FORAGE QUALITY OF TWO COVER CROP GRAZING SYSTEMS AND MEAT QUALITY OF ORGANIC BEEF FROM CROSSBRED DAIRY STEERS FINISHED ON FORAGES

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Those who contemplate the beauty of the earth find
reserves of strength that will ensure as long as life lasts.
There is something infinitely healing in the repeated refrains of nature—
the assurance that dawn comes after night,
and spring after winter.

-Rachel Carson, *Silent Spring*

Abstract

This study analyzed the yield, forage quality, and mineral composition of organic winter rye and winter wheat in grazing systems, and analyzed the meat quality, fatty acids, and consumer acceptability of beef from Holstein and crossbred organic dairy steers finished on winter rye and winter wheat pastures. Steers (n = 30) were assigned to one of three replicate breed groups at birth: (1) Holstein (n = 10), (2) crossbreeds comprised of Montbéliarde, Viking Red, and Holstein (n = 10), and (3) crossbreeds comprised of Normande, Jersey, and Viking Red (n = 10). Breed groups were randomly assigned to graze either winter rye or winter wheat during their finishing phase. The results suggest that winter rye and winter wheat cover crops are viable options for grazing cattle, and suggest beef from crossbred dairy steers leads to an improved fatty acid profile and greater consumer acceptability compared to Holstein steers.

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List of abbreviations

AA	amino acid
ADF	acid detergent fiber
ADG	average daily gain
AGA	American Grassfed Association
AMS	Agricultural Marketing Service
Ca	calcium
CP	crude protein
DM	dry matter
DMI	dry matter intake
FA	fatty acid
HOL	Holstein
K	potassium
Mg	magnesium
Milk/t	kilograms of milk per metric ton of forage
MVH	Montbéliarde, Viking Red, and Holstein
n-3	omega-3
n-6	omega-6
n-6/3	omega-6/3 ratio
NDF	neutral detergent fiber
NEg	net energy gain
NEl	net energy lactation

NJV	Normande, Jersey, and Viking Red
NOP	National Organic Program
NOSB	National Organic Standards Board
OFPA	Organic Foods Production Act
P	phosphorus
PUFA	polyunsaturated fatty acid
SFA	saturated fatty acid
TTNDFD	total tract neutral detergent fiber digestibility
USDA	United States Department of Agriculture
WBSF	Warner-Bratzler shear force
WCROC	West Central Research and Outreach Center
WR	winter rye (*Secale cereale)*
WW	winter wheat (*Triticum aestivum)*

Introduction

Organic beef production in the United States

The National Organic Program (**NOP**) oversees organic agricultural production, which must adopt a system designed to respond to site-specific conditions by integrating cultural, biological, and management practices that augment resource cycling, promote ecological balance, and conserve biodiversity. The term, “organic”, refers to any agricultural product produced in accordance with the Organic Foods Production Act (**OFPA**) of 1990. The OFPA authorizes the NOP to be managed by the United States Department of Agriculture (**USDA**) [1]. Provisions to the OFPA must be approved by the NOP, which the National Organic Standards Board (**NOSB**) [2] effectuates. The NOSB is uniquely comprised of 15 board members of producer, consumer, environmental, retailer, and certifier stakeholders, whom are appointed by the Secretary of Agriculture and are responsible for developing standards for the National List of Allowed and Prohibited Substances [3], which regulates which chemical substances are permitted. The NOSB also advises the Secretary of Agriculture on a wide range of issues related to organic production. The NOP maintains a Program Handbook [4], which includes guidance, directions, policy memos, and other documents to disseminate the organic standards.

For all organic livestock production, animal welfare is a top priority. Regulations require that living conditions are cage-free and allow for natural behaviors, like exercise and grazing. Furthermore, pasture maintenance must be in accordance with the organic standards guidelines and 100% organically grown feed is required when pasture is not available. Prevention of health disorders and illness through management practices must be fulfilled since most conventional treatments, like antibiotics, hormones, and many chemical substances—not included in the National List of Allowed and Prohibited Substances—are prohibited [5]. One of the main differences between conventional and organic beef is the source of feed for cattle. According to the NOP, organic cattle must consume at least 30% of their daily dry matter intake (**DMI**) from pasture during the grazing season, except during the finishing phase, which must not exceed one-fifth of the animal's life (up to 120 days) [5]. Cattle producers must diligently abide by the NOP regulations while capitalizing on new developments that may improve the productivity and revenue for raising organic beef to meet increasing consumer demands.

The organic beef sector is still developing and accounts for a small, but growing, part in total organic sales. In fact, it is one of the fastest growing segments in the organic industry [6], which has tripled in proportion to the entire beef industry between 2005 and 2011 [7]. Consumer demands have primarily influenced growth in the organic beef industry. The perceived benefit of organic beef on human health, food safety, animal welfare, and environmental stewardship, are main drivers of demand [8].

Dairy beef and meat quality

Dairy beef is a critical part of the beef supply chain. Currently, dairy cull cows represent approximately 7–8% of the beef industry [9]. However, dairy steers account for a larger portion of the beef industry—an estimated 13–18% [9,10]. Furthermore, a producer survey conducted in the United States by Asem-Hiablie et al. [11] in 2016 reported that 21% of beef feedlots finished dairy cattle. Of those feedlots, dairy cattle represented 34% of their herd. Of all dairy beef breeds, Holsteins are the most common [12,13]. In the past, beef from Holstein steers was perceived as inferior to the quality of beef breeds [9]. More recently, production management developments have improved the beef quality grades of Holstein steers, which are now more comparable to their beef breed counterparts [9].

Although dairy steer beef has improved in recent years, there are still several differences in growth and carcass characteristics, which separate them from beef breeds. A producer survey conducted in the United States by Asem-Hiablie et al. [11] in 2016 reported that Holstein finishing operations took longer to finish their cattle for harvest than operations with only beef cattle breeds. Furthermore, Muir et at. [14] reported that Holstein and Hereford (a beef breed) steers had similar live weights when harvested at the same age and raised on pasture. However, carcasses from the Hereford steers were 4% heavier and had 3% greater carcass weight yields from live weight, or dressing percentages, than Holstein steers. This is consistent with other studies, which reported lower dressing percentages for dairy breeds than beef breeds [15–17]. Factors that contribute to a lower dressing percent include increased size of digestive tract tissues and less muscling [15,16]. Muir et at. [14] also reported 58% less subcutaneous adipose tissue, or back fat, for carcasses from Holstein steers compared to Hereford steers. Less back fat from Holstein carcasses also contributes to a lower dressing percent compared to beef breeds. However, dairy and beef breeds have similar kidney, pelvic, and heart fat percentages and similar or greater intermuscular fat scores, or marbling scores [15,16]. In fact, Muir et at. [14] found that Holstein carcasses had a 6% greater marbling score than Hereford carcasses. Holsteins have an innate ability to deposit intermuscular fat, which may be a quality grade advantage since marbling score is the primary determinant of quality grade [15]. Long-term genetic selections for milk production traits in the Holstein breed has resulted in homogeneous meat quality characteristics [15] and the consistency in meat quality of the breed is valued by many meat packers [10]. Since many customers are interested in lean beef, dairy beef may represent a profitable niche marketing enterprise [10].

For many dairy farms, dairy bull calves are not profitable to sell [10]. However, raising dairy steers for beef potentially offers additional revenue for dairy farmers by diversifying areas of income, especially when the price of milk is low. Furthermore, some dairy farmers reported that raising dairy steers along with their dairy operation had a small cost of investment and labor, since dairy steers require less labor than raising dairy heifers and require forage of lower quality than lactating dairy cows [18]. Producers have also selected genetic traits for docility over time in dairy breeds. Subsequently, dairy steers are also more docile and trainable than most beef breeds, which may allow them to work well in intensive grazing systems [19]. Because of the growth trend in the organic beef market, organic dairy cull calves may represent a potential new resource for organic beef in the United States.

Crossbreeding

The emphasis on genetic selections for milk yield traits, and subsequent inbreeding, in the Holstein breed has sacrificed the resilience of other traits, like calving ease, fertility, milk fat, and milk protein, which are now main concerns for producers [20]. Although, Holsteins are the predominant dairy breed in the United States, crossbreeding, which incorporates other dairy breed genetics, has become an interest amongst dairy producers as a method to reduce inbreeding [12]. A producer survey conducted in the United States by Weigel and Barlass [20] found that cows from crossbred herds were less likely to leave the herd due to illness, injury, or infertility, and had greater calving ease than cows in purebred Holstein herds. Weigel and Barlass [20] also reported lower milk yield, but higher milk components and conception rates in crossbred herds compared to purebred Holstein herds. Crossbreeding may result in improved reproductive performance and longevity. Furthermore, introducing other dairy breeds with superior reproductive performance, such as Montbéliarde and Normande, results in lower replacement costs [21], which may also be a contributing factor that encourages producers to implement crossbreeding.

Holstein steers require 10–12% more energy for maintenance than other breeds and are less efficient for fat deposition [22]. Reduced feed efficiency may be due to a larger body frame compared to smaller breeds. However, genetic selections in the Holstein breed for milk yield—and thus high metabolic capacity—has resulted in a larger digestive tract, which necessitates greater energy requirements for maintenance compared to other breeds [15]. Crossbred dairy steers may be a viable option for beef production since they may have similar or superior carcass values and may require less energy for maintenance compared to Holstein steers.

Recent studies reported variable differences in growth and meat quality characteristics between Holstein and crossbred dairy steers. McNamee et al. [23] reported similar harvest weight and average daily gain (**ADG**) for Holstein and Norwegian Red x Holstein crossbred steers, but Jersey x Holstein crossbred steers weighed 66 kg less at harvest and had a 9% lower ADG than Holstein steers. Furthermore, carcasses from Norwegian Red x Holstein crossbred steers had superior value compared to Holstein steers; however, Jersey x Holstein crossbred carcasses had inferior marbling and value compared to Holstein carcasses. Crossbreeding systems may also utilize other dairy breeds—like Montbéliarde and Normande. Evans et al. [21] reported similar harvest weight and ADG for Holstein, Montbéliarde, and Normande steers. Furthermore, the dressing percent for Normande carcasses was greater than Holstein carcasses and Montbéliarde and Normande carcasses were leaner in fat and had greater value compared to Holstein carcasses. Meat quality differences between Holstein and crossbred dairy steers may vary based on particular breeds and crossbreeding systems. However, there is little research on steer performance and meat quality involving crossbreeding systems.

Grass-fed beef

Industry

Prior to World War II, the majority of beef in the United States was derived from grass- or limited-grain-finished cattle raised on small-scale, diversified farms [24]. In the following decades, machinery developments, fertilizer breakthroughs, and market demands in the United States led to the expansion of large-scale cattle production, which increased the industrialization of grain-finished beef [24]. By the early 1970s, most beef sold in supermarkets was from grain-finished cattle, thus American consumers became conditioned to its flavor, texture, and other sensory characteristics. Today, corporate consolidation and company mergers in the beef industry has limited the management and marketing options for cattle producers [25].

In the 2000s, the consumer demand for grass-fed beef increased, which led to developments in forage- and pasture-based beef production. After public awareness of this growth, the USDA Agricultural Marketing Service (**AMS**) and the American Grassfed Association (**AGA**) worked together to establish the

Grass Fed Marketing Claim Standard and Naturally Raised Marketing Claim Standard in 2006 [26], which attempted to regulate meat labels. However, due to unreliable production audits and ambiguous terminology, producers and meat packers occasionally misused the marketing claim standard. As a result, the AMS withdrew from the Grass Fed Marketing Claim Standard and Naturally Raised Marketing Claim Standard in 2016 [27]. Previously, the AGA established their own Grassfed Beef Standards in 2009, which are similar to the former AMS standards [28]. In an email from C. Balkcom (Executive Director of AGA; standards@americangrassfed.org) in July 2017, the executive director of AGA suggested that AGA is now the main certification resource for forage-based beef producers. The AGA Grassfed Beef Standards include a mandatory 100% forage-based diet, with the exception of milk during the pre-wean period [28].

Currently, the demand for food products derived from natural and holistic production systems remains high [25]. Included in this sector of less industrialized food production systems are grass-fed beef programs. Grass-fed cattle account for only 0.5% of the total national beef cattle herd [29], but represent 7% of beef sales and have an estimated current annual growth rate of 25–30% in the United States [30]. On the other hand, conventionally raised beef makes up a majority of the beef industry, which involves a high concentrate diet and growth-enhancing technologies, like implants and ionophores, in a feedlot setting during the last few months prior to harvest, or finishing phase [11]. Consumers perceive grass-fed beef as healthier [31], raised with better animal welfare standards, and as less of an impact on the environment compared to conventionally raised beef. These perceptions are all main drivers for demand [32,33]. Furthermore, high forage diets reduce the risk of sub-acute acidosis related to high concentrate diets [22], which may also lead consumers to believe that grass-fed beef is raised with superior animal welfare standards compared to conventionally raised beef.

Since forage for grazing is not available the entire year in the United States and stored forages can be expensive, most grass-fed beef is imported from Australia and New Zealand [34]. However, a survey conducted in the United States by Umberger et al. [36] reported that American consumers believe beef imported from other countries is less safe to consume. This perception has contributed to an increase in the demand for beef raised in the United States [33,35,36]. To meet the current and future demand for grass-fed beef raised in the United States, improvements in the availability and quality of forage must be first achieved, so that cattle can perform to their utmost potential [37].

Management

The grass-fed beef market is a niche enterprise, given that only 1.1% of ranches in the United States finish their cattle on forages [11]. These ranches are comprised of small-scale farms raising an average of 40 beef cattle per year [38]. Grass-fed beef production represents less-industrialized, modest production models where producers may have more control over their operations [29]. Thus, farm-level strategies for raising grass-fed beef can vary. A common, low-input feeding strategy is pasture grazing [10,19].

