRASS (6.3) steers had the highest scores for off-flavor compared to the ORG (3.9) and CONV (4.1) steers. The results of the current study suggest there may be a potential market for organic grass-fed dairy steers in the United States.

(**Key words:** organic, dairy steer, beef, grass-fed, omega-3 fatty acid)

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INTRODUCTION

Organic Dairy Production in the United States

The United States Department of Agriculture's National Organic Program (**NOP**) defines organic as a labeling term that declares a particular agricultural product has been produced through approved methods which "incorporate cultural, biological, and mechanical practices that foster cycling of resources, promote ecological balance, and conserve biodiversity" (USDA, 2012a). The standards of the NOP Final Rule became effective October 21, 2002 (USDA National Organic Program, 2012). These standards address production, processing and labeling, certification, recordkeeping, and inputs allowed in organic farming and processing. In order to assure that the guidelines are being upheld, products of organic agriculture are certified by a USDA accredited organization to ensure that the product was grown and processed within the NOP Standards (Moynihan, 2010).

Livestock in organic production systems are to be provided a mandatory organic feed ration, and ruminants six months of age and older must receive 30% of their dry matter intake from pasture for at least 120 days during the grazing season each year (NOP, 2012). Pasture and land in production for organic crops must not have had any prohibited substances, such as synthetic fertilizers or pesticides applied to land 3 years prior to the first use of the crop for organic purposes (NOP, 2012).

Dairy animals for organic milk production must be managed under organic practices from at least the last third of gestation (NOP, 2012). There are no acceptable calf milk replacer products for use in an organic system (OMRI, 2009). Hormones for growth and antibiotics are unallowable substances for use in organic livestock production; however, medical treatment must not be withheld from an animal that is in need of healing methods beyond the scope of organic treatments. Livestock treated with non-organic methods will no longer be qualified as organic (USDA, 2000c).

Nationally, the organic dairy industry has experienced growth in the number of certified organic milk cows at a rate of 553% from the years 2000 to 2008 (USDA, 2010). Minnesota, in particular, is home to over 10,000 certified organic milk cows (USDA, 2012b).

Whole milk feeding

Liquid feed choices for intensively managed dairy farms include (raw or pasteurized) saleable or nonsaleable (waste) whole milk, and commercial milk replacer products (Godden et al., 2005). Nonsaleable whole milk is from fresh cows, ill cows, or medically treated cows. Godden et al. (2005) estimate that around 22 to 62 kg of milk per cow from United States dairy operations is marked and disposed of as nonsaleable each year. Nonsaleable milk is used for some manner of feeding on 87.2% of dairy operations in the United States, whereas milk replacer is provided to calves on approximately 59% of United States dairies (Godden et al., 2005).

Although an inexpensive product, using waste milk for calf feeding can be a concern to dairy producers due to the likelihood of heightened bacterial counts (Moore et al., 2009). Bacterial contamination may stem from milk from a cow with mastitis or lack of cleanliness throughout the milking, handling, and storing of the milk (Moore et al., 2009). Feeding raw waste milk could put a calf at risk of exposure to infectious agents

(Godden et al., 2005). Therefore, it is recommended that waste milk intended for calf feeding be pasteurized to reduce the concentration of bacteria (Hoffman et al., 2003).

Moore et al. (2009) found nonsaleable milk quality differed greatly among samples and many had a low percentage of total solids. Because whole milk contains around 5.4 Mcal of metabolizable energy per kg of solids, a 45 kg calf has a daily need for 2.6 kg of milk for the sole purpose of maintenance (Khan et al., 2011). According to University of Minnesota Extension (2011), dairy calves in the first week of life should be provided with 1.5% of body weight as total milk solids, and 2% of body weight from 2 wk of age until the weaning period begins. The assumed advantage to feeding whole milk is that calves will ingest more calories than those fed the same volume of milk replacer at a 20% protein:20% fat ratio (Moore et al., 2009).

In a nursing period study by Shamay et al. (2005), milk fed calves consumed greater amounts of dry matter, crude protein, and metabolizable energy than the calves fed milk replacer. Weight gain, wither height, heart girth, and hip width were significantly greater in the milk fed calves compared to the milk replacer fed calves at 60 d of age. Milk fed calves in this trial also reached puberty 23-d earlier than did calves fed milk replacer.

Godden et al. (2005) found dairy calves had greater growth rates and fewer health problems when fed pasteurized nonsaleable milk rather than conventional milk replacer. The crude protein to crude fat ratio of the whole milk fed was 25.6:29.6, whereas the ratio was 20:20 for the milk replacer product. Therefore, the milk fed calves were consuming more Mcal of metabolizable energy a day than those fed milk replacer. Greater pre-weaning total weight gain and average daily gains in calves fed pasteurized nonsaleable milk may be explained by the consumption of higher levels of protein and energy in the milk fed group. Decreased health problems and mortality in the milk fed group may be attributed to more immunoglobulin and immune factors in the whole milk.

Group housing

Although individual calf housing is the most popular housing method used on United States dairies, group housing systems are becoming more widespread (USDA, 2010). The benefits of group housing include socialization among the calves and reduced labor and bedding costs (Moore et al., 2010). Full social contact is valuable to calves, as social animals, and will aid in the development of social skills (Jensen et al., 2006).

For group housing systems where animals are in close contact to each other, disease has the capability of spreading rapidly. Therefore, only healthy calves should enter and any sick calves should be removed from a group housing arrangement. It is important for the calf management team to be observant and attentive to each individual calf's health status in a group pen. Group housing should only be an option for those calves that possess adequate passive immunity (Quigley, 2010).

Cross-sucking, which is sucking on another calf's head or body, can be an issue in group housing (Jensen et al., 2006). Research by Jensen et al. (2006) found calves spent more time cross-sucking other pen mates and licking objects in the pen when bucket fed rather than teat fed their milk. The teat fed calves spent more time consuming the milk and then continued to suck on the empty teat after feeding. Bucket fed calves were observed to leave the bucket when empty, and consequently, sucked on other calves in the pen.

Calves in group housing have differing growth rates than those housed individually (Bernal-Rigoli et al., 2012), and calves in pens of 4 had greater dry matter intake and higher body weights at weaning than calves housed individually. De Paula Vieira et al. (2010) found calves raised in pairs consumed more starter in the pre-weaning period than calves housed in individual pens. Furthermore, grouped calves had greater feed intake, higher weight gain, and reduced negative behavioral responses than did individually housed calves (De Paula Vieira et al., 2010).

Once a day feeding

Most dairy calves in the United States are fed at least twice daily (USDA, 2010b); however, once-a-day milk feeding of calves may reduce labor costs. Galton et al. (1976) reported feeding calves once per day required about 40% less labor than calves fed 2 times per day. Stanley et al. (2002) found feeding milk replacer once versus twice daily to dairy calves had no adverse effects on weight gain. The authors concluded that starter consumption, weight gain, and glucose metabolism were not adversely affected by feeding milk replacer once or twice daily to calves. Furthermore, Kehoe et al. (2007) found that feeding calves milk once a day may provide economic benefit to dairy farms, with no adverse growth effects for calves.

Weaning

The most important consideration for weaning calves is degree of rumen development. Rumen development is adequate and calves are ready to be weaned when calves consume 0.91 to 1.36 kg of grain daily, eat hay or forage, and have adequate body condition (Hoffman et al., 2003). The most common weaning age of calves on dairy farms in the United States is between 6 and 8 weeks of age (USDA, 2010b); however, de

Passille et al. (2011) found that calves weaned at 12 or 13 weeks of age had greater growth rates and decreased signs of hunger during weaning and post-weaning. Rather than weaning at a certain age, de Passille et al. (2011) recommended weaning based on solid feed intake. Calves that consume 1.3 to 1.5% of their body weight in dry feed are candidates for weaning (Hoffman et al., 2003). Research by Khan et al. (2011b) demonstrated that supplementing chopped hay to calves fed high amounts of milk in the pre-weaning period increased solid feed intake and rumen development.

Roth et al. (2009) recommended a concentrate-dependent weaning method (milk feeding reduced based on grain consumption compared to weaning at 12 wk of age). The milk was gradually reduced beginning at 8 wk of age in the conventional group, and was completely removed at 12 wk of age. Milk began to be reduced in the concentrate-dependent group when calves consumed 700 g or more of grain daily for 4 consecutive days, and milk was removed when calves consumed 2000 g or more of concentrate daily for 4 d consecutively. Results of the study found that calves were weaned at a younger age on the concentrate-dependent treatment compared to conventional 12 wk weaning. Roth et al. (2009) recommended that producers should apply a concentrate-dependent weaning method to attend to the nutritional needs of calves.

Gradual weaning compared to immediate weaning is different because gradual weaning greatly increases solid feed intake in pre-weaned calves due to gradual milk reduction, and thus calves will maintain a nutrient balance at weaning which lessens any negative growth effects (Khan et al., 2011a). Calves at 14 d of age begin eating significant amounts of solid feed and consume more as a consequence of reduction in milk allowance. Although concentrate consumption begins at a young age, calves gradually weaned at 19 d of age did not receive adequate amounts of nutrients from an increased intake of grain in response to the end of milk feeding. However, calves over 3 wk of age were observed to effectively increase concentrate intake when milk provision was gradually decreased (Khan et al., 2011a).

Calf growth

Growth measurements are a successful way to monitor calf health and development. Body condition score assesses the amount of fat on a calf's body (Wildman et al., 1982), and body condition score affects health, productivity, reproduction, and longevity (Shamay et al., 2005).

Furthermore, growth of calves can be tracked by body weights, hip and wither heights, and heart girths. In a study by Shamay et al. (2005), milk fed calves and milk replacer fed calves were compared using parameters of growth. Skeletal measurements of the milk fed calves were significantly greater than those of the milk replacer calves at 180 d of age. From 180 to 550 d of age the body weights of the calves fed whole milk were significantly greater than those of the calves fed milk replacer.

Profitability

Raising heifers, either conventional or organic, is an expensive investment for a dairy operation, and therefore, early life feeding of calves is critical to the subsequent productivity and longevity of the dairy cow (Soberon et al., 2012). After feed cost, raising replacement heifers is the second largest expense for a dairy farm, accounting for 25% of the total costs of milk production (Zwald et al., 2007). The cost of feeding pre-weaned organic calves may depend largely upon how much nonsalable or saleable milk is fed to calves. According to Moore et al. (2009) the best feed for calves is whole milk, although using this product, which is normally sold for human consumption, can be an economical loss in calf raising. For raising healthy dairy calves, costs must be taken into account (Godden et al., 2005). Therefore, the use of milk replacer as a less expensive alternative to whole milk has been widely accepted as a nutritious feed source, as well as the feeding of nonsaleable waste milk (Moore et al., 2009). Results from a budget analysis by Godden et al. (2005) determined that there is a positive economic outcome when feeding calves pasteurized nonsaleable milk versus milk replacer. Greater growth rates and fewer health issues were observed in calves fed pasteurized nonsaleable milk than those fed milk replacer, which led to higher economic gains.

Organic beef livestock production in the United States

Hormones and antibiotics are not allowed for use in organic livestock production; however, antibiotic treatment must not be withheld from an animal when all organic treatment methods have been exhausted and therefore, livestock treated with non-organic methods will no longer be qualified as organic (USDA, 2000c). Beef labeled and sold as organic must be harvested at a plant that is certified organic and state or federally inspected (Rinehart, 2011).

One of the goals of organic agriculture is to limit the use of chemicals, growth enhancers, and feed additives without negatively affecting production and profitability (Fernandez, 1999). Organic farmers strive to achieve sustainability by preserving the environment, producing a sufficient amount of food, and ensuring a healthy living for the producer and subsequent generations (Fernandez, 1999). The market for organic beef is growing rapidly in the United States (Rinehart, 2011). In the European Union, organic beef production from the calves of dairy cows have not seen a similar increase in numbers (Nielsen, 2002).

Dairy beef

There has been recent action in the United States beef industry to include production of top quality dairy beef, mostly from Holstein bull calves (Comerford, 2008). Holstein bull calves have value in the market when raised on a high energy ration and weigh 522 to 590 kg at harvest (Comerford, 2008). Holstein steers differ from contemporary beef breeds because they require a higher plane of nutrition for maintenance, are more prone to environmental stress, have more feet and leg issues, marble more thoroughly with less external fat, and have less muscling (Anderson, 1991). Although Holstein cattle comprise the majority of the dairy beef harvested, Jersey bull calves are known for producing well-marbled beef, often with higher kidney, pelvic, and heart (KPH) fat in steers compared with Holstein steers (Arnett, 2011). Jersey steers are slower growing than Holstein steers, and Jersey steers have lighter carcass weights and less muscle area than conventional beef breeds (Arnett, 2011).

Implementation of a beef program on a dairy farm provides the producer a way to expand his/her operation and achieve added profit (Fanatico, 2000). Dairy bull calves are commonly sold off the farm at 2 to 5 days of age. However, producers, especially small scale farmers, have the opportunity to increase profit by raising bulls calves for beef while utilizing existing infrastructure on the farm (Comerford, 2008). Feeding forages and grazing pasture can be an effective way to rear dairy steers, as well as yield a naturally lean product that could be direct-marketed (Fanantico, 2000).

Although dairy-beef may present an additional enterprise for organic dairies, a survey in Denmark found that only 10-15% of organic dairy bull calves in Denmark are harvested as organic (Nielsen, 2002). Because they are considered less profitable than dairy cows, most young bulls are sold to be reared on conventional farms. This can be viewed as an ethical problem for organic agriculture, which is meant to achieve more holistic production methods without involvement of conventional practices. Across a year in Denmark, 66% of organic dairy bull calves are sold to conventional farms; however, the survey found that most organic producers would have liked to keep the calves on their own operation. Limited infrastructure and livestock feed prevented farmers from retaining the cattle, although farmers voiced concern that selling bull calves to conventional farms was counterintuitive to organic principles (Nielsen, 2002).

Conventional beef management

The landscape of American beef production changed in the 1950s as research found more efficient ways of raising cattle that improved marbling and decreased time on feed (Daley et al., 2010). The common feedlot diet for finishing beef cattle is heavily dependent on corn-grain, which comprises 70 to 90% of a finishing cattle ration (Rosmann, 2004). A beef feedlot ration in Minnesota is typically 80% concentrate and 20% roughage, along with mineral supplementation (Anderson, 1991).

