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Evaluation of Protein Sources and Holstein Finishing Systems for Organic Beef Production and a Comparison of Single and Dual Implant Strategies in Finishing Heifers

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EVALUATION OF PROTEIN SOURCES AND HOLSTEIN FINISHING SYSTEMS FOR ORGANIC BEEF PRODUCTION AND A COMPARISON OF SINGLE AND DUAL IMPLANT STRATEGIES IN FINISHING HEIFERS

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Two *in situ* experiments were conducted to compare the rumen undegradable protein content (RUP) and RUP digestibility of conventional and organic field peas, fish meal, dehydrated alfalfa, and soybean meal. Significant differences were detected between feed samples in both studies for all variables measured. Variation existed between sample types but the data did not suggest that organic and conventional feeds are different when processed with the same methods. A performance experiment was conducted utilizing individually fed Holstein steers comparing the effect of RUP source in a simulated organic production system. Dietary treatments were: no supplemental protein (NONE), field peas (FP), field peas and fish meal (FPFM), soybean meal (SBM), or SoyPass (SP). Steers fed FPFM were more efficient than those fed NONE, with the other protein sources intermediate. These data indicated that conventional values of protein degradability may be used to formulate organic diets, and that similar performance can be achieved with a variety of different RUP sources.

A commercial feedlot study compared two implant strategies on growth performance and carcass characteristics. Heifers were implanted with Synovex ONE

Feedlot (day 0, **ONE**) or Synovex Choice (day 0) followed by Synovex Plus (day 93-95, **CH/PLUS**). Heifers implanted with CH/PLUS had lower marbling scores and calculated yield grade but greater DP and LM area compared to heifers implanted with ONE. No other differences were observed. These results indicated flexibility in implant strategy.

The performance of Holstein bulls and steers was evaluated in a simulated organic production system harvested at 308, 343, 378, and 413 days on feed (DOF) was compared. Bulls had greater ADG, DMI, live BW, and HCW than steers, while steers had greater 12th-rib fat thickness. Steers showed greater linear increases in marbling scores than bulls as DOF increased. Live BW, DMI, and HCW responded linearly as DOF increased. These data suggest potential for improved animal performance feeding Holstein bulls in an organic system.

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Introduction

Protein is a critical nutrient in all cattle diets but is especially important in the diets of growing calves, where requirements are high to support tissue growth (NRC, 2000). Distillers grains (DGS) and other corn coproducts are often high in protein content and are typically priced competitively when compared to other protein and energy sources, making DGS a common source of both protein and energy in cattle diets. However, in parts of the United States where DGS are not readily available, or in organic beef production systems where organic DGS are difficult to source, other supplemental proteins must be used to meet protein requirements. Many times, these alternative protein sources are more expensive per unit of protein and energy than DGS, and their use will result in an increase in feed costs. Increases in feed costs provides an incentive to limit costs by formulating diets to meet the protein requirements of the animal without providing excess protein.

To meet the protein requirements of an animal without feeding excess protein, a thorough understanding of the system used to determine protein requirements of beef cattle is necessary. Burroughs et al. (1974) proposed the metabolizable protein (MP) system to describe the protein requirements of ruminants and the MP system was first adopted by the National Research Council in 1985 (NRC, 1985). Metabolizable protein is the quantity of amino acids absorbed by the digestive tract after rumen fermentation, and consists of microbial sources of protein as well as dietary protein that escapes degradation by rumen microbes, called rumen undegradable protein (RUP); both are then digested and absorbed in the small intestine of the ruminant (Trenkle, 1980). Microbial protein sources are affected by microbial growth in the rumen, which is influenced by the

supply of energy and nitrogen entering the rumen. The rumen microbes utilize nitrogen from microbially degradable feed protein sources and non-protein nitrogen, which together make up rumen degradable protein (RDP). The MP content of a diet is therefore dependent upon the energy, RUP and RDP content of the diet. While values for crude protein (CP), digestible RUP, and RDP have been estimated for most common feeds in conventional cattle feeding systems, there are limited data available examining feeds produced in organic production systems. Determining the quantity and quality of these components found in the diet is a critical step in formulating a diet that meets the protein requirements of the animal.

It is established that the use of a hormonal implant can increase average daily gain (ADG) and feed efficiency by up to 20% and 13.5%, respectively (Duckett and Pratt, 2014). Because most cattle require more than 120 days to reach finished weight and most implants are only effective for between 60 and 120 days an implant strategy that uses multiple implants with one implant given at the beginning of the feeding period and another given at a later time has become common. Implant strategies that utilize multiple implants throughout the feeding period have proven to be an effective way to improve performance over an extended period of time (Preston, 1999). But, re-implanting cattle requires that cattle must be processed again. Handling may result in stress and reduced performance, although good handling practices can minimize this (Grandin, 1984; Petherick et al., 2009). Furthermore, labor costs associated with processing to re-implant should not be ignored. A single implant that could cover the entire feeding period on long-fed cattle may be appealing to producers who wish to reduce labor costs or to reduce handling-associated stress.

The use of hormonal implants and other growth promotors are prohibited in organic beef production. In an organic production system, there may be an opportunity to partially compensate for the loss of this technology by leaving male calves intact. Historically, feeding bulls has been and remains a common practice outside of the United States. When compared to non-implanted steers, bulls had greater ADG and carcass weight while steers achieved greater fatness (Marti et al., 2013).

The purposes of this review are to examine potential differences in protein content and digestibility of feeds produced in organic and conventional systems, to explore the use of different protein feeds in beef cattle diets, to compare carcass yield and feeding efficiency of bulls and steers, and to compare single and multiple implant systems.

Chapter I: Review of Literature

Protein and Amino Acids in Ruminants

Protein Degradation in the Rumen

In ruminants and other pre-gastric fermenters, the microbes in the foregut have the first opportunity to utilize nutrients entering the digestive system. The microbes are then passed into the small intestine along with rumen digesta, and then are digested and absorbed by the animal. The protein that is absorbed by the animal is comprised of both microbial and dietary sources (Wilkerson et al., 1993). Metabolizable protein (MP) is the quantity of protein absorbed by the digestive tract after rumen fermentation. The Nutrient Requirements of Beef Cattle (NASEM, 2016) utilizes the MP system to describe the protein requirements of beef cattle. Metabolizable protein consists of microbial sources of protein as well as dietary protein that escapes degradation by rumen microbes, which are digested and absorbed in the small intestine of the ruminant (Trenkle, 1980). Microbial

protein sources are affected by the microbial growth in the rumen. The main inputs to microbial protein synthesis are adequate supplies of energy and nitrogen. Sources of nitrogen utilized by rumen microbes include non-protein nitrogen (NPN) sources such as urea and nitrogen from amino acids that have been deaminated to produce free ammonia (Trenkle, 1980). Nitrogen can also be recycled back into the rumen as urea passing across the rumen wall in blood or entering the rumen in saliva. The portion of protein degraded by rumen microbes, called rumen degradable protein (RDP), also supplies peptides and amino acids utilized by microbes for growth. The dietary protein that escapes rumen degradation is called rumen undegradable protein (RUP). The amount of MP supplied by a diet is therefore dependent upon the RUP and RDP content of the feedstuffs in that diet.

The ruminal degradation of protein is dependent upon the same factors that affect degradation of all feeds, including solubility of the protein and rate of passage through the rumen (Allen and Mertens, 1988; Klopfenstein et al., 2001). The more soluble the protein, the more degradable the protein is and the lower the fraction of RUP. Similarly, the longer the protein remains in the rumen, the more opportunity microbes have to degrade the protein and the lower the RUP value (Trenkle, 1980). Retention time can be affected by many factors, such as intake, particle size, fiber inclusion, and fluid flow rate. Measuring microbial flow into the small intestine is important in determining microbial crude protein (CP) contributions to the total MP. The microbes that pass into the small intestine with the rumen digesta are about 80-85% digestible in the small intestine (Zebrowska et al., 1997). Rumen degradable protein can be estimated via subtraction once the RUP fraction of CP has been measured. Directly measuring the quantity of RDP

provided by a feed can be difficult and requires predictions of microbial flow out of the rumen and amount of nitrogen recycling into the rumen via blood and saliva.

Post-Ruminal Digestion and Absorption of Amino Acids

Before attempting to measure protein characteristics, and in particular protein digestibility, it is important to understand how proteins are digested and absorbed once they enter the small intestine. After exiting the abomasum, the digesta is mixed with secretions from the liver and pancreas containing bile, enzymes, and bicarbonate. In contrast to other species, in ruminants gastric pepsin is the primary proteolytic enzyme acting on the proteins entering the duodenum. This is due to a lower measured bicarbonate output of the pancreas in ruminants. The major pancreatic proteases trypsin, chymotrypsin, and carboxypeptidase do not reach full activity until digesta has entered the jejunum (NRC, 1985). The role of the proteases is to take proteins and reduce them to small peptides and free amino acids, which can then be absorbed by the intestinal enterocytes. Although there are peptide transporters in the rumen and omasum (Gilbert et al., 2008), the majority of peptide and free amino acid uptake is observed in the jejunum and ileum of the small intestine (NRC, 1985). A significant amount of peptide and amino acid catabolism occurs in the mucosal cells of the intestine, suggesting that amino acids may be a significant energy source for intestinal enterocytes (Wu, 1998). Absorbed peptides and amino acids that are not catabolized by intestinal enterocytes enter the portal bloodstream and are distributed to peripheral tissues. Microbial protein is digested and absorbed by the same processes as dietary protein that escaped rumen degradation and enters the small intestine.

Essential and Limiting Amino Acids in Growing Cattle

Essential amino acids are those that must be supplied by the animal's diet, as they cannot be synthesized by the body in sufficient quantity to sustain growth (Rose et al., 1948). Ruminants are somewhat unique in that the rumen microbes supply essential amino acids to the animal. In adult animals, rumen microbes are produced in a quantity large enough to supply the essential amino acids necessary for maintenance of body tissues. However, if amino acid requirements are high, such as in the growing animal, or if microbial CP production is limited, microbial CP likely will not meet the amino acid requirements of the animal (Merchen and Titgemeyer, 1992). Supplemental RUP helps to correct this deficiency in essential amino acids and improves performance, but only if the limiting essential amino acids are supplied. The supplemental source of RUP must therefore either have high concentrations of the limiting essential amino acids, or be supplemented in large enough quantity to make up the deficiency.