After weaning in a conventional system, producers commonly feed dairy steers high-energy diets until they reach weights of 160–180 kg, then introduce a high-forage diet until steers reach 320–360 kg to support muscle and frame development during their growth phase [10]. This practice takes advantage of innate high feed efficiency in young steers [13]. Alternatively, for dairy steers in a forage-based system, producers feed a forage or pasture-based diet after weaning. However, some producers have reported reduced weight gain when the steers first initiate grazing, which may be mitigated by grazing steers at a younger age to encourage early adaptation to grazing behaviors and maximize performance later in their finishing phase [10]. However, this management decision may depend on pasture availability. Furthermore, grass-fed beef producers decide when to harvest or sell their cattle based on various factors. A producer survey conducted by Gillespie et al. [39] reported that producers decide when to harvest or sell their cattle based on equal influences of live weight, consumer demand, forage availability, age, body frame, and time of year. Furthermore, forage availability tended to be the most variable factor for producers when deciding when to sell cattle. Gillespie et al. [39] also reported that 96% of grass-fed beef producers direct-market their beef to consumers and only 16% market to wholesalers or retailers. Compared to conventionally raised dairy steers fed high energy diets in their finishing phase to reach market weight, grass-fed dairy steers take longer to reach market weight and weigh less at harvest [10]. In an email from N. Koester (Nathan.koester@organicvally.coop) in July 2017 and in a producer survey [38], it was suggested that the typical market weight for grass-fed cattle is roughly 470 kg as opposed to about 615 kg for grain-finished beef [11]. Bjorklund et al. [41] reported that grass-fed dairy steers took almost 4 months longer to reach market weight and weighed 175 kg less at harvest compared to conventionally raised steers. Feed cost is the greatest expense for raising dairy steers in both conventional and forage-based systems [39]. Bjorklund et al. [41] reported that feed and total costs for forage-based dairy steers was lower compared to feed costs for conventionally raised steers. However, extending the finishing period for forage-finished steers may result in reduced profit compared to conventionally raised steers [39]. Furthermore, many abattoirs and buyers prefer smaller grass-fed cattle and carcasses due to the price premium for grass-fed beef. Finishing steers on forage, as opposed to grain, may decrease carcass quality [10,37] if energy demands are not met. Bjorklund et al. [41] also reported that grass-fed steers had less overall fat, marbling, and quality grades than conventionally raised steers. However, this may be variable depending on factors such as breed [29], forage quality, and forage availability [19,37].

Pasture management

Like any other agricultural crop, environmental conditions, like drought, moisture, and temperature, primarily control pasture forage production. However, management practices that minimize the negative effects of unforeseen environmental extremes can help extend the length of the grazing season and maintain the quality of pasture forages. The conventional pasture management system involves continuously grazing the same area of pasture during the grazing season. Alternatively, management-intensive grazing (**MIG**) utilizes several paddocks divided within a pasture. In this system, cattle rotate to a new paddock every few days based on forage availability while the remainder of the pasture regrows. MIG enables enhanced forage utilization and uniform grazing during periods of rapid forage growth.

Oates et al. [42] reported that MIG systems produced greater forage mass and quality during the grazing season than continuously grazed pastures. This management technique has the potential to improve forage production and subsequent steer performance in their growing and finishing phases [19,41].

Small grain winter cover crops

According to the NOP, all organic operations must maintain an active soil building plan [4]. As more concern is placed on soil health, the emphasis on reducing soil erosion and nutrient leaching has become the main reason to utilize winter cover crops in rotation with other annual crops [42]. In the upper Midwest, perennial grass and legume species and annual forages are the traditional pasture forages for many grazing beef producers [11]. However, perennial grasses and legumes are not available to graze most of the year and typically begin growing as late as May [41]. Grazing small grain winter cover crops in the early spring to extend the grazing season may be a viable option.

Producers may achieve early spring forages for grazing by planting small grain winter cover crops in the fall to overwinter. Small grain winter cover crops are adapted to grow in cooler temperatures than most perennial grass species and have been suggested as a potential grazing source [43]. A producer survey conducted in the United States by Asem et al. [11] in 2016 reported that 19% of beef cattle ranchers grazed small grains as a method to maximize forage production during the year. This may be a useful strategy because one of the main obstacles organic beef producers face is lack of forage supply for grazing [29]. Furthermore, grazing winter cover crops may help organic producers meet the soil-building plan and pasture DMI requirements mandated by the NOP.

Winter rye and winter wheat for spring grazing

Some farmers may be reluctant to graze small grain winter cover crops in the spring because of concerns for rapid decreased forage quality across the grazing season as forages mature and due to variability in forage quality between small grain species [44]. Collar and Gene [47] and Moyer and Coffey [48] reported that small grains rapidly decreased in crude protein (**CP**), energy, and digestibility across the growing season. However, the digestibility of small grains before early heading is adequate for grazing cattle [44,47].

Winter rye and winter wheat are popular small grain cover crops in the upper Midwest due to their adaptation to low temperatures [47]. Although winter rye is less palatable than other forages, it generally produces more herbage mass in the early spring than other small grains due to its rapid growth, adaptation to low temperatures [47]. Although winter wheat matures later than winter rye [44], it begins growing earlier than perennial grasses and legumes so it may also be effective to extend the grazing season in the early spring. Lauriault and Kirksey [50] reported that winter wheat matured over 2 weeks later than winter rye when harvested for silage. Furthermore, Moyer and Coffey [48] reported that during the first half of the spring winter rye had greater forage yield compared to the second half of the spring, and had greater yield compared to winter wheat during the first half of the spring. Winter wheat had greater yield in the second half of the spring compared to winter rye. However, winter rye and winter wheat had similar total yield, and winter wheat had similar yields during the first and second halves of the spring. Alternative grazing systems, which incorporate winter rye and winter wheat cover crops, may extend the grazing season and maximize forage production.

Forage quality for finishing dairy steers

Raising dairy steers on pasture requires management decisions to achieve high quality forage for growth [10]. A forage quality analysis provides information about the nutritional quality of forages for cattle. Arelovich et al. [51] reported that DMI was positively correlated with weight gain, which makes maximizing intake a main priority when considering finishing dairy steers on forages. Furthermore, the fiber, digestibility, CP content, and mineral composition of forages also play a role in DMI, production potential, and overall cattle health.

Fiber digestibility

Dietary fiber affects DMI and is especially important to evaluate in forage-based systems due to the use of fiber as a source of energy in cattle diets. Neutral detergent fiber (**NDF**) and acid detergent fiber (**ADF**) are measurements of fiber. The NDF includes plant cellulose, hemicellulose, and lignin, and ADF includes plant cellulose and lignin, which are all structural fibrous components of forages. Cellulose and hemicellulose are the digestible components of fiber that provide energy to cattle; however, lignin is not digestible and reduces the digestibility of other plant constituents. The ADF represents the least digestible fiber portion of forages. Arelovich et al. [51] reported that the DMI (as % of body weight) of beef cattle was positively correlated with NDF between the range of 7.5–35.3% dry matter (**DM**), and higher concentrations of NDF in the diet led to reduced DMI (as % of body weight) due to rumen fill. DMI restrictions are main concerns for producers since most forages are high in NDF. Although NDF can be a predictor of DMI potential, Wilkins [52] reported that DMI is also dependent on the total tract NDF digestibility (**TTNDFD**) of forages (especially at high NDF levels). When the TTNDFD, or digestibility of NDF, is high, feed passes through the digestive tract quickly, resulting in increased intake potential [51]. Furthermore, low TTNDFD limits DMI and the ability to consume sufficient forage to meet nutritional requirements [51].

Forage digestibility relates to plant maturity, which is an important concept in terms of forage quality during the grazing season. Collar and Gene [47] reported that as the NDF increases with plant maturity, the TTNDFD decreases and so does the energy value of the forage. The leaves are more digestible than the stems; as the proportion of leaves to stems decreases with plant maturity, the digestibility of the plant decreases [52]. The negative correlation between digestibility and plant maturity also reflects lignification of the entire plant [45,52]. Forage-based diets tend to have higher NDF values than diets containing grain, so monitoring TTNDFD is important in order to maximize DMI and meet nutrient requirements.

Crude protein

Another important component of a forage quality analysis is CP, which is an evaluation of the amount of nitrogen in forages that estimates the amount of protein in forages. Protein supports growth and performance of cattle [53]; however, CP decreases with plant maturity [45]. The recommended CP level is 12–14% DM for growing steers and 11–12% DM for finishing steers [22]. Forages typically contain high CP levels, especially in the early spring. In fact, one issue that arises with pasture grazing is excessive CP in the diet and not enough energy for protein utilization [10]. Some producers may decide to supplement concentrates as an energy source, however Caton and Dhuyvetter [56] reported that supplementing grain on pasture may reduce forage DMI and digestibility. Supplementing with grain lowers ruminal pH, which may be detrimental to cellulolytic bacteria—the microbe responsible for fiber digestion. Without proper fiber digestion, the undigested dietary fiber contributes to rumen fill and lowers DMI.

Minerals

Dietary mineral composition is important to balance since minerals can be limiting or excessive and can cause deficiencies or toxicities in cattle. Furthermore, the complex interactions between minerals can hinder their absorption [55,56]. The mineral concentration in forages varies by plant species, maturity, soil fertility, and precipitation [57]. George et al. [60] reported that the mineral concentration decreases with plant maturity and therefore across the grazing season, which can be a concern for growing cattle.

Typically, mineral requirements are met for growing steers if the concentration (% DM) exceeds 0.5 for potassium (**K**), 0.3 for calcium (**Ca**), 0.21 for phosphorus (**P**), and 0.20 for magnesium (**Mg**) [55,56]. The K in forages is usually well above the maximum tolerable level of 3% DM, especially during the early spring. Furthermore, Dove et al. [58] reported that high levels of K may reduce DMI and inhibit Ca and Mg absorption.

Grazing rapidly growing cereal crops in the early spring can lead to Mg deficiency, which can cause hypomagnesemia resulting in reduced performance or even death of cattle [55,56]. Dove et al. [58] reported that hypomagnesemia may also be induced by a high P to Mg+Ca ratio over 2.2. Furthermore, high intakes of P decrease the ability to absorb Mg [55], which can exacerbate a Mg deficiency. Soil amendments, such as manure, contain high quantities of P, which absorb and accumulate in forages. Therefore, precaution for excess P application is necessary if the pasture requires fertilizer.

It is a common practice in the United States to supplement free-choice minerals to grazing steers [56] to balance and meet mineral demands, especially when grazing cereal forages. Dove et al. [58] reported that mineral supplementation may increase weight gain by 3–24% in grazing steers, and it was suggested that Ca and Mg are the most important minerals to supplement for growing steers to prevent metabolic disorders. The mineral composition of forages varies, therefore it is important to consider mineral supplements during the grazing season.

Fatty acid composition in beef

Beef is a major contributing source of fat in the human diet and different fat types play various roles in the human body. Saturated, monounsaturated, and *trans* (a bi-product of biohydrogenation in the rumen) fatty acids (**FAs**) make up the majority of fat in beef [59,60]. However, they can be synthesized in the human body and have no known beneficial role in preventing chronic diseases, so they are not required in the diet [61]. Although some types of saturated, monounsaturated, and *trans* FAs are healthy in the human diet, they are main health concerns amongst beef consumers [59] due to the risk of chronic diseases, like coronary heart disease, obesity, and diabetes [61] at high levels.

Recently, nutritionists have focused on the beneficial role of individual essential polyunsaturated fatty acids (**PUFAs**) and the omega-6 (**n-6**) to omega-3 (**n-3**) ratio. N-6 and n-3 are two types of PUFAs and are essential in the human diet. However, n-6 is abundant in the typical American diet, whereas n-3 is deficient [61,62]. N-3 plays an important role as a structural membrane lipid and also modulates the metabolism of n-6, therefore a balance between n-6 and n-3 is necessary in the human diet [61]. Furthermore, some studies suggest that n-3 protects against cancer, heart disease, and other chronic illnesses [61,62]. It is recommended that a lower dietary n-6:n-3 ratio of 4:1 or less is healthier [62], which may be achieved by increasing the amount of n-3 in the human diet. Furthermore, conjugated linoleic acid (**CLA**) is a group of PUFAs that exist as positional isomers and stereoisomers of C18:2 found in beef, lamb, and dairy products. It has been suggested that CLA is beneficial to human health by reducing the risks for cancer, heart disease, diabetes, and obesity [63].

Altering dietary ingredients for cattle may manipulate the FA profile of beef. Forage species have different FA profiles, which may vary based on the environment and management practices [64]. The dietary FA composition for cattle may influence the FA profile in the adipose and muscle tissue of beef [64]. There is considerable interest in the FA profile difference between grass-fed and conventionally raised beef. Numerous studies report that grass-fed beef has about 16% less monounsaturated FAs [60,65–69] and about 29% more PUFAs [65,69] compared to conventionally raised beef. Furthermore, Scollan et al. [72]

reported that increasing the amount of dietary forage during the lifetime of beef cattle increases n-3 and lowers n-6 in muscle and adipose tissue, due to the presence of α-linolenic (C18:3n-3) acid in forages [71]. Many studies have reported that grass-fed beef has about 2.5 times more n-3 [32,65–67,72] and 7% less n-6 [60,67,68] compared to conventionally raised beef [32,59,60,72]. Subsequently, grass-fed beef also has a lower, healthier n-6:n-3 ratio of about 2:1 compared to conventionally raised beef—which is about 9:1 [32,60,65–67,72,73]. Furthermore, CLA is approximately 2 times greater in grass-fed beef than conventionally raised beef [59,74,75]. The healthier FA profile of grass-fed beef compared to conventionally raised beef may influence consumer preference [76], which may be viewed as an investment in their health [77].

The FA profile of beef may also differ by breed. Various studies have compared the FA profiles of beef from different breeds. In a study comparing Holstein and Simmental beef [72], Holsteins had greater n-3 and lower n-6 compared to Simmentals, resulting in a lower n-6:n-3 ratio. Furthermore, other individual saturated FAs, monounsaturated FAs, and PUFAs may vary by breed [70,72,78].

Amino acid composition in forage-finished beef

Amino acids (**AAs**) are the building blocks of proteins, which are the major structural components of all cells in the human body. Of the 18 AAs found in beef, nine are essential and must be consumed in the human diet [61]. Because grass-fed beef has 36–42% less fat [66,75], the protein concentration is greater compared to conventionally raised beef. Malekian et al. [78] reported a greater concentration of protein in grass-fed beef compared to grain-finished beef. Furthermore, specific AAs may differ by feeding system. Frank et al. [80] and Patel et al. [81] reported that essential AAs were greater in grass-fed beef compared to conventionally raised beef.

Sensory characteristics of forage-finished beef

Sensory attributes determine the consumer acceptability of cooked beef. Price differences between quality grades are indicative of the emphasis the beef industry has placed on sensory attributes [80]. However, quality grade does not explain the variation in sensory attributes of cooked beef [80], indicating that consumer acceptability may be multifactorial. Furthermore, the sensory attributes of beef are especially important for grass-fed beef producers since most have a direct relationship with their customers and word-of-mouth is their primary marketing strategy [38].