Hormones that increase body weight gains are commonly used in feedlot production (Rosmann, 2004). Hormone implants for Holstein steers increased weight gains over non-implanted steers by 0.18 to 0.27 kg/d (Lehmkuhler, 2005). Recommendations indicate Holstein steers should be implanted with estrogen hormones three times after reaching a minimum beginning weight of 91 kg (Anderson, 1991). Lack of re-implantation throughout a feeding period may cause a loss of 9 to 14 kg of marketable weight (Anderson, 1991).

Fernandez et al. (1999) weaned crossbred beef steers from a conventional farm and a low-input farm into either a conventional or organic feedlot system. The authors found that steers finished in the conventional system had faster and more efficient rates of gain, were on feed for a shorter period of time, and feed cost and yardage costs were lower. Woodward et al. (1999) evaluated the carcass characteristics of the steers in this experiment and found the implanted steers had higher carcass weights. Steers in the conventional feedlot had larger ribeye areas, less backfat, and less intramuscular fat than steers in the organic system (Woodward, 1999).

Organic beef management

Prior to the 1940s, beef was generally produced entirely from pasture (Daley, 2010); however, today, the grass-fed beef market comprises 3% of the total beef market in the United States (Rinehart, 2011). Recently, consumers who are becoming increasingly conscious of their eating decisions are turning to grass-fed beef as a healthy meat alternative (Steinberg, 2009). These consumers are aware of research that shows a nutritionally superior fatty acid content in pasture raised animals (Steinberg, 2009; Daley, 2010).

Organic livestock are required to graze forages on pasture which leads to less time in any type of confinement system and more exposure to naturally occurring bacteria (Rinehart, 2011). These cattle are often healthier, have lower death risk, and can be more profitable than conventional livestock (Rinehart, 2011). When grazing forage quality is not optimal, organic beef producers may choose to supplement the diet with grain or high quality hay (Rinehart, 2011). Lehmkuhler (2005) reported when supplementing organic cattle with grain, growth will be maintained, protein and energy of the diet will increase, and therefore, overall animal performance will improve.

The use of hormones and ionophores is unallowable in organic livestock production, and without the use of such management tools, organic cattle grow at slower rates than conventionally managed cattle. Organic animals that were fed pasture with grain supplementation at 0.5% of body weight in early summer and 1.0% in late summer were on feed nearly two months longer than feedlot animals being fed concentrates at 2.0% of body weight. Pastured cattle also produced a lower amount of quality grade Choice animals and had lower dressing percentages than the conventional group (Rosmann, 2004).

Meat quality

The quality of beef is affected by a number of influences. Maturity and genetics of livestock influences meat quality, whereas environmental factors such as feed, exercise, and harvesting protocol also play an important role (Priolo, 2001). Alterations in beef genetics have led to a leaner product for United States beef consumers (Daley, 2010). Livestock diets have perhaps the greatest influence on meat quality, although this may be confounded by differing levels of activity when comparing varying styles of production, for instance, feedlot versus pasture-based farming (Priolo, 2001). With increasing levels of forage in a steer's diet, dressing percentage and degree of backfat for the animal is decreased (Arnett, 2011).

Dairy beef will have less dressing percentage, fewer valued cuts from the rib and loin areas, decreased ribeye area, and a smaller amount of backfat than traditional beef breeds (Fanatico, 2000). However, Holsteins are known to have high marbling, which will often produce quality grades above beef breeds (Fanatico, 2000). The marbling, or intramuscular fat, of an animal is the main determinant when assigning a quality grade to a carcass.

The value of a carcass is highly correlated to hot carcass weight, which is the total weight of the carcass after removing the hide, head, gastrointestinal tract, and internal organs, before the chilling process. The average range of hot carcass weights in United States abattoirs is from 295 to 385 kg (Parish, 2009). Data collection in an abattoir also includes measuring the size of the ribeye area between the 12^{th} and 13^{th} ribs, the percentage of kidney, pelvic, and heart fat, back fat, physiological maturity on an A to E scale (A = 9 to 30 mos., B = 30 to 42 mos., C = 43 to 72 mos., D = 73 to 96 mos., E = 97 or more mos.) based on the appearance of the spinal cartilage and color and shape of the ribs, and intramuscular fat as expressed with the following marbling scores: abundant, moderately abundant, slightly abundant, moderate, modest, small, slight, traces, or practically devoid (Parish, 2009). Following an 18 to 48 hour chilling, beef carcasses are given a yield grade on a 1 (highest percentage of retail product) through 5 (lowest percentage of retail product) scale and a quality grade listed from most to least desirable as Prime, Choice, Select, or Standard (Parish, 2009).

Fatty acid composition in beef

Consumers are becoming more concerned about the quality of food products. Meat, seafood, and eggs are the only foods that supply a human diet with omega-3 long chain polyunsaturated fatty acids which have benefits to human health (Razminowicz, 2006). Higher levels of omega-3 fatty acids in the human diet have been linked to lower incidence of depression, enhancement of immune function, prevention of heart disease, a reduced risk of developing Alzheimer's disease, decreased inflammation due to rheumatoid arthritis, and lower occurrence of memory loss due to aging (Daley, 2010; Poulsen, 2004).

In a study by Razminowicz et al. (2006), beef from grass-fed operations was higher in omega-3 fatty acids and lower in omega-6 fatty acids than beef from conventional operations. Higher forage intake for livestock significantly increases the omega-3 content in the meat without affecting the omega-6 content, thus producing a better balanced ratio. Conjugated linoleic acids are groups of polyunsaturated fatty acids which are beneficial to human health (Razminowicz, 2006). Linoleic acids contribute to reduced cancer rates, lower diabetes risk, and atherosclerosis (Poulson, 2004; Nielsen, 2002; Steinberg, 2009; Daley, 2010). They are a mix of conjugated isomers of linoleic acid and are found in larger quantities in grass-fed steers compared to grain-fed steers (Daley, 2010). Decreasing the amount of concentrates fed to beef cattle increased the level of conjugated linoleic acid expressed in their intramuscular fat (Poulson, 2004). Rosmann et al. (2004) concluded from their study that higher concentrations of conjugated linoleic acid and a lower ratio of omega-6 to omega-3 fatty acids make grass-fed meat with low levels of grain supplementation a healthier alternative than conventionally produced beef.

Sensory characteristics of beef

A majority of beef consumers in the United States prefer the taste of grain-fed beef, and the United States cattle industry most commonly finishes animals on a corn-based ration (Daley, 2010). Conversely, in the European Union beef consumers assert meat from livestock managed under less intensive production systems has a superior taste than meat from intensive production systems (Priolo, 2001). Currently, consumers are evaluating their food-purchasing decisions and are changing to pasture-fed beef as an alternative (Steinberg, 2009). For consumer sensory evaluation, Steinberg et al. (2009) reported United States consumers preferred grain-fed beef compared to grass-fed beef when considering flavor, juiciness, and tenderness. Two characteristics of meat which influence consumer purchasing choices are tenderness and appearance (Razminowicz, 2006).

There are a number of factors that affect the flavor of beef, and Steinberg et al. (2009) reported that consumers found beef from pasture-fed animals to have a pungent, grassy off-flavor. The authors proposed that increased levels of conjugated linoleic acid may have affected flavor negatively. Elevated amounts of linolenic acid ($C_{18:3}$) in meat reduced the liking for beef consumers (Priolo, 2001); however, oleic acid ($C_{18:1}$) is found not to be related to those same negative sensory characteristics (Priolo, 2001).

Rosmann et al. (2004) finished steers on pasture with grain supplemented at a level of 1% body weight and another group in a drylot with forages and grain supplementation at a level of 2% body weight. Results from a trained taste panel showed no significant difference between the two groups, and therefore, demonstrated that the lower level of concentrates given to the pastured beef was ample enough to satisfy sensory attributes in the meat. Feeding concentrates for the final three months in finishing cattle was found to be the optimum amount of time needed to eradicate the pastoral flavor from the meat (Priolo, 2001). Although grass-fed beef has received a negative association with off-flavor, Steinberg et al. (2009) reported that 23% of beef consumers favored the taste and would spend more money for grass-fed beef.

Economics

In a study by Fernandez et al. (1999), results showed that the price differential between steers finished conventionally or organically on high grain diets would have to be 39% greater for organic beef in order to achieve profit. Feed price dictated the total cost of gain for the experimental steer groups. Because organic steers had a delayed finish compared to the conventional steers, organic steers had increased feed expenses. Increased feed costs for the organically steers was coupled with higher yardage fees, largely due to increased labor . Contrary to Fernandez and Woodward (2009), Rosmann et al. (2004) found higher revenue for the organic cattle compared to conventional dry lot cattle. The conventionally raised steers incurred an additional cost of $50 per head compared to the organic steers.

A marketing strategy needs to be in place for all types of livestock operations; however, determining how product will be sold as an organic beef producer is even more crucial in order to guarantee premium pricing. For an organic producer who finishes cattle, 50% of the profit variation is determined by the marketing plan for the beef (Fernandez, 1999). Niche markets use a certain population of people as buyers for a specific product in a particular industry. This group of individuals is often not content with conventional food and will pay a premium for food grown more closely to their specifications (Fanatico, 2000). There are more risks associated with niche marketing; however, there are consumers that desire beef which has been grass-fed, and provided no antibiotics or growth hormones (Fanatico, 2000).

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Manuscript 1

Whole milk feeding duration, calf growth, and profitability of group-fed calves in an organic production system.

INTERPRETIVE SUMMARY

The objective was to evaluate the effect of early life feeding duration on growth and economics of organic dairy calves fed once per day. Early weaned calves had lower body weight than later weaned calves, but weaning groups did differ for body weight at 120-d of age. Total costs and cost per kg of gain for the first 90-d of age were lowest for early weaned calves. Heifer calves fed once per day in a group-fed organic system may achieve adequate gains during the pre- and post-weaning period.

CHAPTER SUMMARY

The objective of this study was to evaluate the effect of early life feeding duration on calf growth, health, and economics of organic dairy calves fed once per day. Heifer calves born during the spring of 2011 (n = 67) and the spring of 2012 (n = 57) were used to evaluate the effect of weaning age, growth, and profitability of group-fed calves in an organic dairy production system. Calves were assigned to replicate feeding groups of ten in super hutches by birth order, and were born at the University of Minnesota West Central Research and Outreach Center, Morris organic dairy. Breed groups were Holsteins (n = 15) selected for high production (HO), Holsteins (n = 23) maintained at 1964 breed average level (H64), crossbreds (n = 54) including combinations of HO, Montbéliarde, and Swedish Red (HMS), and crossbreds (n = 32) including combinations of HO, Jersey, and Swedish Red (HJS). Groups of calves were weaned at 30 (EW), 60 (MW), or 90 (LW) d of age, and groups were fed 1.5% of birth weight of 13% total solids organic whole milk once daily and weaned when the group of ten calves consumed an average of 0.91 kg starter/calf/day for four consecutive days. Body measurements were recorded at birth, weekly during the pre-weaning period, at weaning, and monthly thereafter, and profitability was estimated as a function of the total cost for organic milk and grain for weaning groups to weaning and to the first 90 days of age. Pre-weaning group performance was weaning age (d), EW (47.6), MW (64.5), LW (93.7); gain per day (kg), EW (0.51), MW (0.63), LW (0.75); and weaning weight (kg), EW (61.8), MW (79.2), LW (108.1). There were no significant differences in body weight (kg) for weaning groups at 90 days of age; however, MW calves had significantly lower 120-d body weight (kg) than LW calves, but EW calves did not differ from either MW or LW calves for 120-d body weight. Total feed costs to weaning were $1,092.97 for EW, $1,871.24 for MW, $2,956.64 for LW groups of calves; however, the cost per kg of gain was significantly higher for the EW ($5.54) group than the MW ($4.60) or LW ($4.14) groups during the pre-weaning period. Total costs and cost per kg of gain for the first 90-d of age were lowest for EW and highest for LW.

(**Key words:** group housing, organic dairy, performance, profitability)

INTRODUCTION

Dairy producers from around the United States have turned to an organic production system to capitalize from the higher milk price received for organic milk. The number of organic dairy farms has increased during the past decade (McBride and Greene, 2009), slowing the decline of smaller dairy operations in the Upper Midwest. The number of certified organic dairy cows in the United States increased 271% from 2002 to 2008, and Minnesota had over 10,000 certified organic dairy cows in 2011 (USDA, 2010a; USDA, 2012a). The number of organic dairy farms has increased due to the fact that during 2002, the United States Department of Agriculture introduced the National Organic Program (**NOP**) as a method of standardization for organic agriculture (USDA National Organic Program, 2012b).

Raising heifers, either conventional or organic, is an expensive investment for a dairy operation, and therefore, early life feeding of calves is critical to the subsequent productivity and longevity of the dairy cow (Soberon et al., 2012). After feed cost, raising replacement heifers is the second largest expense for a dairy farm, accounting for 25% of the total costs of milk production (Zwald et al., 2007). The cost of feeding pre-weaned organic calves may depend largely upon how much nonsalable or saleable milk is fed to calves. According to the NOP, organic dairy farms are required to feed only whole milk to dairy calves (UDSA, 2012b). This milk can be either nonsalable (milk from newly freshened cows, sick cows, or high SCS cows) or saleable.

Currently, an increasing number of dairy producers are choosing group housing over individual hutches for calf rearing. Benefits of group housing include reduced labor and bedding costs, socialization among calves, and greater growth rates (Chua et al., 2002; Bernal-Rigoli et al., 2012). De Paula Vieira et al. (2010) reported group-fed calves after weaning consumed more feed, but had higher weight gains compared to individually fed calves.

The most common weaning age of calves on dairy farms in the United States is between 6 and 8 weeks of age (USDA, 2010b); however, de Passille et al. (2011) found that calves weaned at 12 or 13 weeks of age had greater growth rates and decreased signs of hunger during weaning and post-weaning. Most dairy calves in the United States are fed at least twice daily (USDA, 2010b); however, once-a-day milk feeding of calves may reduce labor costs. Galton et al. (1976) reported feeding calves once per day required about 40% less labor than calves fed 2 times per day. Stanley et al. (2002) found feeding milk replacer once versus twice daily to dairy calves had no adverse effects on weight gain. Furthermore, Kehoe et al. (2007) found that feeding calves milk once a day may provide economic benefit to dairy farms, with no adverse growth effects for calves.

There are small differences in raising dairy calves between organic and conventional dairy farms; however, no organic milk replacers are available in the United States, and therefore, whole milk from high SCC organic cows or bulk tank organic milk must be fed. The cost versus benefits of milk consumption and weaning age is very important and has not been researched with organic dairy calves. Therefore, the objective of this study was to investigate the effect of early life feeding duration on growth and profitability of group-fed calves fed once per day in an organic dairy production system.