Methionine and lysine are typically identified as the first limiting amino acids for growing cattle (Chalupa and Chandler, 1975; Richardson and Hatfield, 1978; Komarek et al., 1983). Supplementation of rumen protected amino acids can improve the quality and quantity of protein entering the duodenum (Titgemeyer et al., 1988). However, the feed ingredients that compose the diet naturally influence which amino acid is first limiting depending on the microbial CP production, quantity of RUP supplied, the amino acid composition of the RUP, and the digestibility of the RUP and by extension the amino acids. For example, lysine is likely the first limiting amino acid in corn-based diets because cattle respond positively to supplemental rumen-protected lysine in diets high in corn (Burris et al., 1976; Titgemeyer et al., 1988). Fenderson and Bergen (1975) found that cattle fed diets containing 80% barley benefitted from supplemental rumen protected

methionine, indicating that the first limiting amino acid in barley diets is methionine. Hussein and Berger (1995) found that supplementation of rumen protected lysine and methionine in increasing amounts to growing 182 kg Holstein steers fed diets containing 71% whole corn, 4% condensed distillers solubles, 10% corn silage, and either 4.9% mineral and vitamin supplement and 10.1% soybean meal or 9.1% mineral and vitamin supplement and 5.1% soybean meal and 0.8% urea largely had no effect on animal performance, suggesting that neither lysine nor methionine were limiting in those diets. These data indicate that growing cattle require a supplemental dietary RUP source that has an amino acid profile complementary to the amino acids supplied by the rest of the diet that escape microbial transformation.

A Comparison of Organic and Conventional Feeds

Before attempting to compare organic and conventional feeds, a thorough understanding of the organic production system is necessary. Furthermore, while the standards explained here are for the United States, most organic programs across the globe are very similar.

Organic Crop Production

All farms that intend to market organic crops must be certified under the National Organic Program (NOP; Coleman, 2012). The certification process involves submitting an application to an accredited certification agent. The application must include a complete field history of both existing and new fields, a farm map, an Organic System Plan (OSP), an estimate of organic yields and sales, and a statement of operator agreement or affiliation. The Organic System Plan is a description of the farm and operations including crops to be grown and plans for source of seeds or plants, control of

pests, weeds, and diseases, plans to maintain soil fertility, and plans for crop sales and marketing. Fields are eligible for organic status if no prohibited materials including prohibited crops, fungicides, pesticides, herbicides, and fertilizers have been applied for a period of 36 months. After an initial review of the application, an inspector visits the farm and ensures that the OSP accurately describes the farm and verifies that the farm meets the standards for organic certification through reviewing invoices, production records, and current inventories. The inspector may also request to take samples of materials such as soil, crops, fertilizers, etc. to test for residues of prohibited materials. Upon receiving and reviewing the inspector's report, the certifier will award organic certification provided that the operation is in compliance with regulations.

Organic crop production requires that all crops must be a non-genetically modified cultivar and only pesticides and fertilizers that are approved for use in organic production may be used (Coleman, 2012). There is an emphasis on use of cover crops, intercropping, crop rotation, and other management practices to control weed and insect pests before using mineral or synthetic crop protection agents including pesticides, fungicides, and herbicides. There are pesticides, herbicides, and fertilizers that are allowable in organic crop production. Biological pesticides that contain live microbes or microbially derived toxins are used to control various insect pests. Pesticides derived from botanical sources such as pyrethrum or garlic are also allowable, as are sprayed oils to suffocate insect pests, pheromones, and insecticidal soaps. Mineral pesticides and fungicides allowed in organic production include copper and sulfur products. Acceptable fertilizers in organic crop production include plant material, animal manure and animal byproducts, composts, mineral fertilizers such as rock dust and natural potassium sulfate,

and sodium nitrate provided it is applied at the rate of no more than 20% of the crop's nitrogen requirement.

Organic Livestock Production

Organic livestock production follows similar regulations (Coffey and Baier, 2012). In an organic beef production system, no antibiotics may be administered to an animal and then subsequently market that animal as organic. However, it is expressly forbidden to withhold antibiotic treatment of disease; animals should be treated and then moved to a conventional system. Animals may be obtained from a conventional operation provided that the dam is managed according to organic standards during the final third of gestation. For example, a conventionally managed cowherd could produce organic calves if the cows are managed to organic standards during the final three months of gestation. Dairy animals must be maintained in an organic system for 1 year before the milk may be considered organic. Synthetic antiparasitics may not be used in animals intended for human food, although breeding stock may be given fenbendazole or moxidectin and their offspring may be certified organic if the antiparasitic treatment was given to the dam prior to the final third of gestation. Vaccines are allowed and encouraged under organic production requirements. The use of pharmaceuticals such as lidocaine, procaine, xylazine, flunixin, oxytocin, aspirin, atropine, and butorphanol are all allowed under the guidance of a licensed veterinarian provided withdrawal periods for slaughter stock are adhered to. Poloxalene may be used for the emergency treatment of bloat.

All feeds must be produced in an organic system and animals must have outside access, although there is no minimum outdoor space requirement. The use of urea or ammonia as a non-protein nitrogen source in animal feed is prohibited, as is the use of

animal manure. Ruminants must have access to pasture during the grazing season for the region at no less than 30% of their dry matter intake (DMI; Rinehart and Baier, 2011). The DMI requirement for ruminants can be determined using methods described in the National Research Council publication for the species, such as a percent of body weight for cattle. Organic standards do not require any one specific method of calculation, but the provided ration for each type and class of animal on an operation including pasture allowance must be documented along with the amount of feed actually fed. The grazing season must be at least 120 days per year and may be longer based on regional climate. For example, the grazing season would be longer in southern states with more growing degree days than in northern states with fewer growing degree days. The grazing season is determined by the producer, written in the operation's OSP, and reviewed by the inspector and certifiers during the application process. The grazing season does not need to be continuous. Ruminants raised for slaughter are exempt from the 30% pasture dry matter intake requirement during the finishing period but must be maintained with access to pasture during the grazing season. This can be accomplished by using a feedlot pen with pasture access during the grazing season. The finishing period may only be 120 days or one-fifth of the animal's life, whichever is shorter.

Nutritional Values of Organic and Conventional Crops

There are limited data on the nutritional value of organically produced crops for both human and animal consumption. Previous research has focused on the comparisons of protein content, protein quality, and vitamin and mineral content. Direct comparisons of organic and conventional crops are challenging because most studies compare crops grown not only in different production systems but under different environmental

conditions. Furthermore, because genetically modified crops are not allowed to be used in organic production systems, crops from organic and conventional production systems are likely genetically different when comparing crops like corn, alfalfa, and soybeans. The differences in production methods and possibly genetics between conventional and organic cropping systems influence differences observed in crop yield. For example, Seufert et al. (2012) compared yields of conventional and organic fruits, oilseed crops, cereal grains, and vegetables and found that organic crops overall yielded 75% of the yield of conventional crops, organic corn had 85% the yield of conventional corn yields, and organic soybeans had 90% of the yield conventional soybeans. These data are reflected in a study by de Ponti et al. (2012) comparing yields of organic and conventional cereal grains, roots and tubers, oilseed crops, vegetables, fruits, and animal fodder crops, where overall organic crop yields were 80% of conventional crop yields, organic corn yielded an average of 89% of conventional yields, and organic soybeans yielded 92% of conventional soybean yields. These relative yields are important to bear in mind because they influence total nutrient yield per acre.

A 21-year field experiment compared wheat grown under organic and conventional systems and found no differences between production system for protein quality or mineral concentration; however, total DM yield per ha, total protein yield per acre, and protein content were greater for the conventionally reared wheat (Mäder et al., 2007; Table 1). The authors stated that seeding rates were 10-25% greater for organic wheat because organic seeds had reduced emergence.

Kelley and Bateman (2010) obtained samples of conventional and organic lettuces and tomatoes from different growers over a wide geographic area and found lower nitrate

and higher phosphate content when comparing organic and conventional lettuces. Organically grown tomatoes had higher Ca, Cu, Zn, and rubidium content but lower Mn content when compared to conventional tomatoes.

Worthington (1998) evaluated 34 publications comparing the nutrient content and quality of organic and conventionally produced crops. In Table 2, the number of studies that observed increased, similar, or decreased nutrient content of organic crops relative to conventional crops are listed. Of the 3 studies examining protein quality, all found that organically produced crops increased in quality compared to conventional crops while conventional crops were generally higher in nitrate content. Protein quality in these studies referred to the proportion of total amino acids that were essential amino acids. Organic crops appeared to be higher in vitamin C and have similar or increased mineral content compared to conventional crops. However, Worthington determined that a clear conclusion could not be made due to the variability of the available data. Worthington's findings were echoed by several subsequent literature reviews that also noted a high degree of variability between studies. Caution is recommended in comparing studies conducted years apart due to developments in conventional production practices (Williams, 2002; Magkos et al., 2003). There is some evidence of a trend for reduced protein content but increased protein quality in some organic vegetables and cereal crops relative to conventional crops (Magkos et al., 2003).

Srednicka-Tober et al. (2013) examined the effect of wheat, carrots, potatoes, and onions grown with organic crop protection agents and organic fertilizer, organic crop protection agents and conventional fertilizer, conventional crop protection agents and organic fertilizer, and conventional crop protection agents and conventional fertilizers.

They found that among all groups and crops there were similar concentrations of Cu, Ni, and Pb but that crops under organic management showed increased concentrations of polyphenols. Crops fertilized with conventional fertilizer had increased concentrations of protein compared to those managed with organic fertilizer.

These data indicate that organic and conventional crops do not differ in macronutrient composition but may differ in micronutrient composition. Variability in the results of the studies examined in these reviews could be influenced by differences in crop management between studies, variation in crop harvest and processing methods, and the progression of agricultural practices over time. Variance in nutrient content of conventional crops can be observed between different operations and geographical locations due to differences in management and climate and the same likely holds true for organic crops. Development of new technologies and techniques may also introduce variation between studies. It is possible that the results of early studies in these reviews do not reflect performance of more current organic and conventional crops due to advances made in both production systems over time.