In general, consumers prefer the sensory characteristics of conventional, grain-finished beef to grass-fed beef [60,72,81,82]. However, some studies report similar [75] or more desirable sensory characteristics for grass-fed beef [10,83]. Furthermore, Duckett et al. [77] reported that finishing cattle on different forage species also may influence the sensory attributes of cooked steaks. The preference for conventionally raised beef may be due to the fact that consumers are accustomed to beef with a high fat content which is derived from grain-finishing [72,75]. Furthermore, grass-fed beef contains more PUFAs which may oxidize and cause an off-flavor [70]. Although consumers may prefer beef with a healthier FA profile, they are unlikely to compromise on the sensory attributes of beef [70].

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Manuscript 1

Herbage mass and forage quality of winter rye (*Secale cereale*) and winter wheat (*Triticum aestivum*) across the grazing season for finishing dairy steers with implications to dairy cow production.

Overview

Forage from organic winter rye and winter wheat cover crops, grazed by dairy steers, was evaluated and compared for herbage mass, dry matter, forage quality characteristics, and mineral composition. Winter rye and winter wheat pastures were established on two adjacent 4 ha plots in September 2015 at the University of Minnesota West Central Research and Outreach Center (Morris, MN). During spring of 2016, winter rye and winter wheat pastures were randomly assigned three replicated steer paddock groups each (29 steers total). Steer groups moved to a new paddock every three days in a rotational grazing system for seven weeks. For statistical analysis, independent variables were the fixed effects of forage and week within forage. Paddock within collection number was a random effect with week as a repeated measure. Winter rye (2925 kg DM/ha) and winter wheat (2674 kg DM/ha) had similar mean herbage mass across the grazing season; however, winter rye had greater herbage mass during the beginning of the grazing season and winter wheat had greater herbage mass during the end of the grazing season. Winter wheat (19.0%) had 8.0% greater mean crude protein than winter rye (17.6%), and winter rye (48.0%) had a 6.4%

greater mean NDF during the grazing season compared to winter wheat (45.1%); however. Total tract neutral detergent fiber digestibility was similar between forages. Forage quality decreased over the course of the grazing season; however, both forages met the nutritional requirements for beef cattle. The results suggest winter wheat and winter rye cover crops are viable options for grazing dairy and beef cattle in the spring.

(**Key words:** grazing, forage quality, small grains, dairy steers)

Introduction

There is a continuing increase in the demand for organic products due to consumer interest in sustainable farming practices and animal welfare [1]. Consumer demand has led to an increase in the number of organic farms, including organic beef and dairy farms. According to the USDA-National Organic Program (**NOP**), cattle must consume at least 30% of their daily dry matter intake (**DMI**) from pasture during the grazing season, except during the finishing phase for beef, which must not exceed one-fifth of the animal's life (up to 120 days) [2]. Grass-finished beef has gained interest among consumers [3,4]. However, shorter growing seasons in the U.S. make it difficult for producers to finish beef cattle on forage, therefore 75–80% of grass-finished beef products are imported from Australia, New Zealand, and other countries [5]. Growth trends in the organic and grass-finished beef market have allowed producers to capitalize on forage production for grazing systems.

According to the NOP, all organic operations must maintain an active soil building plan [2]. As more concern is placed on soil health, the emphasis on soil erosion and nutrient leaching have become the main reasons to utilize winter cover crops in rotation with other annual crops [6]. In the upper Midwest, perennial species (i.e., orchardgrass, bromegrass, and meadow fescue) are the traditional pasture forages for many producers. However, these pastures are not available to graze most of the year and are typically available to graze in May [7]. Incorporating winter cover crops may offer additional available forage earlier than perennial pastures in the spring. Producers plant winter cover crops in the fall, which begin growing during the coldest parts of the spring. They are cold hardy and can grow in cooler temperatures than most perennial grass species and have been suggested as a potential forage source for grazing [8]. This may be a useful strategy because one of the main obstacles organic beef producers face is lack of supply of pasture-based feed [9]. Furthermore, grazing winter cover crops may help organic producers meet the soil-building plan and DMI requirements mandated by the NOP. Growing winter cover crops in rotation with other annual cash crops not only improves soil health and reduces nutrient leaching and soil erosion, but it could also provide forage for grazing cattle.

Some farmers may be reluctant to graze small grain winter cover crops in the spring because of concerns for rapid decreased forage quality across the grazing season as the forages mature [10] and variation in forage quality between small grain species [11]. However, the digestibility of small grains before the boot stage or early heading is adequate for grazing cattle [11,12]. Winter rye is a popular cover crop in the upper Midwest due to its adaptability to low temperatures [12]. Winter rye generally produces more herbage mass for grazing in the early spring than other small grains due to its rapid growth, adaptation to low temperatures, and production on infertile soil, but it is less palatable than other forages [12]. Winter wheat is also a popular cover crop in the upper Midwest. Winter wheat matures later than winter rye [11], but begins growing earlier in the spring than perennial forages so it may also be used to extend the grazing season into the early spring. Alternative grazing systems, which incorporate winter cover crops, may be useful to achieve a longer grazing season and maximize forage production.

As organic beef and dairy industries continue to grow, it is important to understand the impact of forage species on forage production and quality across the grazing season. Therefore, the objectives of this study were to compare winter rye and winter wheat pastures for herbage mass, dry matter, forage quality characteristics, and mineral composition across the grazing season.

Materials and methods

Ethical statement

Researchers conducted the study at the University of Minnesota West Central Research and Outreach Center, Morris, MN (**WCROC**) organic dairy in Morris, Minnesota. The University of Minnesota Institutional Animal Care and Use Committee approved all animal care and management (Animal Subjects Code number 1411-32060A).

Experimental approach

The research dairy at the WCROC has 300 low-input conventional and organic grazing cows. The organic dairy was certified with Midwest Organic Services Association in June 2010 and is regulated by the USDA-NOP and certifying agencies [2]. The research herd has implemented a crossbreeding program since 2000, which are thoroughly described in Heins et al. [13].

Pasture establishment

Manure from cattle during the grazing season fertilized pastures in this study. Pasture management excluded additional fertilizer and irrigation. Winter rye (*Secale cereale*) (**WR**) and winter wheat (*Triticum aestivum*) (**WW**) cover crops were established on two adjacent 4 ha plots in September 2015 at the WCROC. The current study used these small grains due to their success and popular utilization as cover crops in the upper Midwest. Prior to planting, the WCROC utilized the land for dairy cattle grazing and included perennial forages for at least 20 years.

Weather data

For the current study, the WCROC weather station in Morris, MN recorded daily weather data (Table 1). Also reported is the normal monthly temperature, precipitation, and snowfall as averages for years 1886–2016. The temperature during the growing season (September 2015–June 2016) was slightly warmer during the winter and cooler during the spring compared to the 130-year average. Furthermore, the precipitation during the months of May and June 2016 was lower than the 130-year average. This resulted in about 25% less precipitation during the growing season compared to the 130-year average. The snowfall during the growing season of current study was about 35% less than the 130-year average.

Cattle grazing of pastures

Thirty bull calves were born at the WCROC from March to May 2015 and assigned to one of three replicated breed groups at birth. Details on rearing and care are explained in Phillips, 2017 in press. Breed groups were: (1) purebred Holstein (**HOL**, n = 10), (2) crossbreeds comprised of Montbéliarde, Viking Red, and HOL (**MVH**, n = 10), and (3) crossbreeds comprised of Normande, Jersey, and Viking Red (**NJV**, n = 10). Six groups of five calves were established (n = 30). After weaning, steers were relocated to a loose-confinement barn, remained in their respective groups, and were fed an organic total mixed ration diet consisting of organic corn silage, alfalfa silage, corn, soybean meal, and minerals from the time of weaning until 25 April 2016. One NJV steer died from peritonitis and was removed from the study.

Grazing was initiated when forage height reached 15 cm for both systems on 25 April 2016. Each steer group was randomly assigned to graze either WR (n = 15) or WW (n = 14), so that forage type was balanced by breed and age. Steers remained in their groups throughout the grazing season, separated by paddocks using temporary fencing. Starting from the north end of the pastures, steer groups rotationally grazed until 13 June 2016 with supplemented free-choice minerals for seven weeks. Steers moved to a new paddock every three days and grazed the pastures three times. Briefly, steers grazed on WR and WW had similar (P = 0.88) average daily gains (**ADG**; 0.87 kg/d) from birth until harvest, which are similar to results in Bjorklund et al. [15] who reported an ADG range of 0.62–0.82 kg/d for grass-fed and organic steers of similar breeds in the current study. Furthermore, steers grazed on WR (0.33 kg/d) and WW (0.32 kg/d) had similar (P = 0.64) ADG from the first day of grazing to the last day of grazing.

Forage samples

Three random forage clippings were taken from each paddock before grazing by randomly throwing a 0.23 m^2 quadrat and clipping the forage within the quadrat to a height of 5 cm above the soil, resulting in two or three collections per week. The three clippings were used to determine dry matter (**DM**) and herbage mass for each sample. The DM value was obtained by weighing the fresh clipping, drying for 48 hours at 60° C, and weighing the dry clipping. The DM was calculated by using the equation: percent DM = dry sample (kg) ÷ fresh sample (kg) × 100. The DM herbage mass (kg/ha) was determined from the DM weight of each clipping by using the equation: herbage mass = dry sample (kg) ÷ 0.23 m^2 ÷ 0.0001. The three clippings were averaged to obtain a single measurement for each paddock per date for WR (n = 48) and WW (n = 48).

Dried forage clippings were ground through a 2 mm screen (Model 4, Wiley Mill, Thomas Scientific, Minneapolis, MN). One of the three clippings from each paddock was randomly chosen for forage quality analysis for each collection date. A total of 48 WR and 48 WW samples were analyzed at the end of the grazing season. Ground samples were stored in WhirlPak® bags before analysis with near-infrared reflectance spectroscopy using standard equations for forage quality characteristics (Rock River Laboratory, Inc. in Watertown, WI). Acid detergent fiber (**ADF**) and neutral detergent fiber (**NDF**) were quantified using Ankom procedures (Ankom A2000, Method 12 and Method 13). Individual forage minerals were quantified using wet chemistry with ICP-OES (Rock River Laboratory, Inc., Watertown, WI). The total tract NDF digestibility (**TTNDFD**) was quantified using validated in vitro procedures.

Statistical analysis

For the analysis of herbage mass, DM, forage quality characteristics, and mineral composition, the independent variables for analysis were the fixed effects of forage (WR, WW) and week (1, 2, 3, 4, 5, 6, 7) within forage. Paddock (1, 2, 3, 4, 5, 6) within collection (1st, 2nd, 3rd of the week) was a random effect and week was the repeated measure using the PROC MIXED procedure of SAS/STAT® software [16]. Herbage mass was averaged for paddocks to obtain one measurement per forage for each date. The CORR procedure of SAS/STAT software [16] was used to obtain correlations between herbage mass, DM and forage quality measurements. All results are reported as least squares means, and significance was stated as $P < 0.05$.

Results and discussion

Herbage mass and dry matter

Least squares means and standard error bars for herbage mass and DM of WR and WW for each week of the grazing season are in Figure 1 and Figure 2, respectively. Least squares means and standard errors for mean herbage mass and DM during the grazing season for WR and WW are in Table 2.

For mean herbage mass, WR (2925 kg DM/ha) and WW (2674 kg DM/ha) were similar ($P = 0.28$). These results are similar to Islam et al. [16], who reported similar total herbage mass for WR compared to WW during the spring and summer in Wyoming. The herbage mass for WR and WW of the current study is lower than reported in other studies, which included irrigated plots, additional fertilizers, no grazing, and had favorable growing conditions to increase forage yield. Holman et al. [17] harvested forages once during May in Kansas and reported greater herbage mass compared to the current study for WR (8829–9648 kg DM/ha) and WW (5745 kg DM/ha). Similarly, Islam et al. [16] harvested forage plots once in the spring and once during the summer and reported greater total herbage mass compared to the current study for WR (5300–5900 kg DM/ha) and WW (4800–5500 kg DM/ha). A study by Patton et al. [18] reported that a light stocking rate of grazing cattle increases herbage mass, but a moderate to heavy stocking rate can decrease herbage mass by 7–25% compared to pastures without grazing. In the current study, a moderate to heavy stocking rate was implemented. Furthermore, irrigation or favorable rainfall increases herbage mass for small grains [20]. In the current study, lower precipitation during the growing season may have decreased herbage mass.

The WR had greater ($P < 0.05$) herbage mass during weeks 1–3 and less ($P < 0.05$) herbage mass during weeks 5–7 compared to WW. The WR had greater herbage mass during the beginning of the grazing season and WW had greater herbage mass at the end of the grazing season. Similarly, Islam et al. [16] reported greater herbage mass for WR during the early spring compared to WW, and greater herbage mass for WW during the summer compared to WR. These results are also consistent with results from Lauriault and Kirksey [20] and Oelke et al. [12], which reported greater herbage mass for WW at the end of the growing season compared to WR. Furthermore, the herbage mass for WR was consistent ($P = 0.38$) between the first and last week of the grazing season while the WW increased ($P < 0.01$) in herbage mass between the first and last week of the grazing season.

For mean DM across the grazing season, WW (23.6%) was greater ($P < 0.05$) than WR (21.2%). Specifically, the WW had greater ($P < 0.05$) DM during weeks 2 and 7. Furthermore, the DM increased ($P < 0.01$) between the first and the last week for both forages. These results are similar to other studies [20,22] which reported increased DM of small grain forages during the growing season. The supporting studies also suggested that the increase in DM across the spring growing season is the result of the increase of stem to leaf ratio [22] and increase of panicles [20].

Crude protein

Least squares means and standard errors for mean CP of WR and WW during the grazing season are in Table 2. The WW (19.0%) had greater ($P < 0.05$) mean CP than WR (17.6%) during the grazing season. Other studies [23,24] reported higher mean CP for WW than WR during the growing season. The mean CP results of the current study are similar to the CP reported for WR (14.0–19.4%) and WW (17.5–21.6%) by Islam et al. [16]. The WW had greater ($P < 0.05$) CP during weeks 1 and 3 compared to WR, and similar ($P > 0.05$) CP during weeks 4–7 of the grazing season. For both forages, the CP decreased ($P < 0.01$) between the first week and the last week of the grazing season. Similarly, other studies [10,20,24,25] reported decreased CP as small grains mature. However, WR and WW met the CP requirements for beef cattle (6.5–13.0%) [26] for all weeks of the grazing season. Conversely, the CP recommendations for lactating dairy cattle (16–18%) [16] were not met during the last week of the grazing season for both WR (13.7%) and WW (12.6%).

Lipids

Least squares means and standard errors for mean lipids of WR and WW during the grazing season are in Table 2. The WR (2.65%) had greater ($P < 0.01$) mean lipids across the grazing season than WW (2.40%). Specifically, the WR had greater ($P < 0.05$) lipids during weeks 1–3, 5, and 6 of the grazing season. Furthermore, lipids decreased ($P < 0.01$) across the grazing season for both forages. The recommendation for lipids in a lactating dairy cow diet (3%) [27] was not met by either forage during the grazing season.