MATERIALS AND METHODS

Experimental Design and Collection of Data

This study was conducted at the University of Minnesota West Central Research and Outreach Center (**WCROC**) Morris, Minnesota, and all animal procedures involving animal care and management were approved by the University of Minnesota Institutional Animal Care and Use Committee. The research dairy at the West Central Research and Outreach Center, Morris has a 200-head low-input and organic grazing system. The research herd has implemented a crossbreeding approach since 2000. Details are thoroughly described in Heins et al. (2010), and the 1964 Holstein control population design is described in Hansen (2000). Data were collected for 124 organic dairy heifer calves from two spring calving seasons: 67 heifer calves were born from March 13 to May 21, 2011 and 57 heifer calves were born from March 19 to May 29, 2012. Breed groups of calves were: Holsteins (n = 15) selected for high production (**HO**), Holsteins (n = 23) maintained at 1964 breed average level (**H64**), crossbreds (n = 54) including combinations of HO, Montbéliarde, and Swedish Red (**HMS**), and crossbreds (n = 32) including combinations of HO, Jersey, and Swedish Red (**HJS**). The distribution of calves by breed group for each weaning group is presented in Table 1.

At birth, calves were separated from their dams, housed indoors in individual pens, and fed 1.89 liters of colostrum per 41 kg of body weight two times per day for 2 d. Calves that were healthy and aggressive eaters were moved to group housing at 3 d of age. The pens for group housing included an indoor area bedded with organic wheat straw with an outside access space that measured 3.66 × 6.10 m (7.32 m^2/ calf inside and outside).

Calves were randomly assigned to one of three weaning groups of ten based on birth order. The time for group formation ranged from 5 to 15 d in 2011 and from 2 to 21 d in 2012. Early weaning (**EW**) groups were fed 1.5% of birth weight of 13% total solids organic milk (unpasteurized whole organic milk from high SCC cows or from the bulk tank) once daily and weaned when the youngest calf in the group reached 30 d of age and consumption of starter averaged 0.91 kg starter/calf/day. Mid-weaning (**MW**) and late weaning (**LW**) were fed in the same manner except weaned at 60 d and 90 d of age, respectively. Groups of calves were fed with a ten-calf Skellerup peach teat feeder with 61 L liquid volume capacity (Skellerup Industries, New Zealand), which was washed and disinfected daily. Calves were fed an organic calf starter starting on day 3 with weighback collected every other day. The organic calf starter was mixed at the WCROC dairy, and was comprised of organic corn, organic wheat, organic expelled soybean meal, organic soybean oil, and organic-certified minerals. The starter was 87.6% dry matter, 18.9% crude protein, 27.7% NDF, 5.95% fat, 7.5% ash, 1.43% calcium, 0.67% phosphorus, 39.9% NFC, 0.27 Mcal/kg NE_G, and 0.40 Mcal/kg NE_M. Water was provided ad libitum from 3 d of age, and organic hay was provided ad libitum at 3 wk of age.

While in group housing, calves were weighed on a digital scale before and after milk feeding once per week to evaluate milk intake. Furthermore, body weight, hip height, and heart girth were recorded at weaning, 90 and 120 d of age, and monthly thereafter. Health treatments and death loss records were obtained on an individual calf basis. Body measurements were birth weight, weaning weight, weaning hip height, weaning heart girth, total gain, average daily gain, 90-d weight, and 120-d weight. The amount of liquid milk and calf starter offered and refused at each feeding was recorded daily.

Post-weaning, calves were moved to longer term group pens. Calves remained in their particular treatment group until 100 d of age. Then, heifers were grouped into twenty to thirty calves based on similar body weight, and all calves were merged together at 5 mo of age. At 6 mo of age, heifers were moved to pasture for grazing and were supplemented with a total mixed ration during the non-grazing season.

Profitability

Total feed cost was estimated as a function of the total cost for milk and grain for weaning groups to weaning and to the first 90 d of age. The default milk price was \$0.6166/kg, which was the mean organic mailbox milk price from 2011 to 2012 for the University of Minnesota WCROC organic dairy. The average organic grain starter mix was \$0.564/kg. Total feed cost was the sum of milk intake and grain intake for a group of dairy calves. Average cost per kg of gain was the total feed cost divided by the total sum of weight gain for a group of dairy calves. The profitability analysis was calculated for the pre-weaning period and for the first 90 d of life. Sensitivity analyses were performed to evaluate the effects of changes in organic milk price on total feed cost and the average cost per kg of gain for dairy calves. Alternative milk prices were used for sensitivity analysis. Three alternative milk price scenarios were a higher milk price (25% higher at \$0.7707/kg), a lower milk price (25% lower at \$0.4608/kg), and a lowest milk price (\$0.2205/kg).

Statistical Analysis

For statistical analysis of birth weight, weaning weight, days on milk, total gain, average daily gain, hip height at weaning, heart girth at weaning, 60-d weight, 90-weight, and 120-d weight, independent variables were fixed effects of year of birth, weaning group, breed group, and the interaction of weaning group and breed group with super hutch as a random replicate. For all body measurements except birth weight, birth weight was a covariable in the statistical model. For statistical analysis of milk intake, grain intake, milk price, total feed costs, total gain from birth to weaning, total gain from birth to 90 d of age, and cost per kg of gain, independent variables were fixed effects of year of birth and weaning group, along with superhutch as a random effect.

Heifers born during 2011 were used for an analysis of BW through 505 d of age to evaluate post-weaning heifer growth. The BW was recorded monthly from 90 to 505 d of age; therefore, most heifers had 9 observations for BW at 45-d intervals (90 to 134 d, 135 to 180 d, 181 d to 225 d, etc.). For statistical analysis of BW, independent variables were fixed effects of weaning group, breed group, and 45-d interval, with heifer within breed group and superhutch as random effects.

For all measurements, the MIXED procedure (SAS Institute, 2012) was used to obtain solutions and conduct the ANOVA. All treatment results were reported as least squares means with significance declared at $P < 0.05$. For the 124 calves in the study, only 5 were treated for health problems in 2011, and 0 calves were treated for health problems in 2012. Due to few health events, health comparisons were not performed in this study.

RESULTS AND DISCUSSION

Body Measurements

Results for pre-weaning and early post-weaning body measurements for the organic heifer calves are in Table 2. The weaning groups were significantly different ($P < 0.05$) from each other for duration on milk (47.6 d versus 64.5 d versus 93.7 d, for EW, MW, and LW, respectively). The EW group was weaned at 47.6 d, contrary to the original 30 d because the calves in the EW group were not eating the required 0.91 kg of calf starter per head per d at 30 d of age. Therefore, the early-weaned calves were weaned about 2 wk later than originally planned, because they simply were not ready to be weaned. Roth et al. (2009) recommended that producers should apply a concentrate-dependent weaning method to attend to the nutritional needs of calves, which was the procedure used in the current study. Consequently, weaning for EW calves was delayed more than 2 wk later than originally planned because stunted growth may have resulted due to lower grain intake and no milk intake post-weaning. Kehoe et al. (2007) reported calves fed once daily and weaned at 4 wk of age had lower body weights than those weaned at 6 and 12 wk of age, which is in agreement with the findings of this study.

As expected at weaning, EW calves had lower ($P < 0.05$) BW, hip height, heart girth, and total gain to weaning than the MW and LW calves. Consequently, average daily gain for weaning groups was lower ($P < 0.05$) for the EW (0.51 kg/d) calves compared to the MW (0.63 kg/d) and LW (0.75 kg/d) calves. The ADG results for MW and LW calves are consistent with the results of Kmicikewycz et al. (2012), who reported ADG of 0.63 to 0.72 kg/d for Holstein and crossbred calves fed 2 or 4 times a day in a

University of Minnesota confinement dairy herd. Conversely, calves in this study were fed once per day and achieved similar growth rates.

Doubling a calf's birth weight by 60 d of age has become an industry standard for Holstein calves (Dairy Calf and Heifer Assoc., Gold Standards I, 2011). However, for the current study only 42 to 51% of calves doubled their birth weight during the first 60 d of life, and weaning groups were not different ($P > 0.05$). For breed groups, 50% of HO calves and 55% of HMS calves doubled their birth weight by 60 d, whereas only 39% of H64 calves and 34% of HJS calves doubled their birth weight by 60 d. Although some calves did not double their birth weight in 60 d, all calves at 60 d were at least 1.5 times greater in BW than their birth weight, and some calves tripled their birth weight. Van Amburgh et al. (2008) suggested that calves should double their birth weight by weaning to achieve higher future milk production; however, doubling calf birth weight by 60 d of age in this study may not be achievable for all calves due to the different genetic composition of the calves.

The EW and LW calves were not significantly different for 90-d and 120-d weight; however, the MW (130.7 kg) calves had lower ($P < 0.05$) BW than LW (140.4 kg) calves at 120 d of age. Growth differences had dissipated by 120 d of age for EW and LW calves, which was also reported by Kehoe et al. (2007) who found calves that were weaned at 3 weeks of age had similar growth rates post-weaning compared to growth rates of calves that were weaned at 4, 5, and 6 wk of age.

Pre-weaning and early post-weaning body measurements for breed groups are in Table 3. The HJS (34.3 kg) calves had lower ($P < 0.05$) birth weights than the H64 (39.0 kg), HO (39.3 kg), and HMS (39.0 kg) calves. Results for birth weight of calves are similar with the results of Heins et al. (2010), who reported Montbéliarde-sired 3-breed crossbred calves had similar birth weights to pure Holstein calves. The lower birth weight of the HJS calves in this study would be expected because Olson et al. (2009) and Dhakal et al. (2013) found Jersey-sired calves had lower birth weights than HO calves. The HO (0.69 kg/d) and HMS (0.65 kg/d) calves were not significantly different for ADG; however, the HO calves had higher ($P < 0.05$) ADG than the H64 (0.58 kg/d) and HJS (0.60 kg/d) calves. No significant ($P > 0.05$) differences for body measurements were found for the H64 calves compared to the HJS crossbred calves. Although the BW of the H64 and HJS calves were lower ($P < 0.05$) than the HO calves prior to weaning, by 120 d of age the difference between the HO, HMS, and HJS calves was not significant ($P > 0.05$).

Body weights from 90 d of age to 505 d of age for the calves born during spring 2011 are in Table 4. Within each 45-d period, the EW calves had less ($P < 0.05$) BW than the LW calves, except during the first 45-d period. The Dairy Calf Association Gold Standards II (2010) recommends that Holstein heifers should achieve a target weight of 374 to 408 kg by 13 to15 months of age. Heifer calves born in 2011 from the present study attained an average weight of 356 kg between 13 and 15 months of age, which is lower than the Dairy Calf Standards (2010). However, the dairy calf recommendations are for Holstein calves, and the lower body weight of the heifers observed in this study is most likely due to the genetic composition of the animals. Higher growth rates early in a calf's life are associated with reduced age at first breeding and increased milk yield in mature dairy cows (Khan et al. 2011). Van Amburgh et al. (2008) found that first lactation heifers produced approximately 385 kg for every 0.45 kg of average daily gain pre-weaning.

Profitability

Least squares means for milk intake, grain intake, and economic sensitivity analysis of milk and grain for weaning groups during the pre-weaning period are in Table 5. All weaning groups of calves were different (P < 0.05) from each other for all economic variables. As expected, the group of EW calves had lower grain intake, lower total feed cost, and less weight gain during pre-weaning because they were weaned earlier than the groups MW and LW groups. However, the average cost per kg of gain for the EW ($5.54 kg/d) calves was higher (P < 0.05) than the LW ($4.14 kg/d) calves, but was similar to the MW ($4.60 kg/d) calves. With the lowest milk price, the cost per kg of gain was similar for all 3 weaning groups. The group of EW calves did not have rapid pre-weaning growth, and therefore, had a higher cost per kg of gain. Perhaps, group-fed calves should not be weaned earlier than 8 weeks of age based on the results of this study. de Passille et al. (2011) reported weaning calves at 12 to 13 wk of age was more advantageous for energy intake and growth of calves than calves weaned earlier than 12 wk.

During the first 90 d of life (Table 6), there were no differences (P > 0.05) between weaning groups for grain intake, total grain costs, and gain from birth to 90 d of age. During the post-weaning phase for the group of EW calves, they consumed more grain than the group of LW calves because they were not provided milk, and therefore, had similar grain intake compared to the LW calves. Consequently, the total feed cost for the group of EW ($1,595.59) calves was lower (P < 0.05) than the group of MW

($2,239.95) and LW ($2,956.64) calves, which was simply a reflection of the lower milk intake of the EW calves. Decreasing the time of the calf rearing period, which reduces the cost of production, is achievable for producers who attain efficient calf growth from a successful feeding program (Hessle et al., 2004). During the pre-weaning period, the EW calves had fewer economic advantages compared to LW calves. Conversely, when all calves were compared at 90 d of age, the EW calves had significant advantages for cost per kg of gain. Feed costs had a proportionately greater effect for the group of LW ($4.13 kg/d) calves compared to the group of EW ($3.02 kg/d) calves for cost per kg of gain. For cost per kg of gain, a higher milk price resulted in higher ($P < 0.05$) cost per kg of gain for the EW calves compared to the LW calves, and the difference increased from 26 to 29% with the higher milk price. However, the gap between the EW and LW calves was substantially reduced for cost per kg of gain (-$1.11 to -$0.18) at the lowest milk price. At the lowest milk price, all weaning groups were not different ($P > 0.05$) from each other for cost per kg of gain.

The source of milk on an organic dairy farm will be the predominant driver of profitability. As no organic milk replacers are available, whole milk from high SCC organic cows, as well as organic bulk tank milk, must be fed. Therefore, organic dairy producers will have to decide whether to use high SCC cows from the herd to feed calves or use expensive milk from the bulk tank. The costs versus benefits of milk consumption and weaning age is very important and may drive important decisions on an organic dairy. Organic dairy producers should regularly evaluate their costs for organic milk and grain fed to calves, along with growth rates, to determine the optimum time for weaning on their farms. Milk price had a greater impact on total feed cost for the LW calves than the EW and MW calves because the LW calves consumed more milk during the first 90 d of life than the other two weaning groups.

Future research with these organic dairy calves should explore the impact of weaning age of organic dairy calves with heifer growth, fertility, and first lactation performance. Results of research will provide guidance to organic dairy producers for methods of feeding organic dairy calves for specific management systems. Irrespective of feeding system, successful management of dairy calves is of critical importance to an organic dairy. Organic dairy producers must focus on all aspects of dairy calf management to maintain growth rates and minimize health problems to ensure future profitability for the dairy farm.