Nutrient Digestibility of Conventional and Organic Crops

There are limited data regarding comparisons of nutrient digestibility between crops grown in organic and conventional systems. Feeding trials have been done comparing organic and conventional feeds and production systems. Srednicka-Tober et al. (2013) found no difference between organic or conventional management of crops fed to rats in final BW, body fat percentage, plasma hormone concentrations, or immune parameters.

Two studies comparing the effects of organic and conventional production systems and feeds on growth and carcass performance in pigs found no difference between the organic or conventional diet on performance or carcass characteristics of the pigs and no interaction between housing and diet (Millet et al., 2004, 2005). Both studies found the pigs in the organic housing system had increased feed intake and ADG. In one study, pigs in an organic housing system had similar lean meat percentage, similar fat thickness, and greater muscle thickness compared to those in conventional housing (Millet et al., 2004). However, the second study observed greater lean meat percentage and muscle thickness in conventionally housed pigs, while pigs in organic housing had greater fat thickness (Millet et al., 2005).

Linden et al. (2001) compared organic and conventional pig production systems and the levels of cadmium (Cd) in the feed, kidney tissue, liver tissue, and manure and found no difference in liver Cd concentration but pigs in the organic production system had greater concentrations of Cd in kidney tissue and manure compared to pigs in the conventional system. However, the pigs raised organically were housed outside and fed organic feed while the pigs raised conventionally were housed indoors and fed conventional feed. The diets were not similar in composition and differed in Cd content, with organic diets containing less Cd than conventional diets. However, the organic diets had more Cd in the vitamin-mineral supplement than the conventional diet, indicating that the source of Cd may have influenced the absorption of Cd by the animal. The authors attributed the differences in Cd concentration to potential soil consumption, differences in feed composition, or increased bioavailability of the Cd in the organic feed components. Without similar diet composition and similar housing systems, it is difficult

to determine if these apparent differences in mineral absorption were due to the animal feeding system or the system in which the feeds were grown.

Fernandez and Woodward (1999 a, b) examined the effect of organic and conventional production systems on live performance and carcass characteristics of finishing beef steers that were born on low input or high input operations. Diets offered were of similar composition and cattle were fed individually using feed bunks with Calan Feed Access Doors; those assigned to the organic treatment were fed organic feed with no feed additives and those in the conventional treatment group were fed conventional feed with monensin (Rumensin, 30 g/ton). Cattle assigned to the conventional production system were given albendazole (Valbazen) and a hormonal implant protocol while cattle in the organic system received no antiparasitics or implants. Steers were harvested when a final BW of at least 567 kg and a 12^{th}-rib fat thickness of 0.75-0.90 cm was achieved. However, 14 calves in the organic production system were harvested at 235 d although the finishing parameters were not met due to time restrictions. Regardless of the source the calves were purchased from, those fed under an organic system gained less, had similar DMI, and were less efficient than those fed in a conventional system. Calves fed in a conventional system had greater final BW, were fed for fewer days, and had reduced costs per kg of gain compared to calves fed in the organic system. Hot carcass weight and longissimus muscle area were greatest for the conventional steers, while the organic steers had greater marbling scores. Dressing percentage, kidney-pelvic-heart fat (KPH) percentage, and 12^{th}-rib fat thickness were similar between finishing systems. While diet composition was similar between production systems, some or all of the performance

differences may be attributed to the utilization of an implant protocol and monensin in the conventional system.

Bystrom et al. (2002) compared the performance of dairy cows fed mixed grass and clover silage with green oat and pea forage and grass hay managed in organic or conventional systems. The conventional forage was found to be higher in ME and CP and cows managed in the conventional system had greater DMI and ME intake, but similar CP intake compared to organically managed cows. Organically managed cows had lower milk yields but higher milk protein content compared to conventionally managed cows during the first 10 weeks of lactation. However, this study did not feed forages harvested at equal maturity or in equal proportions and the rationale behind this decision was not reported. Organic forages were always harvested later than conventional forages and organic silage contained 32% clover while conventional silage had 12% clover. Furthermore, the organically managed cows were provided *ad libitum* access to forage while the conventionally managed cows were offered 1.5 kg DM of forage/100 kg BW. Concentrate feed was offered at levels appropriate for stage of lactation, but the amount offered was not reported.

The above studies may be good comparisons of organic and conventional diets or production systems and their effects on animal performance, but several of the studies assumed equivalent nutrient digestibility between organic and conventional feeds. While animal performance can indicate relative digestibility or energy content when diet composition is similar, the above studies that compared entire production systems were not good indicators of diet degradability due to confounding factors such as hormonal implants, antibiotic treatments, and differences in housing. Understanding the dietary

content of energy content either through digestible energy (DE), metabolizable energy (ME), or net energy for gain, maintenance, or lactation (NEg, NEm, NEl) as well as CP and amino acid digestibility are all necessary in formulating diets for any species. When utilizing the metabolizable protein system to formulate diets for ruminants, accurate measures of digestible RUP and accurate calculation of RDP using the RUP value are critical in meeting the protein requirements of cattle. Without accurate estimates of energy and digestibility values, there is risk of under- or oversupplying nutrients. For example, inadequate supply of dietary protein can result in reduced performance, while feeding excess protein in an organic system would increase feed costs unnecessarily. The NASEM (2016) provides feed composition tables and estimates of energy and digestibility values as well as RUP and RDP for most of the commonly utilized conventional feeds. However, there are limited data available on dry matter digestibility and metabolizable energy (ME) content of diets composed of organic feeds in comparison to conventional feeds, and even less data on protein digestibility. Published data on individual organic feed ingredients are extremely limited.

Feeding an organic diet to gilthead seabream and European seabass resulted in increased C but lower N and P digestibility compared to a commercially available conventional diet. This resulted in reduced C wastes but increased N and P wastes from the organically fed fish compared to the conventionally fed fish. The authors determined that the difference in nutrient wastes between conventional and organically fed fish was due to a difference in nutrient bioavailability. Fish size and diet nutrient content had no effect on nutrient digestibility in either fish species (Ballester-Molto et al., 2017).

A digestibility study comparing conventional and organic feed ingredients was conducted by a Swiss feed company utilizing 752 laying hens fed either a high or low CP basal diet comprised of conventional feeds (Star and Kwakernaak, 2017). The basal diets were fed alone or mixed with the test feeds obtained from multiple different sources to determine digestibility of the test feeds. Feeds examined included conventional and organic corn, wheat, expeller pressed soybean meal, expeller pressed sunflower seed, wheat middlings, and peas. Some differences between organic and conventional feeds in apparent ME content and total tract N and P digestibility were observed, but overall the results did not indicate a clear difference between digestibility of organic and conventional feeds. The authors pointed out that the results may have been influenced by differences in geographical location where each crop was grown and differences in processing between the processed feeds and did not determine that a clear difference existed between organic and conventionally produced feeds.

When lambs were fed diets of organic and conventional cowpea hay and barley grain, similar intakes of DM, CP and ME were observed and no difference was detected between conventional or organically produced feed for digestibility of DM, organic matter (OM), CP, neutral detergent fiber (NDF), acid detergent fiber (ADF), cellulose, and hemicellulose (Singh et al., 2010). Tharparkar (*Bos indicus*) heifers fed organic or conventional sorghum hay harvested at half bloom stage and a concentrate mixture of barley grain, linseed grain, and mineral mixture had similar DMI and digestibility of DM, CP, NDF, ADF, and cellulose. However, the organic diet had greater NDF and hemicellulose digestibility compared to the conventional diet (Singh et al., 2012).

The limited research done comparing digestibility of organic and conventional feeds have produced variable results. The variation may be explained by differences in crop maturity stage, processing methods, or geographic location. However, it does appear that when organic and conventional feeds are produced in a similar geographic location and harvested at similar maturities, there is no difference in nutrient digestibility. More research must be done with individual ingredients before a robust conclusion can be made.

Protein Feed Alternatives to Distillers Grains

Distillers grains in wet or dried forms are extremely useful in cattle diets as both a protein and energy source. Historically, DGS have been an inexpensive feed in dollars per unit of energy, consequentially allowing feedlot nutritionists to formulate diets on an energy basis rather than a protein basis. Formulating diets on an energy basis using DGS results in diets exceeding protein requirements (Bremer et al., 2011). Distillers grains are approximately 30% CP on a DM basis (NASEM, 2016). Dried DGS have an RUP content of approximately 56.3% to 63.0% of CP (Kelzer et al., 2010; Castillo-Lopez et al., 2013). Distillers grains are also an economical source of supplemental protein for growing calves because of their protein composition. Calves grazing a low-quality forage such as corn residue benefit most from supplemental RUP to meet MP requirements (Tibbitts et al., 2016). Furthermore, calves fed diets high in corn silage show improved performance when additional RUP is added to meet MP requirements (Hilscher et al., 2019; Oney et al., 2019). However, there are some areas where DGS may be unavailable or prohibitively expensive and finding DGS that meet organic standards is a challenge. Finding an alternative feed that provides similar or greater protein content would be

useful for those areas where DGS are difficult to obtain. Use of feeds that can be grown on-farm in a crop rotation and meet protein needs of growing and finishing cattle might better fit in an organic beef system.

Field Peas

Field peas (*Pisum sativum*) are a leguminous crop that are primarily grown in the Great Plains region of the United States. Field peas are typically planted beginning in late March and harvested in June to July (McKay et al., 2003). The short growing season does not interfere with the planting and harvest of crops such as corn. When included in a crop rotation system, field peas provide the benefits of nitrogen fixation, pest management, and weed control. Increasing temporal diversity through a rotational cropping system improves weed control in a monoculture planting system (Liebman and Dyck, 1993). Crop rotation systems are also known to reduce pests (Allen and Baghott, 1970; Roberts and Tomason, 1981; Flint and Roberts, 1988) and prevent plant diseases (Butterfield et al., 1978; Conner and Atkinson, 1989; Krupinsky et al, 2002). While the majority of field peas are grown for human consumption (Oelke et al., 1991), those markets are easily saturated with excess product and peas that do not meet quality standards. This surplus of field peas provides an opportunity for livestock feed provided they are priced competitively (Fendrick et al., 2006).