Fiber and digestibility

Neutral detergent fiber

Least squares means and standard errors for mean NDF of WR and WW during the grazing season are in Table 2. The WR (48.0%) had greater ($P < 0.01$) mean NDF compared to WW (45.1%) during the grazing season. These findings are similar to other studies [23,24], which reported greater mean NDF for WR compared to WW throughout the growing season. The mean NDF results of the current study are lower compared to the NDF reported for WR (56.4–63.2%) and WW (43.8–59.3%) by Islam et al. [16]. Low rainfall during the current study may have slowed maturation and decreased the NDF of the forages [20]. Furthermore, the WR had greater ($P < 0.05$) NDF during weeks 2–4 compared to WW. Similarly, Lauriault and Kirksey [20] reported equivalent NDF for WR and WW harvested in the last week of the growing season in New Mexico. For both forages, the NDF increased ($P < 0.01$) between the first and last week of the grazing season. Similarly, other studies [10,20,24] reported increased NDF as small grains mature.

Acid detergent fiber

Least squares means and standard errors for mean ADF of WR and WW during the grazing season are in Table 2. The WR (30.2%) tended to have greater ($P < 0.10$) mean ADF across the grazing season compared to WW

(29.2%). Similarly, Geren [23] reported that WR (41.8%) was numerically greater than WW (39.9%) for mean ADF, but was not significantly different. The mean ADF for WR and WW of the current study is lower than reported in Geren [23] due to some major differences in environmental factors. Geren [23] conducted their study in a Mediterranean climate, which was about 12.1 ºC warmer and had about twice as much precipitation, on average, during the growing season compared to the current study. These growing conditions may have resulted in faster plant maturation and lignification [20] compared to the current study. Furthermore, the WR had greater ($P < 0.05$) ADF during weeks 2 and 3 of the grazing season compared to WW. For both forages, ADF increased ($P < 0.01$) between the first and last week of the grazing season, which agrees with other studies [20,24].

Total tract neutral detergent fiber digestibility

Least squares means and standard error bars for TTNDFD of WR and WW of each week of the grazing season are in Figure 3 and least squares means and standard errors for mean TTNDFD during the grazing season are in Table 2. The WR (56.2%) and WW (55.5%) had similar ($P = 0.61$) mean TTNDFD during the grazing season, and both forages were similar ($P > 0.05$) for all weeks across the grazing season. Goeser [27] suggests that the average TTNDFD of pasture forages is 45.1% and the goal is to be greater than 50%. The mean TTNDFD for WR and WW is well above the recommended value. However, both forages decreased ($P < 0.01$) in TTNDFD between the first and last week of the grazing season, and the TTNDFD during weeks 6 and 7 of the grazing season for WR (49.2 and 43.9%, respectively) and WW (47.2 and 41.4%, respectively) did not meet the recommended TTNDFD value. The decrease in TTNDFD during the growing season agrees with the results of other studies [10,20]. Late grazing of mature WR and WW forages may not meet NDF digestibly recommendations, but they may still be adequate for grazing.

Energy availability

Net energy for gain

Least squares means and standard errors for mean net energy for gain (**NEg**) for WR and WW during the grazing season are in Table 2. The WR (0.98 Mcal/kg) and WW (0.97 Mcal/kg) had similar (P = 0.56) mean NEg during the grazing season. For both forages, NEg decreased (P < 0.01) between the first and last week of the grazing season, but met the NEg requirements of beef cattle (0.44–1.58 Mcal/kg) [28] for all weeks of the grazing season.

Net energy for lactation

Least squares means and standard errors for mean net energy for lactation (**NEl**) for WR and WW during the grazing season are in Table 2. Both forages (1.52 Mcal/kg) had the same (P = 0.62) mean NEl and both forages had similar (P > 0.05) NEl during all weeks of the grazing season. Lauriault and Kirksey [20] reported similar NEl for WR and WW harvested at the late-boot to early-heading stages in the cool, semi-arid region of New Mexico. Furthermore, NEl decreased (P < 0.01) between the first and last week of the grazing season for both forages. However, WR and WW met the NEl recommendations for lactating dairy cows (1.2–1.6 Mcal/kg) [26] throughout the grazing season for all weeks.

Milk yield per metric ton of forage

Least squares means and standard errors for mean milk yield per metric ton of forage (**milk/t**) for WR and WW during the grazing season are in Table 2. The WR (1496 kg) and WW (1484 kg) had similar ($P = 0.65$) mean milk/t during the grazing season and both forages had similar ($P > 0.05$) milk/t for all weeks. Furthermore, milk/t decreased ($P < 0.01$) between the first and last week of the grazing season for both forages.

Mineral composition

Calcium

Least squares means and standard errors for mean calcium (**Ca**) for WR and WW during the grazing season are in Table 2. The WR (0.35%) and WW (0.36%) had similar ($P = 0.59$) Ca during the grazing season. Furthermore, Ca decreased in WW ($P < 0.01$) and Ca tended to decrease ($P = 0.07$) in WR between the first and last week of the grazing season. Both forages met the Ca requirements for beef cattle (0.19–0.48%) [28–30] for all weeks of the grazing season. Adequate dietary calcium is important to prevent hypocalcaemia in lactating dairy cattle. The recommendation for Ca in lactating dairy cattle is 0.65–1.0% [27]. The WR and WW did not meet the Ca recommendations for lactating dairy cattle, therefore supplemental calcium while grazing these forages is necessary.

Phosphorus

Least squares means and standard errors for mean phosphorus (**P**) for WR and WW during the grazing season are in Table 2. The WR (0.34%) had greater ($P < 0.01$) mean P during the grazing season than WW (0.24%). Specifically, the WR had greater ($P < 0.05$) P during weeks 1 and 2 of the grazing season compared to WW. Both forages decreased ($P < 0.05$) in P between the first and last weeks. However, both forages met the recommendation for P in beef cattle (0.12–0.25%) [28–30]. The recommendation for P in lactating dairy cattle is 0.32–0.42% [27]. The WR and WW did not meet the P recommendations for lactating dairy cattle during weeks 4–7, therefore, supplemental P while grazing is necessary for lactating dairy cattle grazing during the last 4 weeks of the grazing season.

Potassium

Least squares means and standard errors for mean potassium (**K**) for WR and WW during the grazing season are in Table 2. The WR (2.84%) had greater ($P < 0.05$) mean K than WW (2.65%). Specifically, WR had greater ($P < 0.05$) K during the second week compared to WW. Both forages decreased ($P < 0.01$) in K between the first and last weeks. Because K is not stored in the body, cattle must consume it daily. However forages are typically well above the maximum tolerable level of 3%—especially in the early spring when forages are immature

[26,29]. The WR (3.42, 3.75, and 3.10%) and WW (3.46, 3.19, and 3.04%) exceeded the maximum tolerable level for weeks 1, 2, and 3, respectively. This is an additional concern for lactating dairy cattle since high levels of K may reduce DMI, milk yield, and inhibit Ca and magnesium (**Mg**) absorption [27,30]. The recommendation for K in lactating dairy cattle diets is 0.7–1.0% [27].

Magnesium

Least squares means and standard errors for mean Mg for WR and WW during the grazing season are in Table 2. Both forages (0.14%) had similar (P = 0.12) mean Mg during the grazing season. A main concern for pastures with rapidly growing cereal crops in the early spring is Mg deficiency, which can led to hypomagnesemia resulting in reduced performance or even death of cattle [31,30]. Dove et al. [29] reported that a high P to Mg + Ca ratio over 2.2 might also induce hypomagnesemia. The P to Mg + Ca ratio for WR (0.69) and WW (0.48) was well below the maximum tolerable ratio of 2.2. Both forages decreased (P < 0.01) in Mg between the first and last weeks, but met the Mg requirement for beef cattle (0.10–0.40%) [28–30] throughout the grazing season. The recommendations for Mg in lactating dairy cow diets is 0.22–0.40% [26], therefore supplemental Mg for lactating dairy cattle is necessary throughout the grazing season for WR and WW.

Comparison to perennial pasture forages

In the upper Midwest, perennial cool season grass and legume species are the traditional pasture forages for grazing cattle. The typical grazing season for these perennial pastures is from late May until October and the grazing season for small grain cover crops in the current study was from 25 April to 13 June. A study [32] conducted at the WCROC from 2013–2015, analyzed the forage quality of cool season perennial pasture consisting of grass and legume forages during the grazing season from June to October. Ruh [31] reported a lower average herbage mass (2228 kg DM/ha) for perennial pastures across the grazing season compared to WR (2925 kg DM/ha) and WW (2674 kg DM/ha) of the current study. For the nutritional quality of the forages, the average CP for perennial forages (23.0%) was greater than WR (17.6%) and WW (19.0%) of the current study. This study also reported greater NDF (49.6%) and ADF (32.2%), and lower TTNDFD (54.6%) across the grazing season for perennial pastures. The greater lignin content and lower digestibility of fiber may have contributed to a lower milk/t (1329 kg) value compared to WR (1496 kg) and WW (1484 kg) of the current study. For the mineral composition of the forages, perennial pastures had greater Ca (0.67%), K (3.10%), and Mg (0.23%) compared to WR (0.35, 2.84, and 0.14%) and WW (0.36, 2.65, and 0.14%), respectively. However, perennial pastures had similar P (0.33%) compared to WR (0.34%), and greater P compared to WW (0.24%) of the current study.

Correlations of forage measurements

Herbage mass and DM are forage measurements that farmers may easily calculate from pastures samples. These two measurements may be useful in predicting other important forage quality characteristics important to cattle nutrition. Pearson correlations for herbage mass, DM, and forage quality characteristics for WR and WW are in Table 3.

For WR, herbage mass only had a weak negative correlation with Ca (-0.33). The lack of significant correlations of herbage mass with other forage quality variables may be because of inconsistent herbage mass throughout the grazing season—high herbage mass at the beginning of the grazing season followed by a reduction of herbage mass. Insignificant correlations for herbage mass may also be a result of a non-linear relationship between herbage mass and other forage quality characteristics. The DM for WR had moderate correlations (±0.4–0.59) with CP, NEg, P, and Mg, and strong correlations (±0.6–0.79) with fat, NDF, ADF, TTNDFD, NEl, and milk/t during the grazing season. The K had a very strong correlation (-0.80) with DM. For WR, herbage mass may not be useful in estimating other forage quality characteristics during the grazing season. However, DM may offer more insight to other forage quality characteristics, especially fat, NDF, ADF, TTNDFD, NEl, milk/t, and K.

For WW, herbage mass had moderate correlations (±0.4–0.59) with fat, NEg, Ca, and K, and strong correlations (±0.6–0.79) with CP, NDF, ADF, TTNDFD, NEl, and milk/t. Furthermore, the DM for WW had moderate correlations (±0.4–.059) with fat, NDF, ADF, NEg, NEl, milk/t, Ca, P, and Mg, and strong correlations (±0.6–0.79) with CP, TTNDFD, and K. For WR, herbage mass may be useful in estimating CP, NDF, ADF, TTNDFD, NEl, and milk/t during the grazing season. The DM may also be useful to estimate CP, TTNDFD, and K.

Conclusions

Both winter rye and winter wheat are viable options for grazing in the early spring and summer. Results suggest that winter rye may offer more herbage mass in the very early spring and winter wheat may offer more herbage mass later in the spring and summer. The Pearson correlation (-0.87 and $P < 0.01$) between TTNDFD and day of grazing season suggests that both forages rapidly decreased in digestibility throughout the grazing season. Therefore, results of this study indicate that producers should initiate grazing early in the spring to maximize digestibility while the small grain forages are immature. Free-choice minerals should be offered to meet mineral demands.

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Table 1: Weather data for the 2015-2016 growing season and the long-term (1886-2016) means from the West Central Research and Outreach Center, Morris, MN weather station.

Year	Sept	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June	Growing season
	Mean temperature, °C										
2015-2016	14.2	5.7	-0.1	-5.9	-11.0	-7.5	-0.3	2.5	9.5	16.1	2.3
LM	15.1	8.2	-1.2	-9.1	-12.9	-10.4	-2.8	6.4	13.5	18.9	2.6
	Total precipitation, mm[1]										
2015-2016	34.0	39.6	47.0 (5.1)	27.2 (287.0)	7.4 (111.8)	16.8 (154.9)	15.5 (35.6)	47.0 (35.6)	50.5	48.0	333.0 (629.9)
LM	58.9	46.7 (17.8)	24.6 (127.0)	17.3 (177.8)	17.5 (177.8)	17.3 (188.0)	29.5 (198.1)	57.7 (83.8)	76.2 (2.5)	101.6	447.3 (972.8)

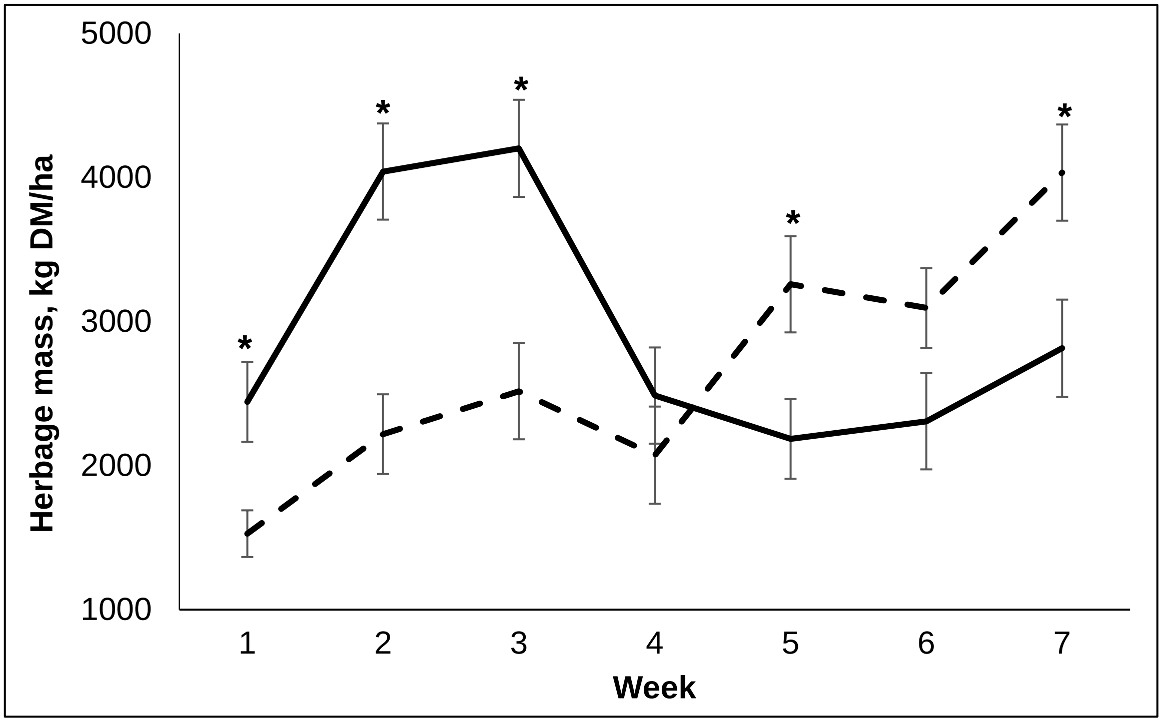
[1] Parentheses indicate snowfall in mm
LM = 50-year long-term mean

Table 2: Mean forage quality characteristics of winter rye and winter wheat across the grazing season.