CONCLUSIONS

The results of this study found the EW calves had lower weight gains and body dimensions than MW or LW calves; however, by 120 d of age the EW and LW calves were similar for BW. Furthermore, the EW calves were not weaned exactly at 30 d of age, because they were not consuming the required 0.91 kg/calf/d of starter. For the first 90 d of life, the EW calves had lower cost per kg of gain than the MW and LW calves. Based on the results of this study, organic dairy producers may achieve adequate body weight gain in group-fed dairy calves.

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Table 1. Distribution of organic dairy calves by breed group and weaning group.

Breed group	Early Wean (n)	Mid-Wean (n)	Late Wean (n)
1964 Holstein	4	11	8
Holstein	4	6	5
HMS[1]	14	23	17
HJS[2]	12	10	10
Total calves	34	50	40

[1]HMS = Crossbreds of Holstein, Montbéliarde, and Swedish Red
[2]HJS = Crossbreds of Holstein, New Zealand Friesian, Jersey, and Swedish Red

Table 2. Pre-weaning and early post-weaning body measurements of group-fed organic dairy calves by weaning group.

	Early Wean		Mid-Wean		Late Wean	
Measurement	Mean	SE	Mean	SE	Mean	SE
Birth weight (kg)	38.4	1.2	37.5	1.0	37.7	1.0
Time on milk (d)	47.6[a]	1.2	64.5[b]	1.1	93.7[c]	1.0
Weaning weight (kg)	61.8[a]	1.8	79.2[b]	1.4	108.1[c]	1.5
Weaning hip height (cm)	89.7[a]	0.88	91.8[a]	0.70	96.9[b]	0.75
Weaning heart girth (cm)	95.8[a]	1.4	100.3[b]	1.4	112.2[c]	1.4
Total gain (kg)	24.1[a]	1.8	41.6[b]	1.4	70.4[c]	1.5
ADG (kg/d)	0.51[a]	0.02	0.63[b]	0.02	0.75[c]	0.02
Double weight by 60-d (%)	42.9	13.5	50.5	11.7	41.7	11.3
90-d weight (kg)	102.5	3.9	104.4	3.4	108.5	3.3
120-d weight (kg)	139.0[a,b]	6.4	130.7[a]	5.9	140.4[b]	5.5

[a,b,c] = Means within a row without common superscripts are different at $P < 0.05$
ADG = Average daily gain

Table 3. Pre-weaning and early post-weaning body measurements of group-fed organic dairy calves for 1964 Holstein, Holstein, and crossbred calf groups.

	1964 Holstein		Holstein		HMS[1]		HJS[2]	
Measurement	Mean	SE	Mean	SE	Mean	SE	Mean	SE
Birth weight (kg)	39.0[a]	1.2	39.3[a]	1.3	39.0[a]	0.8	34.3[b]	1.0
Time on milk (d)	68.0	1.1	69.8	1.2	68.6	0.9	68.1	1.0
Weaning weight (kg)	78.5[b]	2.0	87.4[a]	2.3	85.1[a,c]	1.2	81.1[b,c]	1.7
Weaning hip height (cm)	91.7[a]	0.98	94.7[b]	1.1	92.4[a,b]	0.61	92.2[a,b]	0.82
Weaning heart girth (cm)	100.1[a]	1.7	107.1[b]	2.1	100.8[a]	1.1	103.1[a,b]	1.6
Total gain (kg)	40.8[b]	2.0	49.7[a]	2.3	47.5[a,c]	1.2	43.4[b,c]	1.7
Average daily gain (kg/d)	0.58[a]	0.03	0.69[b]	0.03	0.65[b,c]	0.4	0.60[a,c]	0.02
Double weight by 60-d (%)	30.0	12.9	56.8	14.2	52.2	9.6	41.5	10.9
90-d weight (kg)	97.6[b]	3.7	113.9[a]	4.0	108.0[a]	2.8	100.9[b]	3.3
120-d weight (kg)	131.8[a]	5.7	142.1[b]	5.9	138.4[a,b]	5.1	134.6[a,b]	5.4

[a,b,c] = Means within a row without common superscripts are different at $P < 0.05$
[1]HMS = Crossbreds of Holstein, Montbéliarde, and Swedish Red
[2]HJS = Crossbreds of Holstein, New Zealand Friesian, Jersey, and Swedish Red

Table 4. Least squares means and standard errors of means for body weight of 2011 spring-born heifers from the 90th to 505th day of life for weaning groups.

	Early Wean		Mid-Wean		Late Wean	
Measurement for 45-d period	Mean	SE	Mean	SE	Mean	SE
90 - 134	111.7	7.3	110.8	5.7	118.4	6.3
135 - 179	135.8[a]	8.2	146.5[a,b]	5.7	160.9[b]	7.4
180 - 224	162.7[a]	7.1	175.2[a,b]	5.7	184.2[b]	7.0
225 - 269	198.6[a]	7.4	204.5[a]	5.4	221.2[b]	6.4
270 - 314	234.5[a]	7.0	250.9[a,b]	5.5	262.7[b]	6.7
315 - 359	262.3[a]	7.4	284.1[b]	5.4	292.1[b]	6.4
360 - 404	298.1[a]	7.8	316.3[a,b]	5.6	323.4[b]	6.6
405 - 460	328.9[a]	7.9	354.9[b]	5.6	368.6[b]	6.8
461 - 505	342.3[a]	7.7	368.3[b]	6.3	375.6[b]	12.4

[a,b] = Means within a row without common superscripts are different at $P < 0.05$

Table 5. Milk intake, grain intake, and economic sensitivity analysis of milk and grain for weaning groups during the pre-weaning period[1].

	Early Wean		Mid-Wean		Late Wean	
Measurement	Mean	SE	Mean	SE	Mean	SE
Milk intake (kg)	1659.2[a]	84.6	2671.7[b]	75.7	3921.9[c]	79.6
Average milk price ($0.62/kg)	1,023.09[a]	52.14	1,647.40[b]	46.68	2,418.26[c]	49.09
Higher milk price ($0.77/kg)	1,278.78[a]	65.17	2,059.12[b]	58.35	3,022.63[c]	61.36
Lower milk price ($0.46/kg)	767.40[a]	39.11	1,235.68[b]	35.02	1,813.89[c]	36.82
Lowest milk price ($0.22/kg)	365.86[a]	18.65	589.12[b]	16.69	864.79[c]	17.56
Grain intake (kg)	129.3[a]	30.2	386.3[b]	27.0	940.7[c]	26.6
Grain cost ($0.564/kg)	72.98[a]	17.0	218.03[b]	15.25	530.90[c]	15.02
Total gain, birth to weaning (kg)	201.7[a]	19.7	409.13[b]	17.8	716.6[c]	19.7
Average total feed cost ($)	1,092.97[a]	44.65	1,871.24[b]	40.25	2,956.64[c]	44.65
Higher total feed cost ($)	1,349.41[a]	56.46	2,283.07[b]	50.89	3,563.17[c]	56.46
Lower total feed cost ($)	836.53[a]	33.24	1,459.40[b]	29.96	2,350.11[c]	33.24
Lowest total feed cost ($)	433.82[a]	18.00	812.65[b]	16.22	1,397.62[c]	18.00
Average cost ($)/gain (kg)	5.54[a]	0.23	4.60[a,b]	0.21	4.14[b]	0.23
Higher cost ($)/gain (kg)	6.83[a]	0.28	5.61[b]	0.25	4.99[b]	0.28
Lower cost ($)/gain (kg)	4.24[a]	0.17	3.58[a,b]	0.16	3.29[b]	0.17
Lowest cost ($)/gain (kg)	2.20	0.09	1.99	0.08	1.95	0.09

[a,b,c] = Means within a row without common superscripts are different at $P < 0.05$
[1] = Means for groups are expressed for a group of ten calves

Table 6. Milk intake, grain intake, and economic sensitivity analysis of milk and grain for weaning groups during the first 90 days of life[1].

	Early Wean		Mid-Wean		Late Wean	
Measurement	Mean	SE	Mean	SE	Mean	SE
Grain intake (kg)	1009.1	45.1	1049.1	40.6	938.6	45.1
Grain cost ($0.564/kg)	569.50	25.50	592.10	22.90	529.80	25.50
Total gain, birth to 90-d (kg)	529.16	48.0	666.74	43.3	716.6	48.0
Average total feed cost ($)	1,595.59[a]	46.88	2,239.95[b]	42.26	2,956.64[c]	46.88
Higher total feed cost ($)	1,852.03[a]	57.85	2,651.79[b]	52.15	3,563.17[c]	57.86
Lower total feed cost ($)	1,339.15[a]	36.79	1,828.12[b]	33.16	2,350.11[c]	36.79
Lowest total feed cost ($)	936.43[a]	25.34	1,181.36[b]	22.84	1,397.62[c]	25.34
Average cost ($)/gain (kg)	3.02[a]	0.26	3.41[b]	0.23	4.13[c]	0.25
Higher cost ($)/gain (kg)	3.50[a]	0.31	4.04[a,b]	0.28	4.98[b]	0.30
Lower cost ($)/gain (kg)	2.54	0.20	2.78	0.18	3.29	0.20
Lowest cost ($)/gain (kg)	1.77	0.12	1.79	0.11	1.95	0.12

[a,b,c] = Means within a row without common superscripts are different at $P < 0.05$
[1] = Means for groups are expressed for a group of ten calves

Manuscript 2

Growth, carcass characteristics, and profitability of organic versus conventional dairy-beef steers.

INTERPRETIVE SUMMARY

There is an increase in global demand for organic beef products, especially grass-fed and finished. The objective of this study was to evaluate growth, carcass characteristics, and profitability of organic dairy steers compared to conventional dairy steers. Organic and organic grass-fed dairy steers had lower slaughter weights and greater days to slaughter than conventional dairy steers. For profitability, organic grass-fed dairy steers had significantly more profit per steer than organic and conventional dairy steers. Organic grass-fed dairy steers had the lowest profit per steer compared to organic and conventional dairy steers because of high organic corn prices. Organic bull calves may represent a potential additional source of revenue for organic dairy producers.

CHAPTER SUMMARY

Bull calves (n = 49) were used to compare growth measurements of conventional and organic dairy steers. Calves were assigned to one of three groups at birth; conventional (**CONV**, n = 16), organic (pasture and concentrate, **ORG**, n = 16), and organic-grass only (**GRASS**, n = 17), and were born at the University of Minnesota West Central Research and Outreach Center, Morris from March to May 2011. Breed groups of calves were: Holstein (n = 9), Holsteins (n = 11) maintained at 1964 breed average level, crossbreds (n = 19) that included combinations of Holstein, Montbéliarde, and Swedish Red (HMS), and crossbreds (n = 10) that included combinations of HO, Jersey, Swedish Red, and Normande (HJSN). The CONV steers were fed a diet of 80% concentrate and 20% roughage. The ORG steers were fed a diet of organic corn, organic corn silage, and at least 30% of their diet consisted of organic pasture during the grazing season. The GRASS steers grazed pasture during the grazing season and were fed high quality hay or hay silage during the non-grazing season. Feed intakes were recorded daily with herd management software. A profit function was defined to include revenues and expenses for beef value, feed intake, pasture intake, health cost, and yardage. The GRASS (358.6 kg) steers had significantly lower gain from birth to slaughter than ORG (429.6 kg) and CONV (534.5 kg) steers. Furthermore, the GRASS (0.61 kg/d) steers had significantly lower average daily gain compared to ORG (0.81 kg/d) and CONV (1.1 kg/d) steers. Both organic steer groups had significantly smaller ribeye area (49.5 cm^2, 65.8 cm^2, respectively) compared to CONV (75.4 cm^2) steers. For profitability, GRASS steers had 25% greater profit per steer, than CONV steers. On the other hand, ORG steers had 169% less profit per steer than CONV steers. The higher cost of production for

the ORG steers is due to the extreme high value of organic corn. The results of the current study suggest there may be a potential market for the male offspring of organic dairy cattle in the Midwest.

(**Key words:** organic, dairy beef, pasture, economics)

INTRODUCTION

Markets for organic beef have expanded rapidly over the past decade as health-conscious consumers realize it may provide human health and environmental benefits (Dimitri and Oberholtzer, 2009). To supply this increasing demand, the number of organic farms have increased in the past decade (McBride and Greene, 2009), slowing the decline of smaller dairy operations in the United States. Recently, Smith-Spangler et al. (2012) reported organic foods are no more nutritious than conventional food; however, consumers are choosing organic foods because they want to avoid pesticides, hormones, and other chemicals used in conventional production systems.

The United States Department of Agriculture's National Organic Program (**NOP**) standards became effective in 2002 and address production, processing and labeling, certification, recordkeeping, and inputs allowed in organic farming and processing (USDA-NOP, 2012). Pasture and land for production of organic crops must not have had any prohibited substances, such as synthetic fertilizers or pesticides, applied to it 3 years prior to the first use of the crop for organic purposes (USDA-NOP, 2012). All certified organic livestock must be fed organic feed from certified organic land, and all cattle over 6 mo of age are required to receive at least 30% of their DMI from pasture for at least 120 d during the grazing season each year. Growth hormones and antibiotics are not allowed to be provided to livestock in organic production systems. However, it is forbidden to withhold medical treatment from a sick animal in order to keep its organic status (USDA-NOP, 2012). If beef is to be labeled and sold as organic, it must be harvested at a plant that is certified organic and federally or state inspected.

Organic dairy bull calves may represent a potential additional source of revenue for organic dairy producers, and these organic calves may represent a resource for pasture-raised beef in the United States to address consumers concerns with conventional-raised beef. Dairy bull calves are most commonly sold off the farm at 2 to 5 d of age, and a survey of organic dairy producers in Denmark reported 66% of organic dairy bull calves were sold and shipped to conventional farms, despite the majority of the producers wanting to keep the calves on their own operation (Nielsen et al., 2002). Selling organic bull calves to conventional markets may be viewed as counterintuitive to organic principles and an ethical problem for organic agriculture, which is intended to achieve more holistic production methods without involvement of conventional practices (Nielsen et al., 2002).

Currently in the United States, conventional feedlot diets are dependent on high amounts of corn grain, which commonly comprises over 70% of a steer ration (Rosmann et al., 2004). With price volatility of organic grains in the U.S., pasture-raised dairy-beef may be an additional source of revenue for organic dairy producers. Naturally, cattle are grazers, and producers can lower feed costs by feeding forages and grazing on pasture, which may be an effective way to raise dairy steers, as well as yield a naturally lean product that could potentially be marketed directly to consumers (Fanantico, 2000).