As an ingredient in feedlot diets, field peas may fit well as a source of both protein and energy. Crude protein of field peas is typically around 24%, and RUP content of that CP ranges from 6% to 22% when measured using *in situ* methods (Anderson et al., 2007). Greenwell et al. (2018) measured RUP content and digestibility of two different samples of field peas using an *in situ* method and reported RUP content of those samples

to be 32.6% of CP and 35.2% of CP. The wide range of estimated RUP content for field peas across these different studies suggests that that further research into the rumen degradability of field pea protein is needed. When considering an organic production system where urea may not be used as a non-protein nitrogen source, field peas may also fit well as a source of RDP.

While field peas are higher in NDF content than corn (Gilbery et al., 2007) and contain approximately one-third the starch content of corn (Anderson et al., 2007), some studies have found field peas to be similar in energy content to corn (Loe et al., 2004) while others found field peas to be lower in energy relative to corn (Fendrick et al., 2005). Although field peas have been found to contain various antinutritional factors (Hanbury et al., 2000), the inclusion of field peas even as a large portion of the diet does not appear to negatively affect cattle performance. Several studies reported no difference in G:F between cattle fed field peas and those fed a corn-based diet (Loe et al., 2004; Fendrick et al., 2005; Carlin et al., 2006; Jenkins et al., 2011). Flatt and Stanton (2000) found an increase of G:F with no change in ADG when field peas replaced 20% of the corn in the diet. Replacing other cereal grains with field peas did not affect performance (Reed et al., 2004; Jenkins et al., 2011). Processing field peas by dry rolling has not been found to improve performance over feeding whole field peas (Birkelo et al., 2000; Fendrick et al., 2006) and steam flaking does not improve digestibility of field peas although extrusion may increase N availability (Focant et al., 1990).

Field peas may also be useful as a supplement to growing cattle, particularly when DGS are not readily available. Supplementation of field peas to growing heifers grazing crested wheatgrass at 0.4% and 0.8% of BW resulted in 10% lower ADG compared to an

equal level of supplementation of dried DGS, suggesting that field peas should not be priced equivalent to dried DGS (Troyer et al., 2019).

Fish Meal

Fish meal is a protein-rich byproduct from the fish oil industry that remains after oil is extracted from fish. There are different processing methods, but in general the fish are cooked, pressed, the liquid fraction is centrifuged to remove the oil, and the solid fraction is dried and ground into a fine meal (Hussein and Jordan, 1991). After centrifuging to remove the oil, the liquid fraction is called "stickwater" and contains soluble solids, mostly CP. Stickwater is dried to condensed fish solubles, which is about 30-50% DM and may be added back to the fish meal (Hussein and Jordan, 1991).

Fish meal averages 66% CP and the protein is about 45% RUP (NASEM, 2016). However, some studies have found RUP values as high as 71% (Erasmus et al., 1994), 56.3% (Piepenbrink and Schingoethe, 1998), and 55.6% of CP (England et al., 1997). In general, RUP of fish meal ranges from 30% of CP to 70% of CP (Hussein and Jordan, 1991). Variation between fish species and processing methods can result in variation in nutrient content between fish meals (Hussein and Jordan, 1991; Stern et al., 1994; Mehrez et al., 1980). Processing methods significantly affect RUP content and digestibility of fish meal. Factors such as storage time of raw fish before processing, type of dryer, preservative application, heating duration and temperature, and proportion of fish solubles added to the meal all influence RUP content (Mehrez et al., 1980; Hussein and Jordan, 1991).

In addition to a relatively high RUP content, the intestinal digestibility of the RUP fraction is very high resulting in total tract digestibility of the CP of 95% or greater

(Erasmus et al., 1994; England et al., 1997). There is also evidence that fish meal delivers a large concentration of essential amino acids to the duodenum (Stern et al., 1994; Santos et al., 1998) and that supplementation of fish meal increases plasma concentration of essential and nonessential amino acids in growing calves (Davenport et al., 1990).

Research on including fish meal in growing and finishing diets has produced mixed results. The effect of supplementing ground soybeans, ground soybeans and rumen protected lysine, fish meal and ground soybeans, or fish meal combined with ground soybeans and rumen protected lysine to 220 kg growing calves fed corn silage was examined by Davenport et al. (1990). Supplemental fish meal resulted in an increase in ADG and feed efficiency with no difference in DMI compared to calves supplemented with ground soybeans alone. No effect of rumen protected lysine was observed, indicating that lysine was not limiting in any of the diets and suggesting that a different amino acid that was supplied by the fish meal was limiting. Plasma amino acid concentrations were measured. Plasma concentrations of methionine, isoleucine, leucine, histidine, threonine, tryptophan, arginine, lysine, glycine, citrulline, alanine, proline, and ornithine were increased with fish meal supplementation. Total amino acid, total essential amino acid, and total nonessential amino acid concentrations were also increased in fish meal supplemented calves compared to calves supplemented with ground soybean meal alone. Rumen protected lysine increased plasma concentrations of leucine, histidine, and ornithine in calves supplemented with ground soybeans, fish meal, and rumen protected lysine.

Sanderson et al. (1992) found that feeding growing 110-kg Holstein calves a diet containing ryegrass with inclusions of fish meal at 0%, 5%, 10%, or 15% of diet DM

resulted in a linear increase in DMI and ADG as inclusion of fish meal increased. This suggests that increasing RUP supply using fish meal improved performance in growing calves fed a grass diet.

Mandell et al. (1997) found that inclusion of fish meal at 5% or 10% of diet DM for 56, 112, or 168 d before slaughter resulted in an increase in concentrations of eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA) in the *longissimus* muscle (LM) compared to cattle fed a corn gluten meal/blood meal mixture, with greatest concentrations found in cattle fed 10% fish meal. While ADG and feed efficiency were not different between cattle fed fish meal and those fed a corn gluten meal/blood meal mixture, the cattle fed 5% fish meal had greater DMI and ADG than those fed 10% fish meal, suggesting that increasing fish meal beyond 5% had no performance benefits beyond increasing DHA and EPA in the LM.

The lack of data on the effects of fish meal in growing cattle make it difficult to draw a definitive conclusion on fish meal as a protein supplement. One of the challenges in evaluating fish meal as a protein supplement is the lack of research comparing fish meal to DGS or soybean meal products at dietary inclusions formulated for a similar estimated MP balance. While the quality of amino acids supplied to the duodenum is high when fish meal is fed, it is not established if this supply of amino acids will result in similar performance in young calves compared to plant derived protein feeds when fed at levels to provide similar MP. In spite of a lack of current applied research, the high CP content, RUP content, and RUP digestibility of fish meal indicate that this feed resource should not be ignored by beef producers provided that it can be purchased at a reasonable price per unit of protein.

Expeller Soybean Meal

Soybean meal is a byproduct of the soybean oil industry and is produced during the soybean oil extraction process. The quality of soybean meal as a protein feed for cattle is heavily influenced by the oil extraction method. The most common method of extracting soybean oil is the solvent extraction method. Soybeans are dried to between 1% and 2% moisture, cracked, dehulled, heated, flaked, and treated with a solvent such as hexane to extract the oil. The residual solvent is driven out of the meal by some additional heating (Erickson, 1995). The final solvent extracted soybean meal product may have the soybean hulls added to it, but more commonly now the hulls are sold as a separate byproduct, and the solvent extracted soybean meal is 53% CP, with 30% of that CP as RUP (NASEM, 2016).

Less than 1% of the soybeans in the United States are processed using mechanical extraction (Erickson, 1995); the two types of mechanical extraction are screw pressing and expeller pressing. In the screw pressing process, the soybeans are dried, cracked or flaked, and the hulls may be removed. The soybeans are heated and placed in the screw press, which forces the oil out. The “press cake” is then ground and allowed to cool. The expeller process is similar to the screw press process, except that the beans are extruded rather than cracked or flaked before pressing. The pressure and friction in the press and the extrusion process creates heat which inactivates the antinutritional factors in the soybean protein and changes the digestibility characteristics of the protein in the expeller soybean meal. Expeller soybean meal has a slightly higher oil content than solvent soybean meal, and is therefore about 47% CP (NASEM, 2016) but the heat from

processing results in an increase in the RUP content compared to solvent soybean meal (Mjoun et al, 2010; Paz et al., 2014).

A comparison of the rumen degradability of the CP and amino acids of solvent and expeller soybean meal, extruded soybeans, dried DGS, low fat dried DGS, high protein dried DGS, and modified wet DGS was performed by Mjoun et al. (2010) using the standard *in situ* procedure. The RUP content was highest for low fat dried DGS at 60.4% of CP, and lowest for solvent soybean meal at 32.3% of CP. Expeller soybean meal, dried DGS, and high protein dried DGS were lower in RUP content than low fat DGS at 53.7%, 52.3%, and 54.5% of CP, respectively but had greater RUP content than modified wet DGS, which was 38.3% RUP as a percent of CP. Expeller and solvent soybean meal had similar amino acid composition of the RUP after 16 h of rumen incubation and the concentration of essential amino acids remaining after rumen incubation was not different from the dried DGS or modified wet DGS. Intestinal digestibility of RUP was similar between solvent soybean meal and expeller soybean meal at 97.0% and 98.5%, respectively, while the dried DGS and modified wet DGS had lower RUP digestibility. Intestinal digestibility of the essential amino acids from RUP was similar between solvent soybean meal and expeller soybean meal at 97.3% and 98.9%, respectively, while the dried DGS, low fat dried DGS, high protein dried DGS, and modified wet DGS had lower essential amino acid digestibility at 93.3%, 93.9%, 94.0%, and 92.8%, respectively.