Measurement	Winter rye	Winter wheat	SE[1]	*P*-value
Herbage mass, kg DM/ha	2925	2674	162	0.28
Dry matter, %	21.2	23.6	0.69	0.01
CP, %DM	17.6	19.0	0.49	0.03
Fat, %DM	2.65	2.40	0.02	<0.01
NDF, %DM	48.0	45.1	0.64	<0.01
ADF, %DM	30.2	29.2	0.45	0.10
TTNDFD, %NDF	56.2	55.5	0.96	0.61
NEg, Mcal/kg	0.98	0.97	0.01	0.56
NEl, Mcal/kg	1.52	1.52	0.01	0.62
Milk/metric ton, kg	1496	1484	19	0.65
Calcium, %DM	0.35	0.36	0.01	0.59
Phosphorus, %DM	0.34	0.24	0.01	<0.01
Potassium, %DM	2.84	2.65	0.07	0.05
Magnesium, %DM	0.14	0.14	0.00	0.12

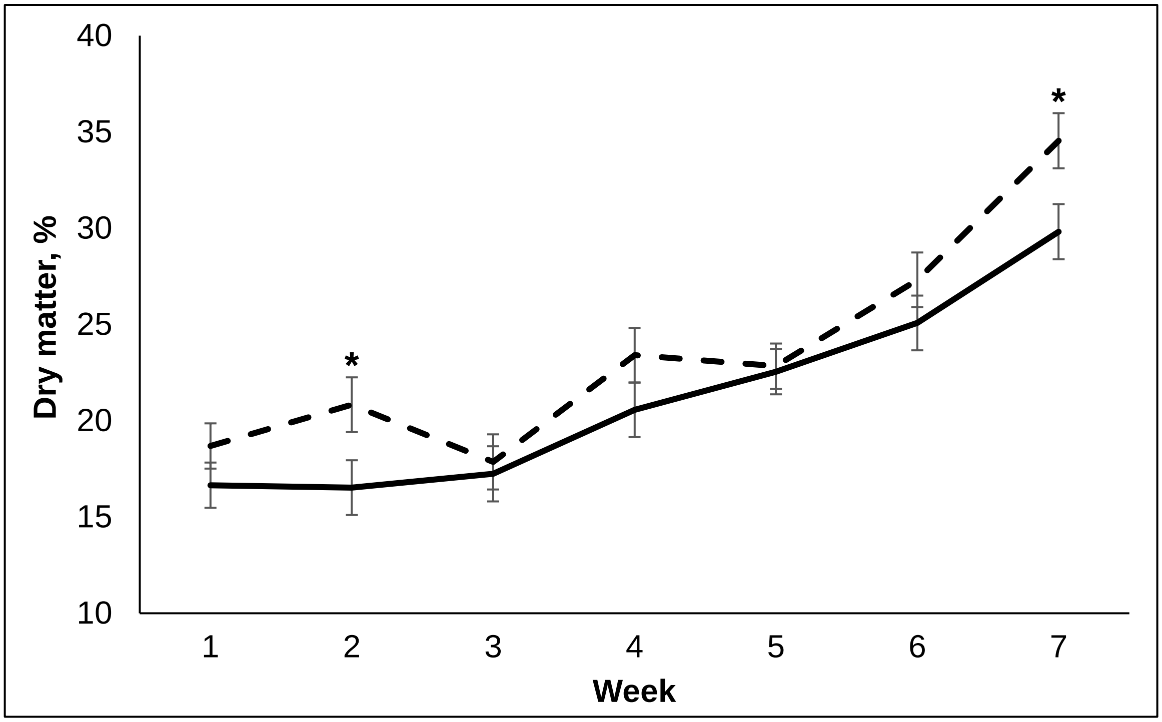
[1] Standard errors are the same between winter rye and winter wheat.

Figure 1: Least squares means and standard error bars of herbage mass across the grazing season for winter rye (–) and winter wheat (- - -) cover crops.



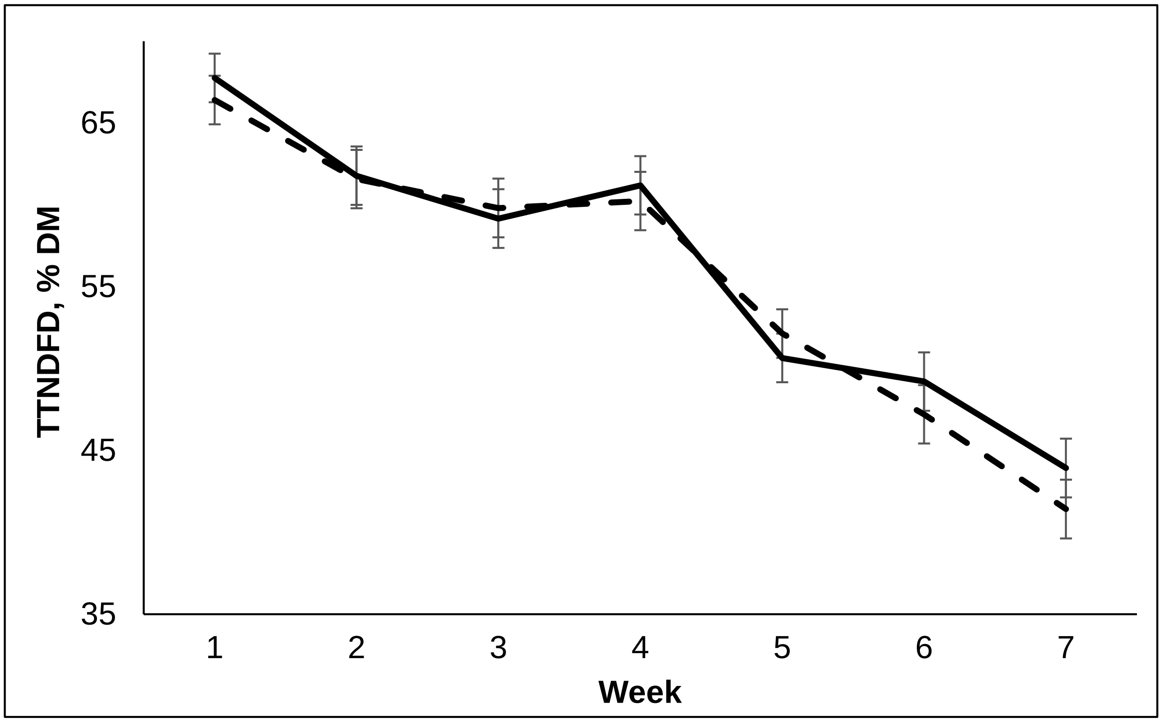
Means within a week with an asterisk are different at $P < 0.05$.

Figure 2: Least squares means and standard error bars of dry matter across the grazing season for winter rye (-) and winter wheat (- - -) cover crops.



Means within a week with an asterisk are different at $P < 0.05$.

Figure 3: Least squares means and standard error bars for TTNDFD across the grazing season for winter rye (—) and winter wheat (– – –).



Means within a week with an asterisk are different at $P < 0.05$.

Table 3: Pearson correlations between herbage mass, dry matter, and forage quality characteristics of winter rye and winter wheat.

Variable	DM	CP	Fat	NDF	ADF	TTNDFD	NEg	NEl	Milk/t	Ca	P	K	Mg
	winter rye												
Herbage mass	**-0.13**	**-0.22**	**0.13**	**0.23**	**0.14**	**0.02**	**-0.06**	**-0.14**	**-0.02**	-0.33	**0.20**	**0.26**	**-0.12**
DM		-0.59	-.066	0.62	0.65	-0.75	-0.59	-0.68	-0.70	-0.34	-0.54	-0.80	-0.57
CP			0.59	-0.88	-0.82	0.82	0.56	0.83	0.71	0.70	0.51	0.76	0.76
Fat				-0.64	-0.65	0.69	0.61	0.69	0.74	**0.28**	0.75	0.76	0.56
NDF					0.96	-0.87	-0.81	-0.94	-0.89	-0.65	-0.54	-0.70	-0.71
ADF						-0.93	-0.92	-0.99	-0.93	-0.47	-0.55	-0.70	-0.56
TTNDFD							0.86	0.96	0.92	0.37	0.58	0.80	0.55
NEg								0.92	0.93	**0.21**	0.50	0.56	0.33
NEl									0.95	0.47	0.57	0.72	0.57
Milk/t										0.36	0.65	0.72	0.50
Ca											**0.25**	0.45	0.87
P												0.79	0.51
K													0.73
	winter wheat												
Herbage mass	.055	-0.69	-0.51	0.71	0.72	-0.72	-0.58	-0.69	-0.64	-0.42	**-0.24**	-0.56	-0.32
DM		-0.71	-0.55	0.58	0.55	-0.72	-0.41	-0.58	-0.57	-0.55	-0.41	-0.78	-0.53
CP			0.76	-0.86	-0.86	0.90	0.64	0.86	0.76	0.77	0.48	0.86	0.62
Fat				-0.66	-0.69	0.74	0.60	0.73	0.67	0.45	0.44	0.77	0.38
NDF					0.98	-0.91	-0.89	-0.96	-0.92	-0.65	-0.32	-0.74	-0.38
ADF						-0.93	-0.92	-0.98	-0.92	-0.58	**-0.26**	-0.70	-0.33
TTNDFD							0.84	0.95	0.91	0.59	0.34	0.79	0.42
NEg								0.94	0.95	0.38	**0.10**	0.50	**0.08**
NEl									0.96	0.57	**0.26**	0.71	0.31
Milk/t										0.51	**0.23**	0.67	**0.21**
Ca											0.58	0.68	0.75
P												0.58	0.69
K													0.56

All correlations are significant at $P < 0.05$ unless value is in boldface.

Manuscript 2

Impact of grazing dairy steers on winter rye (*Secale cereale*) versus winter wheat (*Triticum aestivum*) and effects on meat quality, fatty acid and amino acid profiles, and consumer acceptability of organic beef

Overview

Meat from Holstein and crossbred organic dairy steers finished on winter rye and winter wheat pastures was evaluated and compared for meat quality, fatty acid and amino acid profiles, and consumer acceptability. Two adjacent 4-ha plots were established with winter rye or winter wheat cover crops in September 2015 at the University of Minnesota West Central Research and Outreach Center (Morris, MN). During spring of 2015, 30 steers were assigned to one of three replicate breed groups at birth. Breed groups were comprised of: Holstein (**HOL**; n = 10), crossbreds comprised of Montbéliarde, Viking Red, and HOL (**MVH**; n = 10), and crossbreds comprised of Normande, Jersey, and Viking Red (**NJV**; n = 10). Dairy steers were maintained in their respective replicate breed group from three days of age until harvest. After weaning, steers were fed an organic total mixed ration of organic corn silage, alfalfa silage, corn, soybean meal, and minerals until spring 2016. Breed groups were randomly assigned to winter rye or winter wheat and rotationally grazed from spring until early summer of 2016. For statistical analysis, independent variables were fixed effects of breed, forage, and the interaction of breed and forage, with replicated group as a random effect. Specific contrast statements were used to compare HOL versus crossbred steers. Fat from crossbreds had 13% greater omega-3 fatty acids than HOL steers. Furthermore, the omega-6/3 ratio was 14% lower in fat from crossbreds than HOL steers. For consumer acceptability, steaks from steers grazed on winter wheat had greater overall liking than steers grazed on winter rye. Steak from crossbreeds had greater overall liking than HOL steers. The results suggest improvement in fatty acids and sensory attributes of beef from crossbred dairy steers compared to HOL steers, as well as those finished on winter wheat compared to winter rye.

(**Key words**: crossbred, dairy steers, fatty acids, meat quality)

Introduction

The organic beef industry is still developing and accounts for a small, but growing, part in total organic sales. Organic beef is the fastest growing segment in the organic industry and increased by 46% between 1997 and 2007. Furthermore, organic beef herds were on a steady increase between 2000 and 2005 [2]. According to the USDA-National Organic Program (**NOP**) [3], cattle must consume at least 30% of their daily dry matter intake from pasture during the grazing season, except during the finishing phase, which must not exceed one-fifth of the animal's life (up to 120 days). However, there is a high consumer preference for "grass-fed" or forage-finished beef in the United States, which is perceived as more healthy and as having less impact on the environment compared to grain-finished beef [4]. Because of the growing trend in the organic and forage-finished beef market, cattle producers may capitalize on forage for grazing and organic dairy bull calves may represent a potential new resource for organic forage-finished beef in the United States.

Beef may be a contributing source of unhealthy fats in human diets, like some saturated fatty acids (**SFAs**) and *trans* fats, which are main health concerns among consumers [5,6]. However, beef also contains many beneficial fatty acids (**FAs**), such as omega-3 (**n-3**) (especially docosahexaenoic [C22:6n-3], eicosapentaenoic [C20:5n-3], and α-linolenic [C18:3n-3] acids) and long-chain *cis*-polyunsaturated fatty acids (**PUFAs**) [5,7]. These beneficial FAs have been studied extensively in human diets and play important roles in cardiovascular, cognitive, and inflammatory functions [6]. Forage-finished beef contains greater n-3 and PUFAs, and a lower omega-6/3 (**n-6/3**) ratio compared to grain-finished beef [7–14]. Furthermore, all nine essential amino acids (**AAs**) important to the human diet are in beef and a greater concentration of essential AAs are found in forage-finished beef compared to grain-finished beef [15]. Beneficial FAs and AAs in organic and forage-finished beef may influence consumer preference [5,7,16]; however, some consumers prefer conventionally raised beef over organic and forage-finished beef due to differences in flavor and palatability sensory attributes [7,17].