There are few research studies that have compared organic and conventional beef. Fernandez and Woodward (1999) reported organic steers had longer days to harvest compared to conventional steers. The authors concluded that for organic beef to be profitable, producers need to be guaranteed premium pricing of livestock. There is a lack of available research on the performance and management of organic livestock systems, especially dairy steers. No previous research has compared Holstein and crossbred dairy steers raised in a conventional production system versus an organic and grass-fed production system. Therefore, the objective of this study was to compare the growth, carcass characteristics, and profitability of organic dairy steers and conventional dairy steers.

MATERIALS AND METHODS

Experimental Design

The study was conducted at the University of Minnesota West Central Research and Outreach Center (**WCROC**), Morris, Minnesota, and all animal care and management was approved by the University of Minnesota Institutional Animal Care and Use Committee recommendations (Animal Subjects Code 1104B98412). The research dairy at the West Central Research and Outreach Center, Morris has a 200-head low-input and organic grazing system. The organic dairy herd was certified organic with Midwest Organic Services Association during June 2010. The research herd has implemented a crossbreeding design since 2000. Details are thoroughly described in Heins et al. (2010), and the 1964 Holstein control population design is described in Hansen (2000).

Data

Dairy bull calves (n = 49) were born from March 18 to May 27, 2011. Breed groups of calves were: Holsteins (n = 9) selected for high production, Holsteins (n = 11) maintained at 1964 breed average level, crossbreds (n = 19) including combinations of HO, Montbéliarde, and Swedish Red, and crossbreds (n = 10) including combinations of HO, Jersey, Swedish Red, and Normande. Calves were assigned to one of three groups at birth; conventional (**CONV**, n = 16), organic (**ORG**, n = 16), and organic-grass only (**GRASS**, n = 17). The distribution of calves by genetic group for each steer supplementation group is presented in Table 1.

At birth, calves were separated from their dams, housed indoors in individual pens, and fed 1.89 liters of colostrum per 41 kg of body weight two times per day for 2 d. Calves that were healthy and aggressive eaters were moved to group housing at 3 d of age. The pens for group housing included an indoor area bedded with organic wheat straw with an outside access space that measured 3.66 × 6.10 m (7.32 m^2/ calf inside and outside).

All calves were fed 1.5% of birth weight of 13% total solids organic unpasteurized whole milk once daily and weaned when the youngest calf in the group reached 90 d of age and consumption of starter averaged 0.91 kg starter/calf/day. CONV calves were fed a conventional calf starter and ORG steers were fed an organic calf starter from 3 d of age. However, GRASS steers were not provided calf starter, but were fed free-choice organic grass hay from 3 d of age. The organic and conventional starter was manufactured at the WCROC dairy, and was comprised of corn, wheat, expelled soybean meal, soybean oil, and minerals. The starter was 87.6% dry matter, 18.9% crude protein, 27.7% NDF, 5.95% fat, 7.5% ash, 1.43% calcium, 0.67% phosphorus, 39.9% NFC, 0.27 Mcal/kg NE_G, and 0.40 Mcal/kg NE_M.

Post-weaning, the CONV steers were moved to a cross-ventilated barn at the WCROC with 2.79 m^2/head space and fed a diet of 67% concentrate and 33% roughage. Upon reaching a body weight average of 204 kg, CONV steers were fed a diet of 80% concentrate and 20% roughage, and the ration contained 78.4% dry matter. The total mix ration consisted of corn silage, dried distillers grains with solubles, dry corn, grass hay, soybean meal, and mineral, and the ration was 12.6% crude protein, 14.9% NDF, 3.3% fat, 4.3% ash, 0.72% calcium, 0.40% phosphorus, 65.5% NFC, 1.4 Mcal/kg NE_G, and 2.0 Mcal/kg NE_M. At a pen average of 175 kg, CONV steers were implanted with Synovex® C (Pfizer Animal Health), and at 90 and 120 d post Synovex implantation with Component E-S with Tylan® (Ivy Animal Health, Inc.). During the final 30 d on feed, the CONV steers were fed 400 mg/head/d of Optaflexx® (Elanco Animal Health).

The ORG and GRASS steers were moved to permanent organic pasture that was comprised bromegrass, orchardgrass, and timothy, as well as alfalfa, red clover, and kura clover. The ORG and GRASS steers rotated to a new pasture (0.16 ha) every 3 d. The nutrient composition of the organic permanent pasture mix was 28.2% dry matter, 16.5% crude protein, 49.6% NDF, 4.0% fat, 10.9% ash, 0.71% calcium, 0.29% phosphorus, 40.0% NFC, 0.67 Mcal/kg NE_G, and 1.24 Mcal/kg NE_M. For the ORG steers, at least 30% of DMI was from pasture during the grazing season. Furthermore, the ORG steers were supplemented with an organic total mix ration (61.2% dry matter) of organic corn, organic expelled soybean meal, organic corn silage, and organic certified-minerals, and the ration was 10.9% crude protein, 25.6% NDF, 4.1% fat, 5.3% ash, 0.70% calcium, 1.08% phosphorus, 54.6% NFC, 1.2 Mcal/kg NE_G, and 1.8 Mcal/kg NE_M.

During the study, the GRASS steers were provided certified-organic steer mineral (Vita Plus Corporation) free choice in the pasture. During the non-grazing season, the GRASS steers were fed alfalfa silage. The alfalfa silage was 50.3% dry matter, 20.0% crude protein, 48.9% NDF, 3.3% fat, 10.6% ash, 1.34% calcium, 0.30% phosphorus, 18.1% NFC, 0.6 Mcal/kg NE_G, and 1.2 Mcal/kg NE_M. All conventional and organic hay, alfalfa silage, corn silage, and corn for all steer groups were grown and harvested at the WCROC dairy.

The amount of TMR offered and refused at each feeding for CONV and ORG was recorded daily with a herd management software program (Feed Supervisor, New Richmond, WI). For the ORG and GRASS steers, pre- and post-grazing pasture measurements were recorded during the grazing season with an electronic FILIP'S folding plate pasture meter (Jenquip, New Zealand).

Body and Carcass Measurements

All steer groups were weighed on a digital scale at birth, weaning, and monthly thereafter. Hip heights and heart girths were measured at weaning and the day prior to harvest. The CONV steers were sent for harvest and fabrication on July 24, 2012 to the Tyson Fresh Meats plant in Dakota City, NE, and the ORG and GRASS steers were sent for harvest and fabrication to Lorentz Meats, Cannon Falls, MN on September 19, 2012 and November 13, 2012, respectively.

Hot carcass weight was recorded at the time of slaughter. Post-harvest, all steer carcasses were chilled for 24 h, and backfat thickness, ribeye area, percentage of kidney, pelvic, and heart fat, marbling, maturity, quality grade, and yield grade were recorded for each carcass. After a 48 h chilling period, beef products were fabricated and 8 randomly selected strip loins from each steer group were removed for future evaluation as reported in Bjorklund et al. (2013).

For statistical analysis of pre- and post-weaning body measurements and carcass measurements, independent variables were fixed effects of breed group and steer group.

The general linear model procedure of SAS (SAS Institute, 2012) was used to obtain solutions and conduct the ANOVA.

Additionally, steer groups were compared for BW from 90 d to 595 d of age. For statistical analysis of BW, independent variables were fixed effects of steer group, breed, and 45-d interval (90 to 134 d, 135 to 179 d, 180 to 224 d, etc.), with steer within breed group as a random effect. For the BW analysis the MIXED procedure of SAS (SAS Institute, 2012) was used to obtain solutions and conduct the ANOVA. All treatment results were reported as least squares means with significance declared at $P < 0.05$.

Profitability

Profit was estimated as a function of the revenue and expense of steers during the study. Because feed intakes were based on pen totals, the expenses were divided by the total number of steers in the group to calculate expenses for each steer. Therefore, profit per steer was defined to include revenues and expenses for beef value, feed cost, pasture cost, health cost, and yardage.

Table 2 has default revenues and expenses used to determine profit per steer. Beef income for the CONV steers was $2.71/kg of beef, which was the mean beef price from 2011 to 2012 from beef prices of the USDA Economic Research Service (USDA-AMS, 2012). The organic premium for the ORG and GRASS steers was $0.33/kg, which was the premium above the CONV beef price received for the ORG and GRASS steers (Organic Prairie, LaFarge, WI).

The calf milk cost ($0.6166/kg) and calf grain cost ($0.56/kg) were from the costs at the WCROC organic dairy. The corn silage cost ($0.06/kg), alfalfa silage cost ($0.08/kg), dry hay cost ($0.20/kg), corn cost (conventional = $0.25/kg; organic =

$0.54/kg), dried distillers grains with solubles cost ($0.21/kg), and soybean meal cost (conventional = $0.44/kg; organic = $0.98/kg) were from 2012 prices of the USDA Economic Research Service (USDA-AMS, 2012). Currently, there is no price premium for organic corn silage, dry hay, or alfalfa silage. Pasture costs were $0.02/kg/DM (Benson, 2012), and mineral cost ($1.03/kg) and fixed yardage cost ($0.25/hd/d) were from the WCROC organic dairy. Profitability was calculated as profit per steer. The average cost per kg of gain for each steer was the total feed costs divided by the total weight gain for each steer.

Sensitivity analysis

Sensitivity analyses were performed to evaluate the effects of changes in the input variables on profit per steer. Alternative organic corn price and beef price were used for sensitivity analysis (Table 2). Organic corn cost was decreased from $0.54/kg to $0.41/kg (25% lower) and $0.27 kg (50% lower). Furthermore, organic corn cost was increased from $0.54/kg to $0.68/kg (25% higher), which reflect potential market conditions for organic corn. Alternative organic beef premium scenarios were higher at $0.41/kg, $0.66/kg, and $0.99/kg. Furthermore, an organic direct market price ($7.12/kg) to reflect the price that organic producers may receive on farm or at farmers markets versus marketing organic dairy steers through a commercial abattoir.

For statistical analysis of profit per steer, independent variables were fixed effects of steer group. The GLM procedure of SAS (SAS Institute, 2012) was used to obtain solutions and conduct the ANOVA. Due to very few health events, health comparisons were not performed for steers in this study.

RESULTS AND DISCUSSION

Body Measurements

Least squares means and standard errors of means for pre-weaning body measurements for the CONV, ORG, and GRASS steers are in Table 3. For weaning weight, the GRASS (97.0 kg) steers were not significantly different than CONV (106.3 kg) steers, but were lower ($P < 0.05$) than ORG (109.8 kg) steers for weaning weight. The GRASS (54.6 kg) steers had lower ($P < 0.05$) gain through weaning than the ORG (69.1 kg) and CONV (68.0 kg) steers. Consequently, ADG were lower ($P < 0.05$) for the GRASS (0.60 kg/d) steers than for ORG (0.75 kg/d) and CONV (0.73 kg/d) steers. The pre-weaning ADG for ORG and CONV steers are similar to Bjorklund et al. (2013) and Kmicikewycz et al. (2013) who reported ADG of 0.60 to 0.75 for Holstein and crossbred bull and heifer calves. The ADG for the GRASS steers were 22% lower than the CONV steers because no grain was included in the diet of pre-weaned GRASS steers.

Results for BW for each 45-d period across the 595 d of the study are given in Figure 1. Within each 45-d period, the GRASS and ORG steers had lower ($P < 0.05$) BW than CONV steers, except for period 1 (90 to 134 d of age). The difference in BW of GRASS steers compared with CONV steers ranged from 16 kg for the 1st period to 284 kg for the 9th period, and the difference in BW of ORG steers compared with CONV steers ranged from 0 kg for the 1st period to 159 kg for the 9th period. The BW increased dramatically for the ORG steers for the 4th period because steers were moved to a feedlot for winter; however, the BW growth slowed for the 7th to 8th period, because the ORG steers were moved from a winter feedlot to pasture for the grazing season.

Table 4 gives least squares means and standard errors of means of GRASS, ORG, and CONV steers for age at slaughter, slaughter weight, heart girth gain, hip height gain, and total BW gain from weaning to slaughter and birth to slaughter, along with ADG for the 2 periods. The GRASS (584 d) steers had more ($P < 0.05$) days to slaughter than ORG (528 d) and CONV (466 d). Additionally, the GRASS (401 kg) steers had lower ($P < 0.05$) slaughter weights than ORG (470 kg) than CONV (573 kg) steers. Furthermore, slaughter weights were different ($P < 0.05$) for the ORG and CONV steers. Cozzi et al. (2010) reported that organic pasture-grazed beef steers had significantly more days to slaughter than conventional confinement beef steers. The slaughter weights for the GRASS steers may be lower than expected; however, the steers were slaughtered once the grazing season had ended in November 2012. Furthermore, organic livestock markets prefer not to slaughter large carcasses because, currently, there is no marketing potential for large cuts of beef, because consumers will not purchase large cuts of meat at premium prices. The organic beef market is in its infancy; however, it is has grown over 46% during the last decade (Dimitri and Oberholtzer, 2009). Therefore, in the future there may be a need to finish carcasses at weights that are similar to CONV steers.

The GRASS (+359 kg) steers had lower ($P < 0.05$) gains from birth to slaughter than the ORG (+430 kg) and CONV (+535 kg) steers. Hence, ADG from birth to slaughter for the GRASS (0.61 kg/d) steers were lower ($P < 0.05$) than ORG (0.81 kg/d) and CONV (1.1 kg/d) steers. The ADG for ORG and CONV steers were different ($P < 0.05$). Fernandez and Woodward (1999) reported CONV steers had fewer days on feed, higher ADG, and more total gain than ORG steers when ORG steers were raised in total confinement systems. Cozzi et al. (2010) had somewhat lower ADG, at 0.95 kg/d versus

0.74 kg/d for ORG and CONV steers, respectively. Results for ADG of the GRASS steers are higher than those reported by Comerford et al. (2001), who found that pasture steers had ADG of 0.53 (kg/d) during the grazing season. Importantly, the GRASS steers in this study did not receive any concentrates during their lifetime and were only fed organic grass pasture during the grazing season and organic hay or alfalfa silage during the winter.

Carcass Characteristics

Least squares means and standard errors of means of GRASS, ORG, and CONV steers for carcasses characteristics at slaughter are in Table 5. As expected, the GRASS and ORG steers had lower ($P < 0.05$) hot carcass weight, less fat thickness, smaller rib eye area, and a lower dressing percentage. The results are in agreement with those of Comerford et al. (2001), who reported that pasture-fed Holstein steers during the grazing season had significantly lower dressing percentage, less fat thickness, and smaller ribeye area than Holstein steers in a feedlot. Woodward and Fernandez (1999) found that ORG steers had lower carcass weights than ORG steers, which is in agreement with this study.