In a similar *in situ* study, Paz et al. (2014) compared three different blood meals, canola meal, low fat dried DGS, and solvent and expeller soybean meal. Expeller soybean meal had higher RUP content than solvent soybean meal, which was similar to

low fat DGS in RUP content (63.0%, 31.2%, and 23.1% of CP, respectively). Expeller soybean meal had lower concentrations of residual essential amino acids compared to solvent soybean meal after 16 h of rumen incubation, and low fat dried DGS had lower concentrations of residual essential amino acids than either of the soybean meals tested. This study also examined intestinal digestibility of the RUP and amino acids, and due to a lack of residue after digestion they were unable to test the solvent extracted soybean meal, indicating a very high digestibility. Expeller soybean meal had 98.8% digestible RUP, but not enough residue remained to test amino acid digestibility. Both soybean meals had higher concentrations of digestible RUP than the low fat DGS, which was 89.7% digestible RUP.

Research on feeding expeller soybean meal to growing or finishing cattle is extremely limited. A feeding trial conducted by Anderson et al. (2015) compared a 50:50 blend of expeller and solvent soybean meal with low fat dried DGS and high fat dried DGS as protein sources when fed to growing Holstein heifers. The heifers were fed individually using Calan Feed Access Doors, and diets contained 39.79% grass hay, 24.86% corn silage, 1.54% vitamins and minerals, and different proportions of protein supplement and ground corn. Diets were formulated to provide 16.3% CP, 9.8% RDP, and 6.5% RUP as a percent of DM. There were no differences between sources of protein for final BW, ADG, DMI, or feed efficiency.

Walker et al. (2006) compared the effects of supplementing urea, solvent soybean meal, and expeller soybean meal to 475 kg finishing heifers. The study was 28 d long and heifers were individually fed diets that contained 13.7% CP and either 0 $mg \cdot animal^{-1} \cdot d^{-1}$ or 200 $mg \cdot animal^{-1} \cdot d^{-1}$ of the β-adrenergic agent ractopamine-HCl. An interaction was

observed between protein source and ractopamine-HCl for final BW and live ADG. Heifers given ractopamine-HCl had no response to protein source in final BW or ADG. Heifers not fed ractopamine-HCL had the greatest final BW and ADG when fed expeller soybean meal and lowest final BW and ADG when fed urea, with heifers fed solvent soybean meal having intermediate final BW and ADG. Protein source had no effect on DMI, feed efficiency, or hot carcass weight (HCW). These data imply that even with increased muscle deposition, finishing cattle do not require supplemental RUP late in the finishing period.

The composition of digestible amino acids delivered to the small intestine by expeller soybean meal appears to be similar to that of DGS, and expeller soybean meal appears to have greater RUP digestibility when compared to dried DGS. These data indicate that expeller soybean meal may be an excellent protein feed resource for growing cattle when DGS is not available, even though data from applied research is limited. More research to examine the effect of expeller soybean meal on the performance of growing or finishing cattle is necessary to support or contradict conclusions made from the nutrient digestibility research.

Steroidal Hormones and the use of Hormonal Implants in Cattle

Steroidal hormones like estrogen, progesterone, testosterone, and synthetic analogues of those compounds have been approved for use in beef production since the 1950s and can be used in suckling calves as well as grazing and finishing steers and heifers (Duckett and Andrae, 2001). Implants are inserted subcutaneously in the middle third of the back of the ear to prevent the implant site from entering the human food supply (Johnson and Beckett, 2014). Steroidal hormone implants have been proven to

increase ADG by 16% to 20% and feed efficiency by 9% to 14%, resulting in a significant increase in returns per animal compared to non-implanted cattle (Duckett and Pratt, 2014). Because of this improvement in performance, over 91% of steers and 94% of heifers entering the feedlot receive at least one implant according to a survey of feedlots in 12 states conducted by the USDA National Animal Health Monitoring System (2013). Furthermore, that survey found that 95.8% of heifers entering the feedlot under 318 kg received two implants, while about half of heifers weighing 318 kg or more when entering the feedlot received two implants. In addition, of steers weighing less than 318 kg when entering the feedlot 62.7% received two implants and 17.1% received three or more implants. Only 22% of steers weighing 318 kg or more received two implants. The use of multiple implants is due to the length of time cattle are on fee and the length of time the implant is actively releasing hormone and creating a response in performance, called the payout period. Many of the commonly used implants on the market today have a payout period 120 d or less; however, the majority of cattle on feed stay in the feedlot for 160 d or more (Samuelson et al., 2016; Waggoner, 2018).

Mode of Action

Steroidal hormones act through the endocrine and paracrine systems to regulate growth and protein metabolism (Meyer, 2001). Hormones bind to cytosolic receptors and promote gene expression and translation of growth promoting hormones such as growth hormone and insulin-like growth factor-1 (IGF1) (Bryant et al., 2010). Steroidal hormones are naturally occurring in all animals but are also administered to animals in growth promoting implants (Johnson and Beckett, 2014). Muscle hypertrophy and protein synthesis can be observed from the action of steroidal hormones through the activation of

quiescent satellite cells and the action of growth factors like IGF1 to promote cell growth and proliferation (Johnson and Chung, 2007).

It is well-known that androgens such as testosterone have an anabolic effect on muscle tissue. Increased androgen levels increase expression of androgen receptors in several muscle cell types and stimulate myogenic differentiation and satellite cell activation and proliferation which results in muscle protein deposition (O'Connell and Wu, 2014). Androgens also inhibit the ability of some fat cells to store lipids by blocking some cell signals that control adipogenesis (Singh et al., 2006). Trenbolone acetate (TBA) is a common androgen included in growth promoting implants. Meyer (2001) determined that while the exact mode of action is not precisely understood, TBA acts like other androgens and has a strong affinity for the androgen receptor, progestin receptor, and glucocorticoid receptor. There is also evidence that TBA suppresses amino acid catabolism by acting as an anti-glucocorticoid through binding to the glucocorticoid receptor (Meyer, 2001). Trenbolone acetate also promotes proliferation of satellite cells, increasing muscle protein deposition (Johnson and Beckett, 2014).

Estrogen and analogs such as estradiol-17β (E) and estradiol benzoate (EB) have greater anabolic effects than androgens in cattle, and the effects of E increase as dosage increases (Meyer, 2001). Similar to androgens, an increase in E increases the number of estrogen receptors on skeletal muscle cells and consequently increases muscle anabolism (Meyer, 2001). However, Meyer (2001) found E to have significant indirect action on the hypothalamus resulting in release of growth hormone releasing hormone or E acts directly on the pituitary gland resulting in release of growth hormone. The increase in growth hormone increases growth hormone receptor numbers in the liver and results in

an increase in IGF1 into the blood stream. The increase in IGF1 levels promotes hypertrophy of muscle fibers through stimulating protein accretion and proliferation of new cells through the stimulation of inactive satellite cells (Johnson and Chung, 2007; Kamanga-Sollo et al., 2008; Johnson and Beckett, 2014).

Trenbolone acetate and E appear to work together in synergy, with cattle implanted with a combination implant containing both TBA and E showing an increase in performance compared to cattle implanted with either TBA or E (Pampusch et al., 2008; Johnson and Beckett, 2014). The use of implants with a combination of TBA and E results in an increase in cell proliferation rate *in vitro* (Dayton and Wright, 2008) and an increase in IGF1 in longissimus muscle (Johnson and Chung, 2007), supporting muscle hypertrophy.

Live Performance Responses to Implants

In a review of over 30 studies conducted since 1997, Duckett and Pratt (2014) found that implanting steers with either an estrogenic or combination implant resulted in an increase in ADG of 16% to 20% and feed efficiency of 9% to 14% compared to a non-implanted control. Duckett and Pratt (2014) also evaluated the effect of implanting on net returns and found that the use of a single combination implant resulted in an increase in returns of \$163 animal^{-1} over non-implanted cattle, with two combination implants increasing net returns by \$218 animal^{-1} compared to non-implanted cattle. The increase in returns is attributed to the increase in ADG and feed efficiency compared to non-implanted cattle.

Guiroy et al., (2002) summarized 13 trials that examined different implant strategies including non-implanted controls, single implants, and combinations of

multiple implants in both steers and heifers and concluded that implanting improved ADG and feed efficiency compared to non-implanted controls for both steers and heifers. The summary also concluded that the use of anabolic implants results in an increase of mature body size in steers when compared to non-implanted steers. Bryant et al. (2010) found that implanting steers with Revalor-IS followed by Revalor-S had a 10% increase in final BW, 19% increase in ADG, and 12% improvement in feed efficiency compared to non-implanted steers while heifers implanted with Revalor-200 increased their final BW by 4.4% and had a 14% increase in ADG compared to non-implanted heifers.

A consistent improvement in ADG and feed efficiency has been observed with the use of hormonal implants. Furthermore, there is evidence for an increase in mature body size related to anabolic implants. This improvement in performance can result in an increase in sale weight, increasing profitability.

Carcass Quality Responses to Implants

Bryant et al. (2010) found that implanting steers twice resulted in an increase in HCW of 11% compared to non-implanted steers. Montgomery et al., (2001) found that heifers receiving either an androgen or combination implant had increased HCW and LM area compared to non-implanted heifers or those that received an estrogenic implant, and that multiple implants resulted in an increase in HCW and LM area.

Duckett and Pratt (2014) found that the use of a combination implant or the use of multiple implants in the feeding period resulted in an increase in hot carcass weight (HCW) of between 6% and 7.5% compared to non-implanted cattle. Skeletal maturity increased with the use of anabolic implants, with skeletal maturity increasing by 20% to 24% in steers implanted with an estrogenic implant. A decrease in marbling scores of 3%

was observed with the use of estrogenic implants, while the use of combination implants resulted in a 7.5% to 11% reduction in marbling score compared to non-implanted cattle. The authors found that the decrease in marbling score was inversely proportionate to an increase in longissimus muscle (LM) area of between 5.8% and 9% observed in implanted cattle. The authors suggested the increase in LM area due to implant strategy resulted in a dilution effect that reduced marbling score when cattle are fed for similar time periods. No change in 12^{th} rib fat thickness due to implant strategy was observed.