According to the USDA-NOP [3], all organic farms must maintain an active soil building plan. As more concern is placed on soil health, the emphasis on soil erosion and nutrient leaching have become the main reasons to utilize winter cover crops in rotation with other crops [18]. In the Upper Midwest, winter cover crops may be planted in the fall and grazed early next spring to extend the grazing season for livestock. Cover crops may be a useful strategy because one of the main obstacles that organic and forage-finished beef producers face is lack of supply of high quality forages for pasture-based feed [19]. Extending the grazing season not only reduces the need to store feed, but the FA profile in muscle and adipose tissue improves as the grazing duration increases [20]. Increasing the grazing duration with cover crops may help producers provide pasture-based feed, improve FA profiles of beef in terms of human health, and meet the demands for forage-finished beef.

As the organic forage-finished beef industry continues to grow, it is important to understand factors that affect meat quality, characteristics of beef that influence human health, and sensory attributes of cooked beef. Research on alternative breeds and forage types that influence meat quality, FA and AA profiles, and sensory attributes in an organic forage-finished production system is lacking. Therefore, the objectives of this study were to compare beef from Holstein and crossbred dairy steers grazed and finished on winter rye (*Secale cereale*; **WR**) and winter wheat (*Triticum aestivum*; **WW**) for meat quality characteristics, FA and AA profiles, and consumer acceptability.

Materials and methods

Ethical statement

The current study was conducted at the University of Minnesota West Central Research and Outreach Center (**WCROC**) organic dairy in Morris, Minnesota. All animal care and management was approved by the University of Minnesota Institutional Animal Care and Use Committee (Animal Subjects Code number 1411-32060A). The research dairy at the WCROC has a 300-head low-input and organic grazing system. Furthermore, the organic dairy has maintained organic certification since June 2010. The pastures in the current study were not irrigated and no soil amendments were applied.

Experimental approach

Thirty bull calves were born at the WCROC from March to May 2015 and assigned to one of three replicated breed groups at birth. Breed groups were (1) purebred Holstein (**HOL**, n = 10), (2) crossbreds comprised of Montbéliarde, Viking Red, and Holstein (**MVH**, n = 10), and (3) crossbreds comprised of Normande, Jersey, and Viking Red (**NJV**, n = 10). The Viking Red breed was formed by combining the genetic improvement programs for the Swedish Red, Finnish Ayrshire, and Danish Red breeds, which have historically shared ancestry and similar selection criteria. Bull calves were separated at birth from their dams, housed indoors in individual pens, castrated, and fed 2 L of colostrum per 41 kg of body weight twice daily for three days. After three days of age, calves were group housed in large hutches bedded with organic wheat straw. A total of six groups of five calves were established (n = 30). Calves were fed 6 L of unpasteurized, organic milk once daily using a 10-calf Skellerup peach teat feeder (Skellerup Industries, Christchurch, New Zealand) which was washed and disinfected between each feeding. At four days of age, calves were offered starter grain *ad libitum* and were weaned when calves consumed 0.91 kg of starter grain per day at an average age of 10 weeks of age. After weaning, steers were relocated to a loose confinement barn, remained in their respective groups, and were fed an organic total mixed ration diet consisting of organic corn silage, alfalfa silage, corn, soybean meal, and minerals from the time of weaning until 25 April 2016. One NJV steer was removed from the study one month prior to grazing due to death from peritonitis, which was diagnosed by a veterinarian.

During spring of 2016, dairy steers grazed either WR (n = 15) or WW (n = 14) cover crops in the vegetative state. The WR and WW were planted on 10 September 2015 on two adjacent 4-ha plots. On 25 April 2016, each replicate breed group was randomly assigned to either WR or WW and rotationally grazed until 13 June 2016 for 7 weeks with supplemented free-choice certified organic minerals. The WR and WW cover crops were balanced for steer breed. Briefly, for forage quality of grazed cover crops, the dry matter was lower ($P < 0.05$) for WR (21.2%) compared to WW (23.6%). Crude protein was 17.6% and 19.0% for WR and WW, respectively ($P < 0.05$). Total tract neutral detergent fiber digestibility, used to measure the energy of forages, was 56.2% and 55.5% for WR and WW, respectively ($P = 0.61$).

Carcass measurements

The dairy steers were sent for harvest and meat fabrication on two separate dates at a commercial abattoir approved for organic harvest (Lorentz Meats, Organic Prairie, Cannon Falls, MN). The first group of HOL, MVH, and NJV steers were harvested on 27 July 2016 and the second group of HOL, MVH, and NJV steers were harvested on 21 September 2016. The steers were harvested at lower carcass weights because of lower marketability of large organic carcasses at high prices. The organic market values carcasses at a smaller weight than the conventional beef market.

Live body weight was recorded immediately prior to harvest and hot carcass weight was recorded immediately after harvest. Postharvest carcasses were chilled for 24 hours at 4° C according to North American Meat Processors [21] guidelines, and back fat thickness, ribeye area, percentage of kidney, pelvic, and heart fat, marbling, maturity, quality grade, and yield grade were recorded for each carcass.

Strip loin collection

Each carcass was fabricated according to North American Meat Processors [20] guidelines. One strip loin (*longissimus dorsi*) was removed from each carcass. Strip loins were identified using carcass identification tags during harvest and were followed through fabrication and vacuum-packaging.

Strip loins were maintained at 2° C during transportation to the University of Minnesota WCROC in Morris, MN where they were aged for 10 days at 2° C. After aging, strip loins were frozen at -20° C until further evaluation of meat quality and consumer sensory attributes. During November 2016, six 2.54-cm thick, frozen steaks were cut from the cranial end of each strip loin at the University of Minnesota Meat Laboratory (St. Paul, MN). The most cranial steak of the six steaks cut from the frozen strip loin was used for Warner-Bratzler shear force (**WBSF**) analysis. The next two cranial steaks were used for the objective color score analysis, and the remaining three steaks were used for the consumer sensory panel.

Tenderness determination and objective color score

Tenderness was measured on one steak from each strip loin using the WBSF instrument (G-R Elec. Mfg. Co., Manhattan, KS) at the University of Minnesota Meat Laboratory. Vacuum-sealed steaks were removed from the freezer and thawed for 24 hours at 4° C, unpackaged, wrapped in aluminum foil, and cooked in an electric oven to a final internal temperature of 71° C. Each steak was cooled to 4° C for 24 hours, then warmed to room temperature for two hours. Six 1.27-cm cores were removed from each steak parallel to the muscle fiber orientation using a hand-coring device. The average of the six cores from each steak was used as a single peak shear force measurement for each steer.

The color of each steak was measured using a HunterLab Miniscan XE Plus spectrophotometer equipped with a 6-mm aperture (HunterLab Associates Inc., Reston, VA). Objective color score values were 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 established by the Commission International de l'Éclairage [22]. Two vacuum-sealed, frozen steaks (two replicates) from each steer were thawed for 24 hours at 4° C, unpackaged, and exposed to the air in 4° C for two hours before measuring color scores. Readings for each of the L*, a*, and b* values were taken at three random locations on the surface of the steak exposed to the light. Readings were averaged for each steak at the time of evaluation.

Fatty acid profiles

Back fat samples (approximately 6.4 x 0.5-cm) were collected from all carcasses 72 hours postharvest at the abattoir. Samples were placed in Whirl-Pak® bags (Nasco, Fort Atkinson, WI), transported on ice at 2° C to the University of Minnesota WCROC, and shipped on ice at 2° C in a polystyrene insulated container overnight to Minnesota Valley Testing Laboratories (New Ulm, MN) for FA profile analyses.

The FAs were determined according to AOAC method 996.06 [23] by using gas chromatography. Lipids were extracted from a 100 to 200 mg sample of finely ground fat. Pyrogallic acid was added to reduce oxidation of FAs during the analysis. The triglyceride, triundecanoin (C11:0), was added as an internal standard. Lipids were extracted in ether and then methylated to fatty acid methyl esters using Bromine trifluoride in methanol. The fatty acid methyl esters were quantitatively measured by capillary gas chromatography against the triundecanoin standard. Total fat was calculated as the sum of individual FAs expressed as triglyceride equivalents, and saturated and unsaturated fats were calculated as the sum of their respective FAs. Individual FAs are reported in percent weight of the total fat. The n-3 FA is reported as the sum of: α-linolenic (C18:3n-3), eicosatrienoic (C20:3n-3), eicosapentaenoic (C20:5n-3), and docosahexaenoic (C22:6n-3) individual PUFAs. The omega-6 (**n-6**) FA is reported as the sum of linoleic (C18:2n-6), γ-linolenic (C18:3n-6), eicosadienoic (C20:2n-6), arachidonic (C20:4n-6), docosadienoic (C22:2n-6), and docosatetraenoic (C22:4n-6) individual PUFAs.

Amino acid profiles

Meat samples (approximately 6.4 x 0.5-cm) were collected from all carcasses 72 hours postharvest at the abattoir from the strip loin. Samples were placed Whirl-Pak® bags, transported on ice at 2° C to the University of Minnesota WCROC. Samples were aged for 10 days at 2° C. After aging, samples were shipped on ice at 2° C in a polystyrene insulated container overnight to Minnesota Valley Testing Laboratories for AA profile analyses using high performance liquid chromatography.

The AAs were determined according to AOAC method 994.12 [24] by extracting AAs from a sample equivalent to 20 mg of protein. Cysteine, methionine, and taurine were quantified from the performic acid oxidation with acid hydrolysis extraction. The remaining AAs were quantified from the acid hydrolysis extraction.

Total protein is reported in percent weight of sample and individual AAs are reported in percent weight of total protein.

Consumer sensory evaluation

The University of Minnesota Institutional Review Board approved recruiting and experimental procedures with human subjects for the beef consumer panel evaluation of sensory attributes. The University of Minnesota's Food Science and Nutrition Sensory Center (St. Paul, MN) recruited 108 consumers. Consumers were at least 18 years or older, had no food allergies, and had consumed beef within the past month. All consumers were paid $5 for participation in the sensory panel.

Steaks were thawed for 72 hours at 4° C in vacuum-sealed packages then unpackaged. Individual steaks were wrapped in aluminum foil, baked to an internal temperature of 71° C, and cut into 1-cm cubes. Each panelist received two pieces of steak per steer group in lidded 30 mL plastic soufflé cups coded with random three-digit codes. To maintain sample-serving temperature, cups were nested in insulated foam trays. Beef from the six steer groups was served to panelists in two sets of three samples on one tray. The first set corresponded to steers grazed on WW, and the second set corresponded to steers grazed on WR. The three breed samples within each set were balanced for order and carryover effects by personnel from the University of Minnesota Sensory Center using a Latin square design with SIMS Sensory Evaluation Testing Software (http://www.sims2000.com/). Consumers were instructed to consume the first cube and rate it for overall liking, liking of flavor, and liking of texture. Panelists were then instructed to consume the second cube and rate the intensity of toughness, juiciness, and off-flavor. Liking ratings were made on 120-point labeled affective magnitude scales (0 = greatest imaginable disliking and 120 = greatest imaginable liking), with the left-most end labeled *strongest dislike imaginable* and the right-most end labeled *strongest like imaginable*. Intensity ratings were made on 20-point line scales (0 = none and 20 = extremely tough, extremely juicy, and extremely intense, respectively) with the left-most ends labeled *none* and the right-most ends labeled *extremely tough, extremely juicy*, and *extremely intense*, respectively. Panelists repeated this process for each of the six steer groups.

Statistical analysis

For statistical analysis of carcass measurements, the independent variables were fixed effects of forage and breed, with group nested within the forage and breed interaction as a random effect. Each carcass measurement was averaged for each steer group and the average was used as a single measurement for each group. For statistical analysis of WBSF, objective color score, FAs, and AAs, independent variables were fixed effects of breed, forage, and the interaction of breed and forage, with replicated group as a random effect. Replication number was included in the model for analysis of objective color score as a random effect. For the consumer sensory evaluation and analysis of like/dislike categories, independent variables were fixed effects of breed, forage, and the interaction of breed and forage, with consumer as a random effect. The chi-square test of

SAS/STAT software [25] was used to obtain percentages for like/dislike categories for the sensory evaluation. The MIXED procedure of SAS/STAT software [25] was used to obtain least squares means and solutions for all analyses, and conduct the analysis of variance. Furthermore, specific contrast statements were used to compare HOL steers versus crossbred (MVH and NJV) steers.

Results and discussion

Carcass quality of steers

Least squares means and standard errors for carcass measurements, WBSF, and objective color scores are in Table 1. All steers had a kidney, pelvic, and heart fat percentage of 1.0 and a maturity grading of A (not included in Table 1). The age at harvest (not included in Table 1) was not different ($P > 0.10$) for steers grazed on WR (487 ± 10.3 d) and WW (495 ± 10.3 d), as well as for HOL (492 ± 12.6 d), MVH (485 ± 12.6 d), and NJV (497 ± 12.6 d) steers.

Steers grazed on WR (470.2 kg) and WW (471.1 kg) had similar ($P > 0.10$) harvest weights. Furthermore, carcasses from steers grazed on WR (225.0 kg and 47.8%) and WW (230.4 kg and 49.0%) had similar hot carcass weight and dressing percent, respectively. For the grade of intermuscular fat, the marbling score of carcasses was similar ($P > 0.10$) for steers grazed on WR (1.9) and WW (2.1). These results are similar to those found in another study [26] comparing carcasses from steers grazed on ryegrass and ryegrass/chicory mixture pastures. Their results reported similar harvest weights, hot carcass weights, dressing percentages, and marbling scores between steers grazed on different pasture species. Furthermore, the back fat thickness, ribeye area, yield grade, and percent of carcasses with a quality grade of select or greater was similar ($P > 0.10$) for carcasses from steers grazed on WR and WW.

For steer breed groups, the HOL (484.3 kg) and MVH (492.2 kg) steers had greater ($P < 0.05$) harvest weights than the NJV (435.5 kg) steers. Carcasses from

MVH (239.9 kg) steers tended to have a greater ($P < 0.10$) hot carcass weight than carcasses from NJV (211.4 kg) steers; however, hot carcass weight from HOL (231.8 kg) steers were similar ($P > 0.10$) to MVH and NJV steers. These results are similar to those found in another study [27], which reported that HOL steers had a heavier live weight and hot carcass weight than Jersey x HOL crossbred steers. Furthermore, the HOL (47.9%), MVH (48.8%), and NJV (48.5%) carcasses had similar ($P > 0.10$) dressing percentages. For the grade of intermuscular fat, the marbling scores of carcasses were similar ($P > 0.10$) between HOL (1.9), MVH (2.1), and NJV (2.0) steers. Findings in McNamee et al. [28] reported a lower marbling score for Jersey x HOL crossbred carcasses compared to HOL carcasses; however, the Normande and Viking Red genetics in the NJV crossbreed may have played a role in marbling score similarities between HOL and NJV breeds in the current study. Furthermore, the back fat thickness, ribeye area, yield grade, and percent of carcasses with a quality grade of select or greater were similar ($P > 0.10$) for carcasses from HOL, MVH, and NJV steers. Carcass quality measurements were comparable to what was reported by Bjorklund et al. [1] for organic grass-fed dairy steers from similar genetics.