Because of the smaller carcass weight and less backfat of the GRASS and ORG steers, they had less ($P < 0.05$) marbling than the CONV steers. Consequently, the ORG and GRASS steers had less intramuscular fat in the meat, which could affect taste preferences of consumers who purchase beef in the marketplace. However, lower marbling score and quality grades may not be as critical for organic producers that engage in direct sales to consumers (Woodward and Fernandez, 1999). Choice carcasses were fewer ($P < 0.05$) for the GRASS (0.0 %) than for the ORG (12.5%) and CONV (81.3%) steers. Apparently, in addition to having smaller carcasses at slaughter, no

GRASS steers and few ORG steers will achieve Choice grade compared to conventional steers fed exclusively concentrate in a feedlot. Therefore, there may be a decrease in value for organic carcasses at slaughter, and consequently, profitability may be lower for feeding dairy steers exclusively on pasture.

Profitability

For profit per steer (Table 6), GRASS ($593.41) had greater ($P < 0.05$) profit per steer than CONV ($442.41) steers. However, the ORG ($-643.71) had lower ($P < 0.05$) profit per steer than GRASS and CONV steers. Therefore, cost per kg of gain was the greatest ($P < 0.05$) for the ORG ($4.83) compared to the GRASS ($1.77) or CONV ($2.15) steers. The difference among the GRASS steers and CONV steers was rather striking, because the GRASS steers had 34.1% more profit per steer compared with the CONV steers; however, the ORG steers had 245% less profit per steer than did the CONV steers. The results suggest profit per steer of ORG steers was unfavorable at the high organic corn and soybean meal prices. Perhaps, ORG steers would perform better for profit per steer with CONV steers in reduced-grain supplementation systems with lower organic corn price. Organic grazing dairy producers typically have a fixed capacity for the number of animals in their herds because of the amount of land for grazing. Consequently, organic dairy producers trying to seek relief from high grain prices, with additional pasture beyond what is needed for lactating cows may be able to make a profit from feeding organic dairy steers versus selling them to conventional markets.

The advantages for profit per steer of the GRASS steers over the CONV steers may seem modest. However, the number of organic dairy steers born on a typical organic dairy must multiply the profit per steer margin to determine additional profit for an organic dairy producer. A typical Midwest organic dairy would have 50 bull calves born per year. Therefore, this would result in an additional profit of $7,550 for an organic dairy producer to raise GRASS steers rather than CONV steers.

The results for profit per steer may have differed substantially had the GRASS steers been provided more time to slaughter. The GRASS steers would demand 282 more days on pasture and hay to achieve the market weight of the CONV steers, given the modest ADG of the GRASS steers (0.61 kg/d). Therefore, with an average feed cost of $2 to $3 per d, the profit per steer for the GRASS steers would be reduced to +$29 to -$253 per steer, and the advantage for profit per steer of the GRASS steers would disappear. For raising GRASS steers, it is imperative that organic dairy producers have high-quality pasture to maximize dry matter intake and ADG on pasture to achieve a reasonable market weight for steers in the least amount of time possible.

Results from the sensitivity analysis for profit per steer are also in Table 6. A lower organic corn price ($0.27/kg) decreased the difference between the ORG and CONV steers. Compared with the default values; however, the ORG steers continued to have a disadvantage for profit per steer (Table 6). Consequently, the ORG steers gained (-$1,086.12 to -$428.03) for profit per steer relative to the CONV steers. However, a much higher organic corn price resulted in much lower ($P < 0.05$) profit per steer for the ORG steers compared with the CONV steers. A higher organic beef premium dramatically increased profit per steer for the GRASS steers, and reduced the significant loss for profit per steer of the ORG steers. The gap between ORG and CONV steers was substantially reduced for profit per steer (-$1,086.12 to $882.61) at the higher organic direct-market beef price.

The GRASS steers continued to have substantial advantages (+64.3% to +407%) compared with CONV steers for profit per steer when organic beef premiums where higher (Table 6). The difference for the ORG and GRASS steers relative to the CONV steers is largely due to feed costs, especially organic corn price, and has a large effect on the profitability of raising organic steers. Because of the reliance on pastures for feed, grass-based steer production systems may experience fewer economic fluctuations, which may affect conventional steer production systems that rely on expense grain inputs. The results of this study for ORG steers compared to CONV steers were similar to Fernandez and Woodward (1999), who reported ORG steers had greater costs per gain than CONV steers.

The specific partitions of revenue and costs that contributed to profit per steer are in Table 7. The GRASS steers had less ($P < 0.05$) beef revenue than ORG and CONV steers, which were not different. Not surprisingly, feed costs were the highest expense for all of the steers groups. For steer costs, ORG steers had significantly higher corn cost, soybean meal cost, pasture cost, and fixed yardage cost than the CONV steers. The organic corn cost for the ORG steers was very similar to the beef revenue for the ORG steers, and therefore, organic corn price would have to be significantly lower for the ORG steers to remain profitable. The GRASS steers had feed costs that were lower ($P < 0.05$) than the ORG and CONV steers. Increased profit in an organic dairy-beef production system will contribute to the long-term viability of alternative production systems. Therefore, organic dairy bull calves may represent a potential economic resource for pasture-raised beef in the United States.

CONCLUSIONS

Organic dairy producers may improve the profitability of dairying by feeding dairy steers on 100% pasture versus feeding expensive organic concentrates. The GRASS steers had more profit per steer than did CONV steers; however, the ORG and GRASS steers had longer days to slaughter than CONV steers. The higher cost of production for the ORG steers was due to the extremely high value of organic corn. Therefore, a low grain ration may reduce feed costs without sacrificing profit in an organic dairy system, assuming the grass-fed steers can be marketed at a premium price based on the production system.

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Table 1. Distribution of organic (pasture + concentrate and grass-fed) and conventional dairy steers by treatment group and breed group.

Breed group	Conventional	Organic	Grass-fed Organic
1964 Holstein	4	3	4
Holstein	2	3	4
HMS[1]	7	7	5
HJSN[2]	3	3	4
Total	16	16	17

[1]HMS = Crossbreds of Holstein, Montbéliarde, and Swedish Red
[2]HJSN = Crossbreds of Holstein, New Zealand Friesian, Jersey, Swedish Red, and Normande

Table 2. Default revenues and expenses (C = Conventional and O = Organic) and alternative values for sensitivity analysis.

	Variable	Unit	Value	Reference
Revenue	Beef price	kg	(C) $2.71 (O) $3.04	USDA-AMS (2013)
Expense	Calf milk cost	kg	$0.6166	Organic milk price received from U of MN organic dairy
	Calf grain cost	kg	$0.56	Cost to manufacture organic grain at U of MN organic dairy
	Corn silage cost	kg	$0.06	USDA-AMS (2012)
	Hay silage cost	kg	$0.08	USDA-AMS (2012)
	Dry hay cost	kg	$0.20	USDA-AMS (2012)
	Corn cost	kg	(C) $0.25 (O) $0.54	USDA-AMS (2012)
	Dried distillers grains with solubles cost	kg	$0.21	USDA-AMS (2012)
	Soybean meal cost	kg	(C) $0.44 (O) $0.98	USDA-AMS (2012)
	Pasture cost	kg/dm	$0.02	Benson (2012)
	Mineral cost	kg	$1.03	U of MN organic dairy
	Fixed yardage cost	day	$0.25	U of MN organic dairy
Sensitivity	Organic corn cost	kg	Lowest, $0.27 Lower, $0.41 Higher, $0.68	USDA-AMS (2012)
	Organic beef price premium	kg	Double, $0.66 Triple, $0.99 Higher, $1.65	Organic Prairie (2012)
	Organic direct-market price	kg	$7.12	Local organic dairy producers who direct market organic beef

Table 3. Least squares means and standard errors for body measurements from birth to weaning for organic (pasture + concentrate and grass-fed) dairy steers compared to conventional dairy steers.

	Conventional		Organic		Grass-fed Organic	
Measurement	Mean	SE	Mean	SE	Mean	SE
Birth weight (kg)	38.4[a]	1.2	40.8[a,b]	1.2	42.4[b]	1.2
Weaning weight (kg)	106.3[a,b]	3.5	109.8[b]	3.4	97.0[a]	3.3
Hip height (cm)	95.6	1.0	96.7	1.0	95.4	1.0
Heart girth (cm)	110.5[a]	1.3	111.3[a]	1.3	105.1[b]	1.2
Total gain (kg)	68.0[a]	3.3	69.1[a]	3.3	54.6[b]	3.1
ADG (kg/d)	0.73[a]	0.03	0.75[a]	0.03	0.60[b]	0.03

[a,b] = Means within a row without common superscripts are different at $P < 0.05$

Table 4. Least squares means and standard errors for body measurements for organic (pasture + concentrate and grass-fed) dairy steers compared to conventional dairy steers.

	Conventional		Organic		Grass-fed Organic	
Measurement	Mean	SE	Mean	SE	Mean	SE
Age at slaughter (d)	466.2[a]	4.4	528.0[b]	4.4	583.6[c]	4.2
Slaughter weight (kg)	572.9[a]	13.8	470.4[b]	13.7	401.0[c]	13.0
Heart girth gain, wean to slaughter (cm)	80.1[a]	1.5	69.7[b]	1.5	65.1[c]	1.4
Hip height gain, wean to slaughter (cm)	45.0[a]	1.0	43.8[a]	1.0	38.1[b]	0.9
Gain, wean to slaughter (kg)	466.5[a]	11.6	360.5[b]	11.5	304.0[c]	10.9
ADG, wean to slaughter (kg/d)	1.2[a]	0.03	0.83[b]	0.03	0.62[c]	0.02
Gain, birth to slaughter (kg)	534.5[a]	13.5	429.6[b]	13.4	358.6[c]	12.7
ADG, birth to slaughter (kg/d)	1.1[a]	0.02	0.81[b]	0.02	0.61[c]	0.02

[a,b,c] = Means within a row without common superscripts are different at $P < 0.05$

Figure 1. Least squares means for post-weaning body weight by 45-d intervals for organic (pasture + concentrate and grass-fed) dairy steers compared to conventional dairy steers (— = Conventional steers, --- = Organic steers, - - - = Organic grass-fed steers).

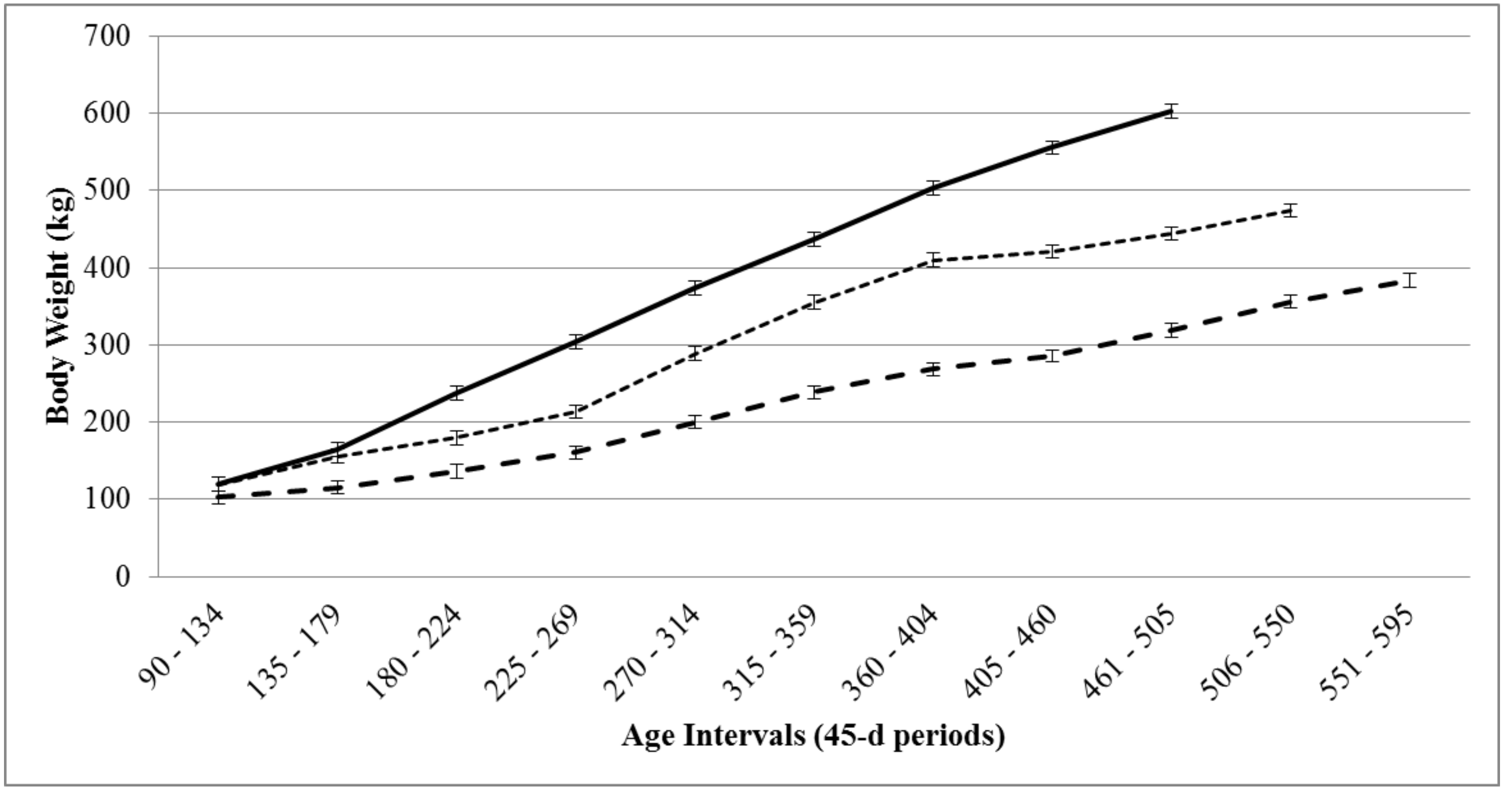

Table 5. Least squares means and standard errors for carcass measurements for organic (pasture + concentrate and grass-fed) dairy steers compared to conventional dairy steers.