Increases in implant potency have been shown to affect carcass quality, indicating that the performance response to implanting is dose dependent. Hilscher et al. (2016) and Parr et al. (2011) reported an increase in dressing percentage (DP) and LM area in response to increasing TBA and E provided by implanting strategy, while marbling score and calculated yield grade (YG) decreased with increasing implant potency. Samber et al. (1996) found that increasing implant potency resulted in a decrease in 12^{th} rib fat depth while Parr et al. (2011) observed a decrease in percentage of carcasses grading Choice and an increase in percentage of carcasses grading Select with increasing potency of the implant strategy. However, the above studies compared implant strategies between cattle fed the same numbers of days.

Nichols et al., (2002) found that carcass composition was similar when comparing implanted and non-implanted cattle harvested at a similar fat endpoint. The percent of the carcass that was protein, fat, and bone was similar in implanted and non-implanted cattle, but implanted cattle had an advantage in HCW and BW. Implants may modify nutrient uptake and delay or shift the growth curve, altering the rate of protein and fat deposition. This is supported by the observed increase in mature body size mentioned above, and

indicates that implanted cattle should be fed longer to allow more time for fat deposition resulting in similar marbling scores when comparing implanted and non-implanted cattle fed to the same fat endpoint.

Payout Period of Hormonal Implants

Hormonal implants used today are most commonly compressed pellets that contain the active ingredient and lactose, cholesterol, or some type of polyethylene glycol polymer as a carrier (Cady et al., 2002). Using lactose or cholesterol as the carrier allows for the pellets to degrade over time. Degradation rate depends on the type of carrier and the amount of pressure used in the manufacturing process (Jennings, 2012). Pellets created with lactose as a carrier are generally hard but easily absorbed and are typically degraded over a 60 to 80 d period while cholesterol-based pellets dissolve over a much longer period (Bartle et al., 1992). Release rate is usually targeted at between 0.75mg/d to 1.2 mg/d to achieve the desired performance response (Cady et al., 2002).

The release of active ingredient in implants generally peaks 1 to 3 d after implantation, after which a decline in concentration following first-order kinetics is observed until measurable response in the animal can no longer be observed (Brandt, 1997; Preston, 1999). Release rate of the active ingredient and ultimately the payout period of the implant is influenced by pressure used to form the compressed pellet, with an increase in pressure resulting in an increase in the length of the payout period (Preston, 1999). Preston (1999) found that performance response to implanting with cholesterol pellets was sustained to 84 d but not 126 d and that implants coated with a polymer or osmotic membrane to regulate the release of active ingredient effectively increased payout period.

Single and Multiple Implant Strategies

The use of a reimplant strategy to supply additional hormone as an initial implant nears the end of its payout period not only allows for continuous supply of hormone but often increases the total dose of active ingredient supplied. However, there are implants available that have some type of polymer or osmotic coating that effectively extend the payout period (Preston, 1999).

Utilizing a single long-lasting implant as opposed to a reimplant strategy may be appealing to some producers because cattle do not need to be processed again after the initial implant. While the use of good management and handling practices can limit production losses, handling and processing of cattle can result in stress and reduced performance (Grandin, 1984; Petherick et al., 2009). Implants such as Revalor-XS (200 mg TBA, 40 mg E; Merck Animal Health) or Revalor-XH (200 mg TBA, 20 mg E; Merck Animal Health) are designed to release active ingredient over a 200-d period and supply similar amounts of active ingredient to popular reimplant strategies such as implanting with Revalor-IS (80 mg TBA, 16 mg E; Merck Animal Health) followed by Revalor-S (120 mg TBA, 24 mg E; Merck Animal Health). Synovex ONE Feedlot (200 mg TBA, 28 mg EB; Zoetis Inc.) is designed to be a slow release version of Synovex Plus (200 mg TBA, 28 mg EB; Zoetis Inc.) with a 200-d payout period. Compudose (25.7 mg E, Elanco) and Synovex ONE Grass (150 mg TBA, 21 mg EB) are both marketed for grazing animals with a 200-d payout period. Encore (43.9 mg E, Elanco) is currently the longest lasting implant available with a 400-d payout period and is approved for use in suckling, grazing, and feedlot cattle.

Nichols et al. (2014) compared the performance of steers implanted with Revalor-XS on d 1 to those implanted with Revalor-IS on d 1 followed by Revalor-S on d 80. The two strategies provided equivalent total amount of active ingredients and cattle were fed a mean of 157 d. No differences were observed between implant strategy in DMI, final BW, ADG, feed efficiency, marbling score, 12th-rib fat depth, LM area, or YG. However, steers implanted with Revalor-XS had a greater proportion of carcasses grading in low Choice and a lower proportion of carcasses grading Select compared to those implanted with Revalor-IS followed by Revalor-S.

Prouty and Larson (2010) compared the performance of steers implanted with Revalor-XS on d 0(200 mg TBA, 40 mg E), Synovex Choice on d 0 and Synovex choice on d 79 (200 mg total TBA, 28 total mg EB), or Synovex Choice on d 0 followed by Synovex Plus on d 70 (300 total mg TBA, 42 total mg EB). Steers were fed for 160 d and the implant strategies provided different amounts of total active ingredient. Steers implanted with Synovex Choice followed by Synovex Plus had significantly greater feed efficiency and tended to have greater final BW and ADG compared to those implanted with Revalor-XS or Synovex Choice followed by Synovex Choice. Dressing percentage and YG were not different between implant strategies, but steers implanted with Synovex Choice followed by Synovex Plus had significantly greater HCW than those implanted with Revalor-XS or Synovex Choice followed by Synovex Choice. Steers implanted with Synovex Choice followed by Synovex Choice had a greater proportion of carcasses grading Prime and Choice compared to those implanted with Synovex Choice followed by Synovex Plus or Revalor-XS.

McLaughlin et al. (2013) conducted a study comparing implanting steers with Synovex ONE Feedlot, Synovex Plus, or Revalor-XS 161 d before harvest. A second study comparing the same implants given to steers 200 d before harvest was also conducted. In both studies, no differences were observed between implant strategy in live performance or carcass characteristics.

These data suggest that implant strategy, particularly the use of a single slow-release implant compared to a reimplant strategy, largely does not affect animal performance as long as implants providing similar total amounts of active ingredient are used. Because cattle performance response to implants is dose dependent, cattle receiving greater amount of active ingredient tend to have improved performance compared to those that receive less active ingredient. Furthermore, it is important to compare implant strategies using cattle fed to an equal fatness endpoint rather than equal days on feed, as greater doses of active ingredient can delay the growth curve and effectively extend the finishing period.

A Comparison of Feeding Bulls and Steers for Beef Production

The use of hormonal implants in beef production is prohibited in some countries and in some programs like non-hormone treated beef or organic programs. As previously discussed in this review, the use of hormonal implants improves ADG and feed efficiency when implanted cattle are compared to non-implanted cattle. Therefore, an opportunity to increase production efficiency is lost when implants are prohibited. Historically, feeding bulls has been and remains a common practice outside of the United States. Leaving bulls intact rather than castrating them may in part compensate for the loss of implant technologies.

Live Performance

Marti et al. (2013) compared the effect of castration and animal age at harvest on performance and carcass characteristics of Holstein calves. Male Holstein calves were randomly assigned to remain as bulls or be castrated at 3 or 8 mo of age, and also were assigned to be harvested at 10, 12, or 14 mo of age. Steers were not implanted. No interactions were observed between castration age and slaughter age for performance data. Bulls had a final BW 6.5% greater than those castrated at 3 mo and 4.0% greater than those castrated at 8 mo. Bulls also had greater ADG and feed efficiency than castrated animals, and castration age had no effect on final BW, ADG, or feed efficiency. Dry matter intake was not affected by castration.

Do Prado et al. (2015) compared the performance and carcass composition of Holstein bulls and steers fed three levels of concentrate. Steers were not implanted. Cattle were an average of 19 mo of age upon study initiation and were fed 116 d. No interaction between castration status and concentrate level were observed. No differences between castration status were observed for DMI. Bulls had 8.8% greater initial BW and 11.4% greater final BW than steers. Bulls had 17.5% greater ADG and 13.0% greater feed efficiency compared to steers.

A comparison of the effect of Burdizzo pre-pubertal castration on performance, carcass characteristics, and meat quality of Holstein bulls fed a high concentrate diet were evaluated by Mach et al. (2009). Bulls 8 mo of age were randomly assigned to no castration or Burdizzo castration, a method of bloodless castration that crushes the spermatic cord and cuts off blood supply to the testes, resulting in testicular atrophy. Steers were not implanted. Cattle were harvested after 121 d. Bulls were found to have

3.9% greater final BW and 6.7% greater ADG than steers, but no difference in feed efficiency was observed.

Jones et al. (1984) compared the performance and carcass composition of beef breed bulls and steers when harvested at similar level of fatness. Steers were not implanted. Cattle were fed a common diet consisting of corn silage and high moisture corn and were harvested at 6 mm of backfat, measured with ultrasound between the 11^{th} and 12^{th} rib. Bulls spent more days in the feedlot, taking longer to reach the 12^{th}-rib fat endpoint than steers, and finished with a final BW 8.0% greater than steers. When harvested at the same 12^{th}-rib fat depth endpoint, bulls had 8.3% greater ADG but similar feed efficiency when compared to steers.

Carcass Quality

When comparing the effect of castration and animal age at harvest, Marti et al. (2013) found that Holstein bulls were had 7.4% greater HCW than animals castrated at 3 mo and 5.2% greater HCW than those castrated at 8 mo. Bulls had greater DP than steers. Steers had similar HCW but those castrated at 3 mo of age had greater DP than those castrated at 8 mo of age. When comparing the composition of the ninth-tenth-eleventh rib cut, no difference in weight of the cut was observed but bulls were found to have a lower percentage of separable fat and a greater proportion of separable lean and bone compared to castrated animals, with steers castrated at 3 mo of age having a higher percent separable fat, lower percent separable lean, and similar percent separable bone compared to steers castrated at 8 mo of age.