Shear force of steaks

For the WBSF (Table 1) of cooked steaks, the steers grazed on WR (3.9 kg) tended to have a greater ($P < 0.10$) WBSF than steers grazed on WW (3.0 kg). Similar to the current study, Duckett et al. [29] reported steers which grazed forage species of mixed pasture, alfalfa, or pearl millet did not influence the WBSF of steaks.

For steer breed groups, steaks from HOL (3.9 kg), MVH (3.6 kg), and NJV (2.9 kg) steers had similar (*P* > 0.10) WBSF. The WBSF values for steaks in the current study are higher than reported by Bjorklund et al. [7] from steers of similar genetics, indicating that the beef in the current study may be more tender based on the WR and WW grazing conditions. The results from the WBSF test are similar to results found by McNamee et al. [28] who reported similar WBSF values for steaks from HOL, Norwegian Red x HOL, and Jersey x HOL steers. Findings in the current study are different than those found by Christensen et al. [30], which found similar WBSF for steaks from Danish Red (similar to Viking Red) and HOL steers; however, the study also reported that steaks from Jersey steers had greater WBSF than steaks from HOL steers. The NJV dairy steer breed was also comprised of Normande genetics, which may have played a role in similar WBSF values between breeds in the current study.

Objective color score of steaks

For objective color scores (Table 1), no differences (*P* > 0.10) were found between steaks from steers grazed on WR and WW for L*, a*, and b*. These results are similar to those found in another study [29], which reported similar L*, a*, and b* values for steaks from steers grazed on mixed pasture, alfalfa, and pearl millet.

For steer breed groups, steaks from HOL (29.0) and NJV (28.2) steers had greater (P < 0.05) L* values than MVH (26.6) steers, and steaks from crossbred steers had a lower (P = 0.01) L* value than HOL steers. However, steaks from HOL, MVH, and NJV steers had similar a* and b* values. Results from another study [28] reported similar L*, a*, and b* values between HOL, Norwegian Red x HOL, and Jersey x HOL steaks; however, the genetics of crossbred steers in the current study may have played a role in the darker color of steaks compared to HOL steers.

Fatty acid concentrations of adipose tissue

Least squares means and standard errors for FAs of back fat from steers grazed on WR and WW are in Table 2, and the least squares means and standard errors for FAs of back fat from HOL, MVH, and NJV steers are in Table 3. Fatty acids from steers grazed on WR and WW, and from HOL, MVH, and NJV steers had the same values (< 0.10% weight of total fat) for caproic (C6:0), caprylic (C8:0), capric (C10:0), lauric (C12:0), tridecanoic (C13:0), behenic (C22:0), erucic (C22:1), lignoceric (C24:0), and nervonic (C24:1) acid and are not reported in Table 2 or Table 3. The most abundant FA was oleic (C18:1) acid, followed by palmitic (C16:0), and stearic (C18:0) acids. Over three-quarters of the total fat content found consisted of these three FAs.

Fatty acids from steers grazed on WR and WW (Table 2) differed (P < 0.05) for butyric (C4:0), tetradecenoic (C14:1*trans*), myristoleic (C14:1), hexadecenoic (C16:1*trans*), margaroleic (C17:1), octadecadienoic (C18:2*trans*), γ-linolenic (C18:3n-6), eicosatrienoic (C20:3n-3), arachidonic (C20:4n-6), heneicosanoic (C21:0), and docosadienoic (C22:2n-6) acids. The sum of SFAs, *cis*-monounsaturated FAs, PUFAs, and *trans* fats were similar ($P > 0.05$) between steers grazed on WR and WW. Furthermore, n-3 FAs, n-6 FAs, and n-6/3 ratios were similar ($P > 0.05$) between steers grazed on WR and WW.

Differences in individual long-chain FAs (C20 to C22) from steers grazed on WR and WW may have been influenced by the different FA content in forages [31]. The amount of total fat in the diet may also influence the FA content in adipose tissue of steers. Microorganisms in the rumen may differ based on feeding systems; however, it is likely that the FA content and forage quality of WR and WW pastures contributed to the back fat FA content of steers based on the different FA concentrations among forage species [32].

Fatty acids from HOL, MVH, and NJV steers (Table 3) differed ($P < 0.05$) for myristic (C14:0), tetradecenoic (C14:1*trans*), myristoleic (C14:1), elaidic (C18:1*trans*), gadoleic (C20:1), γ-eicosatrienoic (C20:3), eicosapentaenoic (EPA; C20:5n-3), docosatetraenoic (22:4n-6), docosapentaenoic (22:5), and tricosanoic (C23:0) acids. Furthermore, elaidic (C18:1*trans*), tricosanoic (C23:0), eicosapentaenoic (EPA; C20:5n-3), and gadoleic (C20:1) acids were greater ($P < 0.05$) in crossbred steers compared to HOL steers. No differences were found for sums of saturated, *cis*-monounsaturated, *cis*-polyunsaturated, and n-6 FAs between HOL, MVH, and NJV steers. For *trans* fats, the HOL, MVH, and NJV steers were similar; however, HOL steers had greater ($P < 0.05$) *trans* fat than crossbred steers.

The MVH (0.589%) steers had greater ($P < 0.05$) n-3 FAs than HOL (0.504%) steers, and the HOL and MVH steers had similar ($P > 0.05$) n-3 FAs compared to NJV (0.551%) steers. The crossbred steers had greater ($P < 0.05$) n-3 FAs compared to the HOL steers. The greater concentration of long-chain PUFAs in the crossbred steers may have influenced the darker L* score observed in the steaks from crossbred steers (Table 1) due to lipid oxidation. Furthermore, the n-6/3 ratio was greater ($P < 0.05$) for HOL (6.18) steers compared to MVH (5.27) and NJV (5.32) steers. Subsequently, the HOL steers had a greater ($P < 0.05$) n-6/3 ratio compared to crossbred steers. These findings contradict those found in another study [12], which reported a greater n-6/3 ratio in Simmental (similar to Montbéliarde) bulls than HOL bulls. The genetics of the specific crossbreeds in the current study may have influenced the differences in FAs.

Amino acid concentrations of beef

Least squares means and standard errors for AAs in steak from steers grazed on WR and WW, and for HOL, MVH, and NJV steer breed groups are in Table 4. The total protein (percent weight of meat sample) was similar for steers grazed on WR (10.3%) and WW (11.7%) (not reported in Table 4). Similarly, another study [33] reported that steers finished on mixed pasture, alfalfa, and pearl millet had similar total protein content in steak. For essential AAs, the steers grazed on WR (1.8, 1.7, 1.0, 0.98, 0.93, and 0.81) had greater (P < 0.05) percentages of lysine, leucine, valine, isoleucine, threonine, and phenylalanine than steers grazed on WW (1.7, 1.5, 0.96, 0.90, 0.85, and 0.76), respectively. However, histidine, methionine, and tryptophan were similar between steers grazed on WR and WW. A study conducted in Sweden [15] reported an increase in essential AA concentrations in steak from cows grazed on pasture compared to cows in a conventional system. For non-essential AAs, glutamine, aspartic acid, arginine, and serine were greater (P < 0.05) for steers grazed on WR compared to steers grazed on WW. Taurine was greater (P < 0.05) for steers grazed on WW (0.011%) compared to steers grazed on WR (0.005%), however taurine was the least concentrated AA found in the steak.

The total protein content was similar for HOL (9.6%), MVH (11.7%), and NJV (11.7%) steers (not reported in Table 4). These results are similar to other studies [28,34], which reported similar total protein concentrations in beef from dairy steers of different breeds. No differences in essential and non-essential AAs were found between HOL and crossbreds steers.

Consumer sensory evaluation of beef

Least squares means and standard error of means for sensory attributes are in Table 5. For overall consumer liking, means for WW (72.0) steaks were greater (P < 0.05) than means for WR (66.7) steaks. For flavor liking, texture liking, and juiciness, means for WW steaks were greater (P < 0.05) than WR steaks. Furthermore, the means for WR steaks were greater (P <0.05) for toughness and off-flavor than WW steaks. In another study [29], which compared sensory attributes of steaks from steers grazed on mixed pasture, alfalfa, and pearl millet, steaks from steers finished on pearl millet had lower off-flavor than steers finished on mixed pasture and alfalfa. Bjorklund et al. [7] reported that consumers preferred steaks from conventionally raised steers over steaks from grass-fed steers. However, some consumers in that study did prefer the grass-fed steaks indicating there is market potential for organic grass-fed beef.

For breed groups, the NJV (71.8) steaks were greater ($P < 0.05$) for overall liking than HOL (67.2) steaks, but were similar to MVH (69.2) steaks. These results are similar to those found in Nuernberg et al. [12], which reported that HOL and Simmental (breed similar to Montbéliarde) steaks had similar overall liking. Furthermore, flavor likeness was greater ($P < 0.05$) for NJV (70.7) steaks compared to HOL (66.5) steaks, but was similar to MVH (67.9) steaks. For texture likeness, the NJV (73.8) steaks were greater ($P < 0.05$) than both HOL (67.5) and MVH (69.4) steaks. The NJV (7.4) steaks were lower ($P < 0.05$) for toughness intensity than both HOL (8.6) and MVH (8.4) steaks. For juiciness intensity, both NJV (8.9) and MVH (9.2) steaks were greater ($P < 0.05$) than HOL (7.8) steaks. No differences were found for off-flavor between breeds. The crossbred steaks had greater ($P < 0.05$) overall, flavor, and texture liking compared to HOL steaks. For the intensity of sensory attributes, crossbred steaks had greater ($P < 0.05$) juiciness intensity and less ($P < 0.05$) toughness intensity than HOL steaks. In another study [35], Brown Swiss (similar ancestry to Montbéliarde) steaks had lower toughness than HOL steaks; however, overall sensory attributes and juiciness were not influenced by breed. Specific crossbreeds in an organic system may have influenced sensory attribute differences in the current study.

Percentages of like/dislike categories for WR and WW steaks, and HOL, MVH, and NJV steaks are in Table 6. According to the likeness scale, more consumers ($P < 0.05$) slightly liked steak from WW (76.5%) than WR (63.6%) steers, and more ($P < 0.05$) consumers moderately liked steak from WW (34.0%) than WR (23.5%) steers. A similar ($P > 0.05$) proportion of consumers liked the steak very much and extremely liked steak from WR and WW steers.

Furthermore, more ($P < 0.05$) consumers slightly liked NJV (77.3%) and MVH (70.8%) steaks than HOL (62.0%) steaks. To complement this, more ($P < 0.01$) consumers slightly liked crossbred steak than HOL steak. Consumers who moderately liked steaks were similar ($P > 0.05$) for HOL, MVH, and NJV steers; however, more ($P < 0.05$) consumers moderately liked crossbred steak than HOL steak. A similar ($P > 0.05$) proportion of consumers liked steak very much and extremely liked steak from HOL, MVH, and NJV steers, and from HOL and crossbred steers, respectively.

The likeness of steak results indicates that the magnitude of differences between the WR and WW, and the HOL, MVH, and NJV steers found in the sensory study only influenced consumers to slightly like or moderately like the WW more than the WR steaks and the crossbred more than the HOL steaks. In total, only 10.0% of consumers liked the steaks very much and only 2.3% of consumers extremely liked the steaks, indicating that sensory attribute results found in this study shows that differences between forages and breeds only have a slight or moderate effect on the actual sensory attributes on the resulting beef product.

Conclusions

Organic bull calves may add value and economic diversity for organic dairy producers if utilized for organic meat products. This study examined the potential for an organic, forage-based diet, including winter wheat and winter rye grazed for 7 weeks in the spring, to supply adequate nutrition for marketable meat quality of dairy steers. Increased forage in the rations of dairy cattle has been reported to improve the FA profile of dairy and beef products. In our study, the FAs from crossbred steers consisted of a greater n-3 FA concentration compared to purebred Holstein (HOL) steers. Furthermore, a lower n-6/3 FA ratio was found in crossbred compared to HOL steers. In sensory evaluation panels, consumers liked steak from crossbred steers more than HOL steaks, and steak from steers grazed on WW over WR. Steak from crossbred steers rated higher than HOL steaks in overall, flavor, and texture likeness. Toughness and juiciness intensities were rated lower and higher, respectively, for crossbred over HOL steaks. Improvements in the nutritional quality of beef may have the potential to improve consumer acceptability of beef and human health.

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Table 1. Carcass quality measurements, WBSF, and objective color scores for steers finished on winter rye and winter wheat and for HOL, MVH crossbred, and NJV crossbred dairy steers.

	Cover crop				Breed group[1]						
	Winter rye		Winter wheat		HOL		MVH		NJV		HOL vs. crossbred
Measurement	LSM	SE	LSM	SE	LSM	SE	LSM	SE	LSM	SE	*P*-value
Harvest weight, kg	470.2	3.5	471.1	3.5	484.3[a]	4.3	492.2[a]	4.3	435.5[b]	4.3	NS
HCW[2], kg	225.0	4.4	230.4	4.4	231.8[AB]	5.4	239.9[A]	5.4	211.4[B]	5.4	NS
Dressing, %	47.8	0.94	49.0	0.94	47.9	1.1	48.8	1.1	48.5	1.1	NS
Marbling score[3]	1.9	0.16	2.1	0.16	1.9	0.20	2.1	0.20	2.0	0.20	NS
Back fat, cm	0.27	0.04	0.30	0.04	0.25	0.05	0.28	0.05	0.32	0.05	NS
Ribeye area, cm^2	50.3	3.1	48.2	3.1	47.3	3.8	52.7	3.8	47.7	3.8	NS
Yield grade	1.9	0.09	1.9	0.09	1.9	0.11	1.9	0.11	1.9	0.11	NS
Quality grade[4], %	66.7	17.0	80.0	17.0	70.0	20.8	80.0	20.8	70.0	20.8	NS
WBSF[5], kg	3.9[A]	0.32	3.0[B]	0.33	3.9	0.39	3.6	0.39	2.9	0.42	NS
L*[6]	28.2	0.37	27.6	0.38	29.0[a]	0.45	26.6[b]	0.45	28.2[a]	0.47	0.01
a*[6]	12.5	0.33	12.0	0.34	12.1	0.40	12.2	0.40	12.5	0.43	NS
b*[6]	10.3	0.27	10.0	0.28	10.3	0.33	10.0	0.33	10.1	0.35	NS

[a,b] Means within a row for cover crop or breed group without common superscript letters are different at $P < 0.05$.