	Conventional		Organic		Grass-fed Organic	
Carcass measurement	Mean	SE	Mean	SE	Mean	SE
Hot carcass weight (kg)	338.5[a]	7.4	248.6[b]	7.4	190.0[c]	7.0
Fat thickness (cm)	0.97[a]	0.1	0.29[b]	0.1	0.25[b]	0.1
Ribeye area (cm^2)	75.4[a]	1.7	65.8[b]	1.7	49.5[c]	1.6
Kidney, pelvic, and heart fat (%)	2.4[a]	0.1	1.0[b]	0.1	1.0[b]	0.04
Dressing percentage (%)	61.0[a]	0.4	54.6[b]	0.4	49.0[c]	0.4
Marbling score[1]	2.9[a]	0.2	3.9[b]	0.2	4.5[c]	0.2
Maturity score[2]	2.1[a]	0.1	1.0[b]	0.1	1.0[b]	0.1
Quality grade of select and greater[3] (%)	100.0[a]	-----	100.0[a]	-----	47.1[b]	-----
Quality grade of choice and greater[3] (%)	81.3[a]	-----	12.5[b]	-----	0.0[c]	-----
Yield grade	3.0[a]	0.1	1.2[b]	0.1	1.0[c]	0.1

[a,b,c] = Means within a row without common superscripts are different at $P < 0.05$

[1]Slightly Abundant = 1, Moderate = 2, Small = 3, Slight = 4, Traces = 5

[2]Maturity A = 1, Maturity B = 2, Maturity C = 3

[3]Standard errors not available because of chi-square test

Table 6. Least squares means for profit per steer and cost per kg of gain from default and sensitivity analysis for organic (pasture + concentrate and grass-fed) dairy steers compared to conventional dairy steers.

	Conventional		Organic		Grass-fed Organic	
Measurement	Mean	SE	Mean	SE	Mean	SE
Profit per steer ($)	442.41[a]	44.2	-643.71[b]	44.2	593.41[c]	42.9
Cost /gain ($/kg)	2.13[a]	0.10	4.91[b]	0.10	1.77[c]	0.09
Lower organic corn price ($0.27/kg)	442.41[a]	44.2	14.38[b]	44.2	593.41[c]	42.9
Lower organic corn price ($0.41/kg)	442.41[a]	44.2	-314.53[b]	44.2	593.41[c]	42.9
Higher organic corn price ($0.68/kg)	442.41[a]	44.2	-972.89[b]	44.2	593.41[c]	42.9
Organic beef price, $0.66/kg premium	442.41[a]	45.9	-484.20[b]	45.9	726.95[c]	44.5
Organic beef price, $0.99/kg premium	442.41[a]	47.6	-324.70[b]	47.6	860.50[c]	46.2
Organic beef price, $1.65/kg premium	442.41[a]	51.4	-5.69[b]	51.4	1127.59[c]	49.9
Organic beef direct-market price, $7.12/kg	442.41[a]	69.8	1325.02[b]	69.8	2241.70[c]	67.7

[a,b,c] = Means within a row without common superscripts are different at $P < 0.05$

Table 7. Least squares means for profit per steer by specific component of revenue and cost for organic (pasture + concentrate and grass-fed) dairy steers compared to conventional dairy steers.

	Conventional		Organic		Grass-fed Organic	
	Mean	SE	Mean	SE	Mean	SE
Revenue ($)						
Beef income	1,579.60[a]	44.80	1,465.97[a]	44.79	1,227.36[b]	0.000
Cost ($)						
Calf milk cost	32.85	0.000	33.50	0.000	35.16	0.000
Calf grain cost	95.29[a]	0.000	101.32[a]	0.000	0.00[b]	0.000
Corn silage cost	38.81[a]	0.000	63.32[b]	0.000	0.00[c]	0.000
Hay silage cost	0.00[a]	0.000	0.00[a]	0.000	199.95[b]	0.000
Dry hay cost	5.53[a]	0.000	2.31[a]	0.000	131.51[b]	0.000
Corn cost	576.80[a]	0.000	1,326.55[b]	0.000	0.00[c]	0.000
DDGS cost	35.22[a]	0.000	0.00[b]	0.000	0.00[b]	0.000
Soybean meal cost	135.23[a]	0.000	281.59[b]	0.000	0.00[c]	0.000
Pasture cost	0.00[a]	0.000	77.99[b]	0.000	76.36[b]	0.000
Mineral cost[1]	85.39[a]	0.000	77.81[b]	0.000	44.87[c]	0.000
Health treatment cost	14.51[a]	0.000	12.50[a]	0.000	0.00[b]	0.000
Fixed yardage cost	117.55[a]	0.000	132.80[b]	0.000	146.09[c]	0.000

[1] Mineral cost for conventional steers includes Optaflexx™ ractopamine cost

[a,b,c] = Means within a row without common superscripts are different at $P < 0.05$.

Manuscript 3

Fatty acid profiles, meat quality, and sensory attributes of organic versus conventional dairy-beef steers.

INTERPRETIVE SUMMARY

There is an increase in global demand for organic beef products, especially grass-fed and finished. Organic bull calves may represent a potential additional source of revenue for organic dairy producers. The objective of our study was to evaluate fatty acid profiles, meat quality, sensory attributes, and consumer acceptance of organic dairy steers compared to conventional dairy steers. The fat from the grass-fed steers was significantly higher in omega-3 fatty acid and significantly lower in monounsaturated and saturated fat. Consumers rated the grass-fed beef the lowest in overall liking and flavor.

CHAPTER SUMMARY

Holstein and crossbred dairy steers were evaluated for fatty acid profiles, meat quality, sensory attributes, and consumer acceptance of organic dairy-beef compared to conventional dairy-beef. Calves (n=49) were randomly assigned to one of three replicated groups (conventional (CONV), organic (ORG, pasture + concentrates), and grass-fed organic (GRASS)) and were born at the University of Minnesota West Central Research and Outreach Center, Morris, Minnesota from March to May 2011. The CONV steers (n = 16) were fed a diet that contained 80% concentrate and 20% roughage, and ORG steers (n = 16) were fed a diet of organic corn, organic corn silage, and organic protein supplement. Furthermore, ORG steers consumed at least 30% of diet dry matter in high-quality organic pasture during the grazing season. The GRASS steers (n = 17) consumed 100% forage from pasture during the grazing season and high-quality hay or hay silage during the non-grazing season. The ORG (46.9%) steers had fat that was significantly higher in oleic acid (C18:1) than the GRASS (35.7%) and CONV (37.8%) steers. The GRASS steers (22.9%, 1.3%) were significantly lower for monounsaturated and polyunsaturated fat than the ORG (42.9, 2.4%) and CONV (39.4%, 3.1%) steers, respectively. Furthermore, the GRASS steers were significantly higher for omega-3 fat and significantly lower for omega-6 fat than the ORG and CONV steers. Consequently, the GRASS (1.6%) steers had a significantly lower omega-6 to omega-3 fat ratio than the ORG (10.1%) and CONV (13.8%) steers. For sensory attributes, there were no significant differences for ORG (71.3) and CONV (69.2) steers for overall liking; however, the GRASS (56.3) steers had the lowest overall liking among beef consumers.

The ORG (73.3) steers had significantly higher flavor liking than the GRASS (56.8) and CONV (69.2) steers. Conversely, the GRASS (6.3) steers had the highest scores for off-flavor compared to the ORG (3.9) and CONV (4.1) steers. The results of the current study suggest there may be a potential market for organic grass-fed dairy steers in the United States.

(**Key words:** organic, dairy steer, beef, grass-fed, omega-3 fatty acid)

INTRODUCTION

The organic beef industry is in the early stages of development in the United States; however, markets for organic meat have expanded rapidly over the past decade as health-conscious consumers realize it may provide human health and environmental benefits (Dimitri and Oberholtzer, 2009). As consumers are demanding natural, local, organic, and grass-fed, there is an opportunity for organic dairy producers to capitalize on the growing organic beef industry (Gillespie and Nehring, 2012).

A majority of beef consumers in the United States prefer the taste of grain-fed beef, and the United States cattle industry most commonly finishes animals on a corn-based ration (Daley, 2010). Conversely, in the European Union beef consumers assert meat from livestock managed under less intensive production systems has more superior taste than meat from intensive production systems (Priolo, 2001). Currently, a number of consumers are evaluating their food-purchasing decisions and are changing to pasture-fed beef as an alternative (Steinberg, 2009). Saturated fat, trans fat, and cholesterol have become major health concerns for consumers (Daley, 2010).

Conjugated linoleic acids are a group of fatty acids that possess human health benefits (Razminowicz, 2006), and conjugated linoleic acids and omega-3 fatty acids are higher in cattle fed high forage and pasture diets compared to cattle fed high grain rations (Poulson, 2004; Daley, 2010). However, for consumer sensory evaluation, Steinberg et al. (2009) reported United States consumers preferred grain-fed beef compared to grass-fed beef when considering flavor, juiciness, and tenderness.

Organic dairy bull calves may represent a potential additional source of revenue for organic dairy producers, and these organic calves may represent a potential resource for pasture-raised beef in the United States to address consumers concerns with conventional-raised beef. No previous research has compared Holstein and crossbred dairy steers raised in a conventional production system versus an organic and grass-fed production system.

Therefore, the objective of this study was to compare conventional, organic, and organic grass-fed dairy steers for fatty acid profiles, Warner-Bratzler shear force (**WBSF**), objective color scores, and consumer acceptability. A companion paper (Bjorklund et al., 2013) reported results from the same steers for growth performance, carcass characteristics, and profitability.

MATERIALS AND METHODS

Data

The study was conducted at the University of Minnesota West Central Research and Outreach Center, Morris, Minnesota, and all animal care and management was approved by the University of Minnesota Institutional Animal Care and Use Committee recommendations (Animal Subjects Code 1104B98412). A detailed description of the study and management of organic dairy-beef steers compared to conventional dairy-beef steers is in Bjorklund et al. (2013).

Briefly, calves were assigned to one of three groups at birth; conventional (**CONV**, n = 16), organic (**ORG**, n = 16), and organic-grass only (**GRASS**, n = 17), and were born at the University of Minnesota West Central Research and Outreach Center, Morris from March to May 2011. The CONV steers were fed a diet of 80% concentrate and 20% roughage. The ORG steers were fed a diet of organic corn, organic corn silage, and at least 30% of their diet consisted of organic pasture during the grazing season. The

GRASS steers grazed pasture during the grazing season and were fed high quality hay or hay silage during the non-grazing season.

Strip loin collection

Carcasses were selected randomly before carcass data collection, and subsequently, fabricated according to North American Meat Processors guidelines (NAMP, 2002). One strip loin was removed from 8 random carcasses from each treatment group, CONV (slaughter conducted on July 24, 2012), ORG (slaughter conducted on September 19, 2012), and GRASS (slaughter conducted on November 13, 2012). Strip loins were identified using carcass identification tags during slaughter. Identified strip loins were followed through fabrication and vacuum-packaged at a commercial abattoir (Tyson Fresh Meats, Inc., Dakota City, NE for conventional steers, and Lorentz Meats, Cannon Falls, MN for organic and grass-fed steers).

Strip loins were maintained at 2° C during transport to the University of Minnesota West Central Research and Outreach Center, Morris, MN where they were unloaded and aged for 10 d postmortem at 2° C before further evaluation of meat quality and consumer sensory panel. After aging, 6, 2.54-cm thick, frozen steaks were cut from the cranial end of each strip loin. The most cranial steak of the 6 steaks cut from the frozen strip loin was used for WBSF analysis, 2 steaks were used for subjective color score analysis, and the remaining 3 steaks were used for consumer panel sensory evaluation.

Fatty acid profiles

Back fat samples (approximately 6.4 x 0.5 cm) were collected from eight random carcasses from each treatment group 72 h postmortem at the commercial abattoir.

Samples were placed in air tight plastic bags, transported on ice to the University of Minnesota West Central Research and Outreach Center, Morris, MN and frozen (-20° C) until subsequent analysis. Five frozen fat samples were chosen at random from each of the three treatment groups, were placed on ice packs in a polystyrene insulated container and shipped to R-Tech Analytical Lab (Arden Hills, MN) for fatty acid profile analysis.

Fatty acids were determined according to AOAC method 996.06 (AOAC, 2002) by R-Tech Analytical Lab (Arden Hills, MN). Briefly, lipids were extracted from a 3 g sample, saponified, derivatized, and then run on the gas chromatograph to determine which fatty acids were contained in the sample. Results were reported in percent weight of the total fat.

Tenderness determination and objective color scores

Tenderness was measured on a steak from each strip loin using the WBSF instrument (G-R Elec. Mfg. Co., Manhattan, KS). Steaks were removed from the freezer, thawed for 84 hours at 4° C, wrapped in aluminum foil, and then cooked in an electric oven to a final internal temperature of 71° C. Internal temperature was monitored with a thermometer inserted into the geometric center of the steak. Each steak was cooled to room temperature, and three 1.27 cm cores were removed from each steak parallel to the muscle fiber orientation using a hand coring device. A single peak shear force measurement was obtained for each core.

The color of each steak was measured using a HunterLab Miniscan XE Plus spectrophotometer equipped with a 6-mm aperature (HunterLab Associates Inc., Reston, VA) to determine color coordinate values for L* (brightness, 0 = black and 100 = white), a* (redness/greenness, positive values = red and negative values = green), and b* (yellowness/blueness, positive values = yellow and negative values = blue) following procedures of the Commission International de I'Eclairage (CIE, 1976). Readings for each of the L*, a*, b* values were taken at 3 spots on the surface of the steak exposed to the light; readings were averaged for each steak at the time of evaluation.

Consumer sensory evaluation

Procedures with human subjects for the consumer panel evaluation of sensory attributes were approved by the University of Minnesota Institutional Review Board. One-hundred consumers were recruited by the University of Minnesota's Food Science and Nutrition Sensory Center. Consumers were at least 18 yr old, had no food allergies, and had consumed cooked beef within the past month. All panelists were compensated $5 for participating in the sensory panel. Steaks were thawed and cooked in the same manner as described for WBSF. When steaks were removed from the oven, cubes of approximately 1 cm x 1 cm x 2.5 cm were placed in double boiler pots containing simmering water and the pots were replenished with cubes every 30 min to serve to the panelists for evaluation. Each panelist received two pieces of steak per sample in lidded 57 ml plastic soufflé cups coded with random 3-digit numbers. To maintain sample serving temperature, cups were nested in insulated foam trays and kept warm with heated towels. The samples were served to panelists in three sets of three samples on one tray. The first set corresponded to replicate 1, the second set corresponded to replicate 2, and the third set corresponded to replicate 3. The three samples within each set were balanced for order and carryover effects.