Steen and Kilpatrick (1995) conducted a study comparing carcass composition of Friesian and crossbred Friesian bulls, steers, and heifers fed either *ad libitum* or at 80% of

ad libitum intake. No interactions between sex and nutritional status were observed. Cattle were 12 to 13 mo of age upon trial initiation. Bulls were harvested at 560, 610, and 660 kg final BW while steers were harvested at 510, 560, and 610 kg final BW and heifers were harvested at 460, 510, and 560 kg final BW. However, linear effect of slaughter weight was removed from analysis. Bulls had 2.8% greater HCW than steers and heifers. Bulls had greater LM area, lower fat depth, and lower marbling score than steers or heifers. Steers and heifers were not different in HCW, however heifers had greater fat depth, LM area, and marbling score than steers. Bulls were estimated to have a carcass composition that had a higher percent lean tissue and bone and lower percent fat than steers and heifers. Heifers had a carcass composition that had a lower percent lean tissue and bone with greater percent fat than steers.

Do Prado et al. (2015) compared the carcass composition of Holstein bulls and steers fed three levels of concentrate. No interaction between castration status and concentrate level were observed. Bulls had 19.6% greater HCW than steers. Bulls had greater DP and a greater percent of edible carcass than steers. Bulls were found to have a greater percent of HCW composed of muscle tissue and a lower percent of HCW composed of fat than steers, with no effect of castration on percent of HCW as bone.

When comparing the effect of Burdizzo pre-pubertal castration on carcass characteristics and meat quality of Holstein bulls, Mach et al. (2009) found bulls to have 6.0% greater HCW compared to castrated animals, while steers had greater carcass fatness. Warner-Bratzler shear force of muscle tissue was lower for steers than for bulls, indicating that castrated animals had more tender meat than bulls. However, 23% of

cattle assigned to Burdizzo castration did not exhibit complete testicular atrophy, suggesting that the castration was incomplete.

When Jones et al. (1984) compared carcass composition of beef breed bulls and steers harvested at a 12th-rib fat depth of 6 mm, bulls were found to have 10.6% greater HCW and a greater proportion of HCW as muscle, less bone, and similar fat than steers. Across the whole carcass, there were no differences in muscle size. However, bulls had enlarged muscle size in the chuck when compared to steers. When feed efficiency was measured as g muscle per kg DMI, bulls converted feed to muscle more efficiently than did steers.

These studies indicate that leaving bulls intact can result in an increase in performance compared to non-implanted steers and heifers, particularly in ADG and feed efficiency. Bulls also appear to have greater HCW and LM area compared to steers and heifers. However, significant changes in carcass composition have been observed. Bulls had lower marbling scores and reduced 12th-rib fat depth when compared to steers or heifers fed the same number of days. Bulls have reduced proportions of fat and increased proportions of lean in the carcass and an increase in total edible yield compared to steers or heifers. There may also be increased percent bone in the carcass of a bull compared to that of a heifer or steer.

The improvement in performance, increase in HCW, and change in carcass composition that is observed when bulls are left intact is likely due to the anabolic properties of the androgens released by the testes, testosterone in particular. As discussed previously, androgens such as testosterone encourage muscle hypertrophy through activation and proliferation of satellite cells which increases muscle protein deposition

(O'Connell and Wu, 2014). Furthermore, the tendency of androgens to inhibit adipogenesis (Singh et al., 2006) is likely the reason why bulls had reduced proportion of carcass as fat or took more days to achieve a predetermined fat endpoint when compared to steers. Because the change in carcass characteristics seen by leaving bulls intact would commonly be considered a reduction in meat quality in the United States, feeding bulls may not become popular. However, if quantity of lean meat is preferred over quality of the product, for example if hamburger or processed meats are a production goal rather than cut steaks, then leaving bulls intact may be an effective method for improving live and carcass gains when the use of hormonal implants are prohibited.

Conclusions

There is no difference between organic and conventional crops in macronutrient content and digestibility. While there is variability between studies, the variability may be explained by the development of new technologies and changing management practices in conventional cropping systems. When organic and conventional crops are grown at the same facility and harvested at the same maturity, no difference in nutrient content or digestibility in ruminants can be observed.

While distillers grains have been a valuable feed resource for beef production, in production systems where distillers grains are difficult to source, protein feeds such as field peas, fish meal, or expeller soybean meal can be utilized with success. While field peas may not be high in rumen undegradable protein content, they can be fed to grazing and finishing cattle as an adequate substitute for distillers grains and fit well into a crop rotation system. When considering an organic production system, field peas may be a valuable source of rumen degradable protein. Fish meal and expeller soybean meal are

both a valuable source of highly digestible rumen undegradable protein, and both provide the duodenum with large proportions of essential amino acids that may complement corn-based diets. Fish meal is variable in rumen undegradable protein content because fish species and variation in processing significantly affects the rumen degradability of the protein.

Hormonal implants are valuable tools that improve live performance, increase hot carcass weight, and increase muscle mass. Because the anabolic action of the active ingredients shifts or delays the growth curve and is highly dose dependent, comparisons between groups of cattle should be made at a common fat endpoint, particularly when comparing implanting strategies of different potency or when comparing implanted and non-implanted cattle. In systems where the use of implants is prohibited, leaving bulls intact results in improved live performance and an increase in hot carcass weight and muscle mass similar to implants. This is due to the anabolic action of hormones released by the testes. However, bulls typically have reduced marbling scores and tougher meat even when compared to steers harvested at a common fat endpoint. Feeding bulls may be an effective strategy to improve performance if the beef production goal does not include producing meat of a high quality grade.

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Tables

Table 1. Yield and nutrient content of wheat grown under two different organic and conventional production systems

Item	CRP[1]	BIODYN	BIOORG	CONFYM	CONMIN	ANOVA	LSD	*n*
Yield, DM, t·ha^{-1}	1	3.45	3.57	3.72	3.61	NS	0.46	24
	2	3.77	4.06	4.99	5.15	***	0.82	24
	3	4.10	4.11	4.62	4.77	***	0.43	24
Yield, CP, kg·ha^{-1}	1	498	512	560	495	**	57.1	24
	2	460	485	679	657	***	82.0	24
	3	535	520	649	686	***	66.9	24
N, g·kg^{-1}	1	25.4	25.2	26.7	24.4	*	1.81	24
	2	22.5	21.8	24.4	23.1	NS	3.22	24
	3	22.9	22.2	24.6	25.4	***	1.91	24
CP, g·kg^{-1}	1	144.9	143.7	152.2	138.9	*	10.31	24
	2	128.3	124.0	138.9	131.4	NS	18.33	24
	3	130.7	126.4	140.4	145.1	***	10.89	24
Ash, g·kg^{-1}	1	19.6	19.9	20.2	21.3	NS	2.10	24
	2	18.5	18.5	19.3	17.6	NS	1.85	24
	3	17.4	16.7	17.2	16.7	NS	1.27	24
P, g·kg^{-1}	1	4.47	4.30	4.50	4.28	NS	0.32	24
	2	4.15	4.08	4.17	4.03	NS	0.27	24
	3	3.86	3.73	3.79	3.65	NS	0.29	24
K, g·kg^{-1}	1	4.59	4.46	4.47	4.65	NS	0.29	24
	2	4.96	4.80	4.75	4.78	NS	0.26	24
	3	4.52	4.53	4.55	4.38	NS	0.49	24
Ca, g·kg^{-1}	1	0.51	0.50	0.50	0.52	NS	0.05	24
	2	0.47	0.45	0.43	0.44	NS	0.06	24
	3	0.44	0.44	0.46	0.48	NS	0.10	24
Mg, g·kg^{-1}	1	1.32	1.28	1.24	1.30	NS	0.16	24
	2	1.26	1.26	1.23	1.19	NS	0.14	24
	3	1.28	1.24	1.18	1.19	*	0.10	24
Mn, mg·kg^{-1}	1	34.1	35.3	39.0	35.9	*	3.84	24
	2	33.9	37.4	42.3	42.5	***	3.89	24
Zn, mg·kg^{-1}	1	34.6	36.9	38.2	35.9	NS	5.92	24
	2	30.5	33.7	33.3	32.2	NS	4.84	24
Cu, mg·kg^{-1}	1	4.38	4.71	4.40	5.49	**	0.94	24
	2	6.63	6.52	5.73	6.45	NS	0.93	24
Mo, mg·kg^{-1}	1	0.27	0.26	0.27	0.25	NS	0.05	24
Co, mg·kg^{-1}	1	0.017	0.018	0.020	0.019	NS	0.01	24

Adapted from Mäder et al., 2007

[1]CRP = crop rotation period, BIODYN = organic production system using slurry and manure fertilizer, BIOORG = organic production system using only slurry fertilizer, CONFYM = conventional production system using mineral fertilizers and manure, CONMIN = conventional production system using only mineral fertilizer

Table 2. Comparison of nutrient content of organic and conventionally grown crops

Nutrient	Increased[1]	Same	Decreased
Protein Quality[2]	3	0	0
Nitrate	5	10	25
Vitamin C	21	12	3
β-carotene	5	5	3
B vitamins	2	12	2
Ca	21	20	6
Mg	17	24	4
Fe	5	14	6
Zn	4	9	3

Adapted from Worthington, 1998

[1]No. of studies showing increased, similar, or decreased nutrient content of organic crops relative to conventional crops

[2]Protein Quality is defined as proportion of total amino acids that are essential amino acids

Chapter II: Evaluation and comparison of in situ measures of rumen undegradable protein and supplementation of potential organic protein sources on performance of Holstein steers fed in an organic production system

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Abstract

Two experiments were conducted to compare the rumen undegradable protein content (RUP), RUP digestibility, and digestible RUP as a percent of dry matter (DM) of conventional and organic feeds using an in situ mobile bag procedure. In experiment 1, conventional and organic field peas, fish meal, and dehydrated alfalfa pellets (DEHY), conventional solvent-extracted soybean meal and organic expeller soybean meal were compared. In experiment 2, conventional and organic DEHY and fish meal, conventional solvent and expeller soybean meals, and organic expeller soybean meal were evaluated. Significant ($P < 0.01$) differences were detected between feed samples in both studies for all variables measured. Variation existed between sample types but the data do not suggest that organic and conventional feeds are different when processed with the same methods. A performance experiment was conducted utilizing 58 individually fed Holstein steers weighing 213 kg comparing the effect of RUP source in a simulated organic production system. Dietary treatments were: no supplemental protein (NONE), field peas (FP), field peas and fish meal (FPFM), soybean meal (SBM), or SoyPass (SP). Except for NONE, diets were formulated to balance for metabolizable protein and contained varying amounts of protein source, dry rolled corn, and 30% alfalfa haylage with 5% supplement. Cattle fed FP or FPFM had significantly lower DM intake than those fed SP, with steers fed NONE and SBM intermediate and steers fed FPFM were more efficient than those fed NONE, with the other protein sources intermediate ($P \leq 0.06$). These data indicate that conventional values of protein degradability may be used to formulate organic diets, and that similar performance can be achieved with a variety of different RUP sources for young, lightweight growing Holsteins.