[A,B] Means within a row for cover crop or breed group without common superscript letters are different at $P < 0.10$.

[1] HOL = Holstein; MVH = crossbred comprised of Montbéliarde, Viking red, and Holstein; NJV = crossbred comprised of Normande, Jersey, and Viking Red

[2] Hot carcass weight

[3] Slightly abundant = 5; moderate = 4; small = 3; slight = 2; traces = 1

[4] Percent of carcasses quality grade of select or greater

[5] Warner-Bratzler shear force

[6] L* = brightness (0 = black; 100 = white); a* = redness/greenness (positive values = red; negative values = green); b* = yellowness/blueness (positive values = yellow; negative values = blue)

Table 2. Least squares means and standard errors of means for fatty acids of back fat from dairy steers grazed on winter rye and winter wheat.

	Cover crop			
	Winter rye		Winter wheat	
Fatty acid	LSM	SE	LSM	SE
	% weight of total fat			
C4:0, butyric	0.004[a]	0.001	0.001[b]	0.001
C14:0, myristic	3.43	0.099	3.32	0.103
C14:1*trans*, tetradecenoic	0.002[b]	0.000	0.005[a]	0.001
C14:1, myristoleic	1.32[b]	0.107	1.68[a]	0.111
C15:0, pentadecanoic	0.552	0.024	0.521	0.025
C16:0, palmitic	25.7	0.361	25.2	0.375
C16:1*trans*, hexadecenoic	0.310[a]	0.019	0.157[b]	0.020
C16:1, palmitoleic	5.66	0.274	6.04	0.285
C17:0, margaric	0.936	0.037	0.850	0.038
C17:1, margaroleic	0.001[a]	0.000	0.000[b]	0.000
C18:0, stearic	13.1	0.576	12.1	0.600
C18:1*trans*, elaidic	2.76	0.168	2.65	0.175
C18:1, oleic	40.3	0.620	41.4	0.646
C18:2*trans*, octadecadienoic	1.16[b]	0.037	1.31[a]	0.039
C18:2, conjugated linoleic	0.576	0.024	0.606	0.025
C18:2n-6, linoleic	2.83	0.099	2.80	0.104
C18:3n-6, γ-linolenic	0.021[b]	0.001	0.029[a]	0.001
C18:3n-3, α-linolenic	0.440	0.017	0.468	0.018
C20:0, arachidic	0.122	0.007	0.107	0.007
C20:1, gadoleic	0.166	0.013	0.155	0.014
C20:2n-6, eicosadienoic	0.051	0.002	0.053	0.002
C20:3, γ-eicosatrienoic	0.081	0.006	0.082	0.006
C20:3n-3, eicosatrienoic	0.063[a]	0.004	0.042[b]	0.004
C20:4n-6, arachidonic	0.035[b]	0.003	0.051[a]	0.003
C20:5n-3, eicosapentaenoic	0.010	0.001	0.009	0.001
C21:0, heneicosanoic	0.028[a]	0.002	0.020[b]	0.002
C22:2n-6, docosadienoic	0.006[a]	0.001	0.003[b]	0.001
C22:4n-6, docosatetraenoic	0.030	0.004	0.028	0.004
C22:5, docosapentaenoic	0.065	0.004	0.059	0.005
C22:6n-3, docosahexaenoic	0.003	0.001	0.002	0.001
C23:0, tricosanoic	0.013	0.001	0.013	0.001
	% weight in fat sample			
Saturated fat	44.3	0.830	42.6	0.864
cis-monounsaturated	47.7	0.907	49.6	0.944
cis-polyunsaturated	3.67	0.110	3.65	0.114
trans fat	4.26	0.186	4.16	0.194
Omega-3 fat	0.535	0.018	0.562	0.018
Omega-6 fat	3.04	0.099	3.02	0.103
Omega-6/3 ratio	5.76	0.192	5.41	0.199

[a,b] Means within a row without common superscript letters are different at $P < 0.05$.

Table 3. Least squares means and standard errors of means for fatty acids of back fat for HOL, MVH crossbred, and NJV crossbred dairy steers.

	Breed group[1]						
	HOL		MVH		NJV		HOL vs. crossbred
Fatty acid	LSM	SE	LSM	SE	LSM	SE	*P*-value
			% weight of total fat				
C4:0, butyric	0.004	0.001	0.002	0.001	0.003	0.001	0.42
C14:0, myristic	3.21[b]	0.121	3.28[ab]	0.121	3.63[a]	0.129	0.12
C14:1*trans*, tetradecenoic	0.003[b]	0.001	0.003[b]	0.001	0.005[a]	0.001	0.14
C14:1, myristoleic	1.37[b]	0.131	1.23[b]	0.131	1.89[a]	0.139	0.24
C15:0, pentadecanoic	0.516	0.029	0.532	0.029	0.561	0.031	0.40
C16:0, palmitic	25.6	0.442	24.8	0.442	26.0	0.468	0.71
C16:1*trans*, hexadecenoic	0.222	0.024	0.253	0.024	0.226	0.025	0.57
C16:1, palmitoleic	5.53	0.336	5.79	0.336	6.22	0.356	0.27
C17:0, margaric	0.943	0.045	0.867	0.045	0.869	0.048	0.19
C17:1, margaroleic	0.001	0.000	0.000	0.000	0.001	0.000	0.78
C18:0, stearic	13.2	0.705	12.8	0.705	11.9	0.748	0.35
C18:1*trans*, elaidic	3.12[a]	0.206	2.56[ab]	0.206	2.45[b]	0.218	0.02
C18:1, oleic	40.3	0.760	41.8	0.760	40.4	0.806	0.40
C18:2*trans*, octadecadienoic	1.23	0.046	1.25	0.046	1.22	0.049	1.00
C18:2, conjugated linoleic	0.616	0.029	0.580	0.029	0.577	0.031	0.31
C18:2n-6, linoleic	2.91	0.122	2.82	0.122	2.72	0.129	0.37
C18:3n-6, γ-linolenic	0.024	0.001	0.025	0.001	0.025	0.001	0.42
C18:3n-3, α-linolenic	0.428	0.021	0.476	0.021	0.459	0.023	0.14
C20:0, arachidic	0.118	0.008	0.117	0.008	0.109	0.009	0.59
C20:1, gadoleic	0.128[b]	0.016	0.202[a]	0.016	0.151[b]	0.017	0.02
C20:2n-6, eicosadienoic	0.052	0.002	0.053	0.002	0.051	0.003	0.81
C20:3, γ-eicosatrienoic	0.067[b]	0.007	0.099[a]	0.007	0.079[ab]	0.008	0.03
C20:3n-3, eicosatrienoic	0.052	0.005	0.058	0.005	0.048	0.005	0.95
C20:4n-6, arachidonic	0.038	0.004	0.047	0.004	0.044	0.004	0.13
C20:5n-3, eicosapentaenoic	0.008[b]	0.001	0.011[a]	0.001	0.011[a]	0.001	0.01
C21:0, heneicosanoic	0.025	0.002	0.023	0.002	0.024	0.002	0.46
C22:2n-6, docosadienoic	0.004	0.001	0.004	0.001	0.005	0.001	0.26
C22:4n-6, docosatetraenoic	0.025[b]	0.004	0.039[a]	0.004	0.024[b]	0.005	0.22
C22:5, docosapentaenoic	0.055[b]	0.005	0.072[a]	0.005	0.060[ab]	0.006	0.11
C22:6n-3, docosahexaenoic	0.002	0.001	0.003	0.001	0.002	0.001	0.21
C23:0, tricosanoic	0.013[ab]	0.001	0.014[a]	0.001	0.011[b]	0.001	0.43
			% weight in fat sample				
Saturated fat	44.0	1.017	42.8	1.017	43.5	1.078	0.50
cis-monounsaturated	47.7	1.111	49.3	1.111	49.1	1.178	0.28
cis-polyunsaturated	3.69	0.135	3.74	0.135	3.56	0.143	0.81
trans fat	4.61	0.228	4.09	0.228	3.93	0.242	0.04
Omega-3 fat	0.504[b]	0.022	0.58[a]	0.022	0.551[ab]	0.023	0.02
Omega-6 fat	3.10	0.122	3.06	0.122	2.93	0.129	0.48
Omega-6/3 ratio	6.18[a]	0.235	5.27[b]	0.235	5.32[b]	0.249	0.01

[a,b] Means within a row without common superscript letters are different at $P < 0.05$.
[1] HOL = Holstein; MVH = crossbred comprised of Montbéliarde, Viking red, and Holstein; NJV = crossbred comprised of Normande, Jersey, and Viking Red

Table 4. Least squares means and standard errors for amino acids of meat from steers grazed on winter rye and winter wheat cover crops and for HOL, MVH crossbred, and NJV crossbred dairy steers.

	Cover crop				Breed group[1]						
	Winter rye		Winter wheat		HOL		MVH		NJV		HOL vs. crossbred
Amino acid	LSM	SE	LSM	SE	LSM	SE	LSM	SE	LSM	SE	*P*-value
Essential					% weight of total protein						
Lysine	1.8[a]	0.05	1.7[b]	0.05	1.8	0.06	1.8	0.06	1.7	0.06	0.98
Leucine	1.7[a]	0.04	1.5[b]	0.04	1.6	0.05	1.6	0.05	1.6	0.05	0.72
Valine	1.0[a]	0.02	0.96[b]	0.02	0.99	0.03	1.0	0.03	0.98	0.03	0.77
Isoleucine	0.98[a]	0.02	0.90[b]	0.02	0.93	0.03	0.97	0.03	0.92	0.03	0.76
Threonine	0.93[a]	0.02	0.85[b]	0.02	0.89	0.03	0.92	0.03	0.87	0.03	0.86
Phenylalanine	0.81[a]	0.02	0.76[b]	0.02	0.78	0.02	0.80	0.02	0.78	0.02	0.74
Histidine	0.77	0.02	0.75	0.02	0.74	0.03	0.79	0.03	0.74	0.03	0.56
Methionine	0.52	0.02	0.49	0.02	0.50	0.02	0.52	0.02	0.50	0.02	0.64
Tryptophan	0.24	0.01	0.22	0.01	0.23	0.01	0.23	0.01	0.22	0.01	0.43
Non-essential											
Glutamine	3.1[a]	0.08	2.7[b]	0.09	2.9	0.10	3.0	0.10	2.8	0.11	0.91
Aspartic acid	1.9[a]	0.04	1.7[b]	0.05	1.8	0.05	1.8	0.05	1.8	0.06	0.96
Arginine	1.2[a]	0.03	1.1[b]	0.03	1.1	0.03	1.2	0.03	1.1	0.04	0.63
Tyrosine	1.2	0.04	1.1	0.04	1.1	0.05	1.2	0.05	1.2	0.05	0.61
Alanine	1.2	0.03	1.1	0.03	1.1	0.04	1.2	0.04	1.2	0.04	0.71
Glycine	0.93	0.03	0.87	0.03	0.88	0.04	0.90	0.04	0.92	0.04	0.65
Serine	0.74[a]	0.02	0.68[b]	0.02	0.71	0.02	0.73	0.02	0.70	0.02	0.78
Cysteine	0.21	0.01	0.20	0.01	0.20	0.01	0.21	0.01	0.20	0.01	0.53
Taurine	0.005[b]	0.001	0.011[a]	0.001	0.01	0.001	0.01	0.001	0.01	0.001	0.12

[a,b] Means within a row for cover crop or breed group without common superscript letters are different at $P < 0.05$.

[1] HOL = Holstein; MVH = crossbred comprised of Montbéliarde, Viking red, and Holstein; NJV = crossbred comprised of Normande, Jersey, and Viking Red

Table 5. Least squares means and standard errors for sensory attributes of steaks for steers grazed on winter rye and winter wheat and for HOL, MVH crossbred, and NJV crossbred dairy steers.

Sensory attribute	Cover crop: Winter rye	Cover crop: Winter wheat	SE[4]	Breed group[1]: HOL	Breed group[1]: MVH	Breed group[1]: NJV	SE[4]	HOL vs. crossbred: P-value
Overall[2]	66.7[b]	72.0[a]	1.4	67.2[b]	69.2[ab]	71.8[a]	1.6	0.02
Flavor[2]	66.5[b]	70.3[a]	1.5	66.5[b]	67.9[ab]	70.7[a]	1.6	0.04
Texture[2]	66.1[b]	74.3[a]	1.4	67.5[b]	69.4[b]	73.8[a]	1.6	0.01
Toughness[3]	8.9[a]	7.3[b]	0.3	8.6[a]	8.4[a]	7.4[b]	0.3	0.03
Juiciness[3]	8.0[b]	9.2[a]	0.3	7.8[b]	9.2[a]	8.9[a]	0.4	< 0.01
Off-flavor[3]	5.6[a]	4.8[b]	0.4	5.3	5.3	5.0	0.4	0.58

[a,b] Means within a row for cover crop or breed group without a common letter are different at $P < 0.05$.
[1] HOL = Holstein; MVH = crossbred comprised of Montbéliarde, Viking red, and Holstein; NJV = crossbred comprised of Normande, Jersey, and Viking Red
[2] Overall flavor and texture liking/disliking: 0 = greatest imaginable disliking; 120 = greatest imaginable liking
[3] Toughness, juiciness, and off-flavor: 0 = none; 20 = extremely tough, extremely juicy, or extremely intense
[4] Standard errors were the same for cover crops and breeds.

Table 6. Means for overall like/dislike categories for steers grazed on winter rye and winter wheat and for HOL, MVH crossbred, and NJV crossbred dairy steers.

	Cover crop		Breed group[1]			HOL vs. crossbred
Sensory attribute[2]	Winter rye	Winter wheat	HOL	MVH	NJV	*P*-value
Like slightly, 60 to 120, %	63.6[b]	76.5[a]	62.0[b]	70.8[a]	77.3[a]	< 0.01
Like moderately, 81 to 120, %	23.5[b]	34.0[a]	24.5	30.6	31.0	0.05
Like very much, 93 to 120, %	8.6	11.4	9.7	11.6	8.8	0.83
Like extremely, 104 to 120, %	3.1	1.5	2.8	1.9	2.3	0.54

[a,b] Means from chi-square test within a row for cover crop or breed group without a common letter are different at $P < 0.05$.

[1] HOL = Holstein; NJV = crossbred comprised of Normande, Jersey, and Viking red; MVH = crossbred comprised of Montbéliarde, Viking red, and Holstein

[2] Overall liking/disliking: 0 = greatest imaginable disliking; 120 = greatest imaginable liking

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