Subjects were asked to taste one piece of the sample and rate it for overall liking, liking of flavor, liking of texture, and off flavor. Samples were evaluated using a labeled affective magnitude scale. A mark was placed anywhere on the scale that appropriately described the panelist's liking of tenderness, flavor, and texture (0 = greatest imaginable dislike, 120 = greatest imaginable like). Furthermore, panelists were then instructed to consume the second piece of meat and rate the intensity of toughness, intensity of juiciness, along with a rating for off flavor (0 = none, 20 = extremely tough, extremely juicy, and extremely intense, respectively). Panelists repeated all steps 2 additional times.

Statistical analysis

For statistical analysis of fatty acid profiles, WBSF, and objective color score, independent variables were fixed effects of breed and treatment group. Replication number was included in the model for analysis of WBSF as a random effect. For consumer acceptability analysis, independent variables were fixed effects of treatment group, replicate, and the interaction of treatment group and replicate. Additionally, consumer subject and the interaction of consumer subject and treatment group were included as random effects in the model. For all measurements, the PROC MIXED procedure (SAS Institute, 2012) was used to obtain solutions and conduct the analysis of variance. All treatment results are reported as least squares means, and significance was declared at $P < 0.05$.

RESULTS AND DISCUSSION

Fatty acid analysis

Least squares means and standard errors for fatty acids for steer groups are in Table 1. The GRASS, ORG, and CONV steers had the same values (0.1% fat) for butyric (C4:0), caproic (C6:0), caprylic (C8:0), capric (C10:0), lauric (C12:0), tridecanoic (C13:0), myristelaidic (C14:1T), pentadecenoic (C15:1), gamma linolenic (C18:3), arachidic (C20:0), eicosadienoic (C20:2), eicosatrienoic (C20:3), homogamma (C20:3), arachidonic (C20:4), eicosapentaenoic (C20:5), behenic (C22:0), docosaenoic (C22:1), docosadienoic (C22:2), docosatrienoic (C22:3), docosatetraenoic (C22:4), docosapentaenoic (C22:5), docosahexaenoic (C22:6), tricosanoic (C23:0), lignoceric (C24:0), and nervonic (C24:1) acid and are not reported in Table 1.

Fat from GRASS steers had higher ($P < 0.05$) means of palmitic (C16:0), palmitelaidic (C16:1T), stearic (C18:0), linoelaidic (C18:2T), linolenic (C18:3), and heneicosanoic (C21:0) acids than fat from ORG and CONV steers. Results are similar to Priolo et al. (2001) who found higher proportions of linolenic acid in grass-fed beef compared to conventional beef, and Daley et al. (2010) reported beef from grass-fed steers had higher amounts of stearic acid than grain-fed beef. Microorganisms in the rumen can differ based on feeding system and the organisms that are present when concentrates are a high percent of the ration provide a reduced hydrogenation reaction compared to those present with a high grass-based diet (Priolo et al., 2001). Therefore, the GRASS steers had higher proportions of linolenic acid because dietary linolenic acid was hydrogenated in the rumen to a greater extent than in the CONV steers. The ORG steers had fat that was higher ($P < 0.05$) in oleic (C18:1) acids than fat from GRASS and CONV steers, which is contrary to the findings of Daley et al. (2010), who reported higher means of oleic acid in grain-fed beef than grass-fed beef. However, the ORG steers where fed a diet that consisted of 70% concentrates and corn, and therefore, their diet contributed to the higher levels of oleic acid than the GRASS steers.

The fat from GRASS (22.9%, 1.3%) steers had lower ($P < 0.05$) levels of monounsaturated and polyunsaturated fat than the ORG (32.9%, 2.4%) and CONV (39.4%, 3.1%) steers. Furthermore, the GRASS steers had higher ($P < 0.05$) levels of omega-3 fat (0.53%) and significantly ($P < 0.05$) lower levels of omega-6 (0.80%) fat than the ORG (0.23% and 2.2%, respectively) and CONV (0.21% and 2.9%, respectively) steers. Consequently, the omega-6 to omega-3 ratio was significantly lower ($P < 0.05$) for the GRASS (1.6%) steers compared to the ORG (10.1%) and CONV (13.8%) steers. The GRASS steers had lower ($P < 0.05$) levels of saturated fat, total fat triglycerides, and trans fat than CONV steers. The results are similar to Razminowicz et al. (2006) and Cozzi et al. (2010), who reported grass-fed beef had significantly higher omega-3 and lower omega-6 fat than conventional beef. In this study, increased forage and grass intake increased the omega-3 fat and decreased the omega-6:omega-3 ratio. Many health organizations have recommended increased consumption of omega-3 fats in food to improve human health. These data indicate that fatty acid composition can be altered by inclusion of grass and more forage in the diet.

Shear force and objective color scores

Least squares means for WBSF values and objective color scores are in Table 2. The GRASS (2.6 kg) steers had steaks that were not different ($P > 0.05$) for WBSF than ORG (2.4 kg) steaks; however, the GRASS steers had higher ($P < 0.05$) shear force than the CONV (2.0 kg) steaks. In a study by Wheeler et al. (1997), a WBSF value less than 4.6 kg was associated with a sensory panel rating of slightly tender. Therefore, all steaks in the current study would be considered tender during a consumer sensory evaluation, although the CONV steaks were the most tender among steer groups.

For objective color scores (Table 2), the ORG (39.2) steaks had lower ($P < 0.05$) L* values than CONV (42.6) steaks, but were not different ($P > 0.05$) from GRASS steaks (40.9). Furthermore, the GRASS (10.5, 11.7) and ORG (11.6, 11.6) steaks had lower ($P < 0.05$) a* and b* values than CONV (14.8, 14.6) steaks, respectively. Beef from grass-fed steers tends to be darker and the fat tends to be more yellow than grain-fed beef (Cox et al., 2006). The results of the study are similar to Cozzi et al. (2010) who reported organic beef had lower L* scores than confinement beef. However, Cozzi et al. (2010) reported organic beef had significantly higher a* and b* values than conventional beef, which is in disagreement with the current study. Perhaps, genetic differences in livestock, forage quality, pastures species, and length of pasture grazing determine the color of the beef in an organic grazing system. Furthermore, the current study evaluated beef from dairy steers, which may alter the color of the beef.

Sensory Panel

Least squares means and standard errors of means for sensory attributes are in Table 3. For overall consumer liking, means were similar for ORG (71.3) and CONV (69.2) beef steaks; however, the GRASS beef steaks were rated lower ($P < 0.05$) than the ORG and CONV beef steaks. Furthermore, means were similar for ORG and CONV beef steaks for texture, toughness, and off-flavor. Surprisingly, the ORG (73.3) beef steaks had higher ($P < 0.05$) flavor ratings compared to the CONV (69.2) beef steaks. The flavor ratings were high for both ORG and CONV beef steaks, and the ORG beef steaks had high ratings because they were fed some corn and concentrates during the grazing season. As expected, the GRASS beef steaks had less ($P < 0.05$) flavor and texture, and the beef was more tough, less juicy, and exhibited significantly more off flavor. The results are similar to a study by Poulson et al. (2004) who found GRASS beef had the highest off flavor scores. Steinberg et al. (2009) reported consumers found GRASS steaks to be too tough, too dry, but consumers did not dislike the beef.

For overall liking of beef (Table 4), only 12.6% of consumers moderately liked the GRASS steaks compared to ORG (30.0%) and CONV (32.0%), and the difference was lower ($P < 0.05$) for the GRASS compared to the ORG and CONV steaks. However, 2.7% of consumers liked the GRASS steaks very much and preferred the GRASS steaks compared to the ORG and CONV steaks. There were not differences ($P > 0.05$) for ORG and CONV steaks for consumer like/dislike categories. Consumer acceptability of GRASS steaks in the marketplace is dependent on flavor and tenderness, and GRASS beef had been noted to have a “grassy” flavor (Cox et al., 2006), and found to be less palatable for consumers than CONV beef (Daley, 2010). However in the current study, 43.9% of consumers had a liking for the GRASS beef steaks, which may indicate market potential for grass-fed beef in the United States. Cox et al. (2006) reported one-third of consumers preferred grass-finished beef and were willing to pay a premium for the beef. In a similar study, Steinberg et al. (2009) reported 23% of United States beef consumers preferred the taste of grass-fed beef and would pay a premium for the meat.

Historically, dairy-beef steers have been viewed as inferior to traditional beef in the marketplace. However, this study suggests that a majority of consumers have an overall liking of dairy beef whether it has been fed a corn-grain diet or a pasture-fed diet. Cattle producers should identify consumers for specific niche markets, especially organic, to take advantage of feeding organic dairy steers on grass.

CONCLUSIONS

Consumers are becoming more concerned about the origins of food, and grass-fed beef and organic beef has the potential to address some of the concerns. The study evaluated fatty acid profiles and consumer acceptance of organic dairy steers compared to conventional dairy steers. The fat from the grass-fed steers was significantly higher in omega-3 fatty acid and significantly lower in monounsaturated and saturated fat. Consumers rated the grass-fed beef the lowest in overall liking and flavor; however, 43.9% of consumers had at least a slight liking for the GRASS steaks. Organic dairy bull calves may represent a potential resource for pasture-raised beef in the United States.

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Table 1. Least squares means and standard errors for fatty acids for organic (pasture + concentrate and grass-fed) dairy steers compared to conventional dairy steers.

	Conventional		Organic		Grass-fed organic	
Fatty acid	Mean	SE	Mean	SE	Mean	SE
	----------------------- (%) weight of total fat ------------------------					
14:0, myristic	4.2[a]	0.29	2.7[b]	0.29	3.3[a,b]	0.29
14:1, myristoleic	1.5[a]	0.15	1.5[a]	0.15	0.87[b]	0.15
15:0, pentadecanoic	0.63[a]	0.05	0.45[b]	0.05	0.72[a]	0.05
16:0, palmitic	26.9[a]	0.66	23.6[b]	0.66	29.4[c]	0.66
16:1, palmitoleic	5.6	0.47	6.3	0.47	4.8	0.47
16:1T, palmitelaidic	0.44[a]	0.02	0.34[b]	0.02	0.53[c]	0.02
17:0, margaric	1.3[a,b]	0.11	1.0[b]	0.11	1.4[a]	0.11
17:1, margaroleic	1.2[a,b]	0.10	1.3[b]	0.10	0.9[a]	0.10
18:0, stearic	10.0[a]	1.10	8.5[a]	1.10	15.0[b]	1.10
18:1, oleic	37.8[a]	1.50	46.9[b]	1.50	35.7[a]	1.50
18:1T, elaidic	5.7[b]	0.73	3.0[a]	0.73	3.0[a]	0.73
18:2, linoleic	3.2[a]	0.24	2.7[a]	0.24	1.2[b]	0.24
18:2T, linoelaidic	0.51[a]	0.03	0.53[a]	0.03	1.01[b]	0.03
18:3, linolenic	0.16[a]	0.03	0.18[a]	0.03	0.85[b]	0.03
20:1, gadoleic	0.13[a]	0.04	0.29[b]	0.04	0.10[a]	0.04
21:0, heneicosanoic	0.21[a]	0.04	0.41[b]	0.04	0.60[c]	0.04
	------------------------ (%) in sample of fat ------------------------					
cis-Monounsaturated Fat	39.4[a]	2.80	42.9[a]	2.80	22.9[b]	2.80
cis-Polyunsaturated Fat	3.1[a]	0.28	2.4[a]	0.28	1.3[b]	0.28
Omega-3 fat	0.21[a]	0.05	0.23[a]	0.05	0.53[b]	0.05
Omega-6 fat	2.9[a]	0.26	2.2[a]	0.26	0.80[b]	0.26
Omega-6/Omega-3 ratio	13.8[a]	0.52	10.1[b]	0.52	1.6[c]	0.52
Saturated fat	37.2[b]	2.90	28.0[a]	2.90	27.8[a]	2.90
Total fat triglycerides	89.4[a]	5.50	79.7[a]	5.50	57.1[b]	5.60
trans fat	5.7[b]	0.69	2.9[a]	0.69	2.6[a]	0.69

[a,b,c] = Means within a row without common superscripts are different at $P < 0.05$

Table 2. Least squares means and standard errors for Warner-Bratzler shear force and objective color scores for organic (pasture + concentrate and grass-fed) dairy steers compared to conventional dairy steers.

	Conventional		Organic		Grass-fed organic	
Measurement	Mean	SE	Mean	SE	Mean	SE
WBSF[1] (kg)	2.0[a]	0.20	2.4[a,b]	0.20	2.6[b]	0.21
L*	42.6[a]	0.98	39.2[b]	0.99	40.9[a,b]	1.00
a*	14.8[a]	0.70	11.6[b]	0.70	10.5[b]	0.72
b*	14.6[a]	0.60	11.6[b]	0.60	11.7[b]	0.62

[1] = Warner-Bratzler Shear Force

[a,b,c] = Means within a row without common superscripts are different at $P < 0.05$

Table 3. Least squares means and standard errors for sensory attributes for organic (pasture + concentrate and grass-fed) dairy steers compared to conventional dairy steers.

	Conventional		Organic		Grass-fed Organic	
Sensory attribute	Mean	SE	Mean	SE	Mean	SE
Overall liking[1]	69.2[a]	1.50	71.3[a]	1.50	56.3[b]	1.50
Flavor liking[1]	69.2[b]	1.50	73.3[a]	1.50	56.8[c]	1.50
Texture liking[1]	67.2[a]	1.70	67.6[a]	1.70	53.0[b]	1.70
Toughness[2]	7.4[b]	0.39	8.0[b]	0.39	10.1[a]	0.39
Juiciness[2]	6.3[a]	0.31	5.5[b]	0.31	3.9[c]	0.31
Off flavor[2]	4.1[b]	0.37	3.9[b]	0.37	6.3[a]	0.37

[1] = Overall, flavor, and texture liking/disliking: 0 = greatest imaginable disliking; 120 = greatest imaginable liking

[2] = Toughness, juiciness, off flavor :0 = none; 20 = extremely tough, or extremely juicy, or extremely intense

[a,b,c] = Means within a row without common superscripts are different at $P < 0.05$

Table 4. Means for overall like/dislike categories for organic (pasture + concentrate and grass-fed) dairy steers compared to conventional dairy steers.

	Conventional	Organic	Grass-fed Organic
Sensory attribute	Mean	Mean	Mean
Like slightly (%)	71.4[a]	76.5[a]	43.9[b]
Like moderately (%)	32.0[a]	30.0[a]	12.6[b]
Like very much (%)	8.5[a]	8.8[a]	2.7[b]
Like extremely (%)	2.0[a]	1.0[a,b]	0.0[b]

[a,b] = Means within a row without common superscripts are different at $P < 0.05$

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