Key Words: rumen undegradable protein, Holstein, organic beef, protein supplementation

Introduction

The rumen degradability of dietary protein is particularly important when considering young growing cattle, because metabolizable protein requirements are greatest during that stage of production to support tissue growth (NASEM, 2016). Insufficient supply of MP through either reduced microbial protein synthesis or inadequate intake of rumen undegradable protein (RUP) reduces weight gain in growing cattle (Lammers and Heinrichs, 2000).

In order to formulate diets, an accurate estimate of the RUP content and digestibility of the feeds is necessary. An abundance of data are available on conventional feeds, but the data are limiting on feeds produced in an organic production system. No data are available comparing protein digestibility or rumen degradability of conventional and organic protein feeds in cattle. Some research in fish suggests a difference in nutrient bioavailability between conventional and organic feeds (Ballester-Molto et al., 2017) while lambs and Tharparkar (*bos indicus*) heifers fed organic or conventional feeds had similar nutrient intake and digestibility (Singh et al., 2010; Singh et al., 2012). These data suggest that further research is necessary.

Distillers grains (DGS) and other ethanol coproducts are commonly utilized in beef cattle diets because they are a competitively priced protein source (Bremer et al., 2011). Distillers grains are also an excellent source of RUP, with an RUP content of approximately 56.3% to 63.0% of CP (Kelzer et al., 2010; Castillo-Lopez et al., 2013). However, while organic corn milling exists, availability of organic DGS is limited.

Alternative protein sources to DGS must be examined when considering an organic beef production system.

The objectives of experiments 1 and 2 were to establish RUP content and digestibility of conventional and organic feeds and any differences between feeds. The objective of experiment 3 was to examine the use of field peas, fish meal, and soybean meal as sources of RUP when fed to lightweight Holstein steers in a simulated organic beef production system.

Materials and Methods

All facilities and management procedures described in the following experiments were approved by the University of Nebraska-Lincoln Institutional Animal Care and Use Committee.

Experiment 1 and 2 – In Situ Measures of RUP

Feed samples were obtained from multiple sources. In experiment 1, conventional and organic field peas, fish meal, and dehydrated alfalfa pellets (DEHY) were compared. Conventional solvent extracted soybean meal and organic expeller soybean meal were also compared. Conventional dry rolled corn, dried distillers grains (DDGS), high protein DDGS, roasted field peas, SoyPass, raw whole soybeans, roasted whole soybeans, alfalfa haylage, and heat damaged DEHY were examined. In experiment 2, samples were obtained from multiple different sources. Conventional and organic DEHY and fish meal were compared along with conventional solvent extracted and expeller soybean meals and organic expeller soybean meal. Individual samples of conventional dry rolled corn, field peas, and alfalfa haylage were also examined along with organic flaxseed meal. The

roasted conventional field peas and whole soybeans were roasted at 80% DM in covered aluminum pans in a forced air oven set to 150°C for 30 min.

The *in situ* procedure used in experiments 1 and 2 was modified from Vanzant et al. (1998). Large and small in situ Dacron bags (ANKOM Technology, Macedon, NY; 10 cm x 20 cm and 5 cm x 10 cm, respectively; 50 µm pore size) were labeled and weighed. Samples that were a meal in texture were not ground, while the dehydrated alfalfa pellets, whole soybeans, field peas, and dry rolled corn were ground to pass through a 6 mm screen. The alfalfa haylage samples were freeze dried and ground to pass through a 2 mm screen. After grinding, 5.00 g and 1.25 g sample were added to the large and small Dacron bags, respectively, with 20 replicate bags of each size per sample: 16 used for rumen incubations and 4 used for washout analysis. Bags of both sizes were ruminally incubated for 16 h in 2 ruminally fistulated steers (experiment 1) or 2 ruminally and duodenally fistulated heifers (experiment 2) fed a diet containing 30% alfalfa haylage, 65% dry rolled corn, and 5% supplement on a DM basis. The supplement contained minerals, vitamins A-D-E, and a fine ground corn carrier. Bags were evenly divided between animals and rumen incubation was replicated twice using 8 bags of each size per day.

After rumen incubation, bags were removed and washed in a machine using 5 cycles with a 1-min agitation and 2-min spin (Whittet et al., 2002). The 4 bags of each size used for washout analysis were washed with the incubated bags and were evenly divided between the 2 washing events. Small bags were then taken through simulated abomasal digestion consisting of incubating bags in a pepsin and HCl solution (1.5 g pepsin per L and 0.01 N HCl) at 37°C for 3 h. After simulated abomasal digestion, all

small bags were frozen at -4^oC and thawed before insertion in the duodenal cannula. Bags were inserted every 5 minutes (17 bags per day in Exp. 1, 20 bags per day Exp. 2) and were retrieved from fecal matter an average of 20 h and 17 h after insertion for experiment 1 and experiment 2, respectively. Bags retrieved from feces were rinsed by hand with distilled water.

After washing, all bags were dried for 24 h in a 100^oC oven and weighed to determine DM disappearance. Haylage and dehydrated alfalfa bags were refluxed in 100^oC neutral detergent solution (NDS; Midland Scientific, Davenport, IA) for 1 h to remove microbial contamination from the residue (Mass et al., 1999; Haugen et al., 2006). After refluxing in NDS, bags were then dried in a 100^oC forced-air oven for 24 h and weighed. All bags were weighed again after air equilibration and residue DM content was determined by calculating the difference in weight of the residue before and after air equilibration. Residues from large bags were composited by animal within day while residues from small bags were composited by animal (experiment 1) or animal within day (experiment 2). Composited residues and the original samples were analyzed for N content using the combustion method and a N analyzer (Flash Smart, CE Elantech, Inc., Lakewood, NJ) to calculate CP content. The following equations were then used to determine RUP as a % of CP, RUP digestibility, digestible RUP as a % of DM, and CP washout:

Eqn 1: RUP, % of CP = 100 × [(residue, g of DM × CP, % of DM)/(original sample, g of DM × CP, % of DM)]

Eqn 2: RUP digestibility, % of RUP = 100 × [(CP after rumen incubation, mg – CP after duodenal incubation, mg)/(CP after rumen incubation, mg)]

Eqn 3: Digestible RUP, % of DM = 100 × (CP, % of DM × RUP, % of CP × RUP digestibility, % of RUP)

Eqn 4: CP Washout, % = 100 × [1 – (residue remaining after washing, g of DM × CP, % of DM)/ (original sample, g of DM × CP, % of DM)]

Data were analyzed using the Glimmix procedure of SAS (9.3, SAS Institute Inc., Cary, NC) with the Tukey adjustment applied. The experimental unit was residues composited by animal within day for RUP content in experiment 1 and all variables in experiment 2, while the experimental unit for RUP digestibility for experiment 1 was residues composited by animal. Animal was considered a random effect and day was considered a fixed effect. For washout analysis, bag size was considered a random effect and day was considered a fixed effect. The experimental unit was residues composited by bag size within day. Means of proportions were determined using the ILINK option and differences were significant at an α value less than or equal to 0.05.

Experiment 3 – Supplementing RUP to growing Holstein Calves in a Simulated Organic Production System

A 214-d growing study was conducted at the Eastern Nebraska Research Extension and Education Center (ENREEC) near Mead, NE using 60 Holstein steers (body weight [BW] = 213 kg ± 25 kg). All cattle were individually fed using the Calan gate system (American Calan, Northwood, NH). Before trial initiation, cattle were limit-fed a diet of 50% alfalfa and 50% Sweet Bran (Cargill Corn Milling, Blair, NE) at 2% of BW to reduce variation in gut fill (Watson et al., 2013). Steers were then weighed on 3 consecutive days in the morning before being fed and the average was calculated to determine initial BW (Stock et al., 1983). Steers were blocked by initial BW and assigned

randomly to 1 of 5 treatments designated by the protein source used in the experimental diets: no supplemental protein (NONE), field peas (FP; 23% CP; 42% RUP as % of CP), field peas and fish meal (FPFM; fish meal 70% CP; 60% RUP as % of CP), solvent extracted soybean meal (SBM; 52% CP; 30% RUP as % of CP), and SoyPass (SP; LignoTech USA, Rothschild, WI; 50% CP; 75% RUP as % of CP). Treatment diets were fed over 3 phases averaging 65 d in length, and all calves were moved to the NONE diet on d 195.The feeding phases were: Phase 1 from d 1 to d 62, Phase 2 from d 63 to d 132, Phase 3 from d 133 to d 194, and Phase 4 from d 195 to d 214. Two animals were removed from study after initiation; one was removed from the NONE group because it proved to be a cryptorchid bull and one was removed from the FPFM group due to chronic bloat that had to be treated with a trocar.

Experimental diets (Table 2) consisted of 30% alfalfa haylage (17.4% CP, 10% RUP as % of CP) and 5% supplement with protein source displacing dry rolled corn (8.8% CP, 60% RUP as % of CP). The supplement consisted of limestone, trace minerals, vitamins A-D-E, and a fine ground corn carrier in all diets except for the FPFM diet, which used fish meal as the carrier in phase 1 and then was blended with the regular supplement in phases 2 and 3. All diets except for NONE were balanced for MP on d 1 of each phase based on average initial BW of each phase. Average daily gain was assumed to be 1.0 $kg \cdot d^{-1}$ and predicted dry matter intake (DMI, NRC, 2000) and a microbial efficiency of 13% (Table 3).

All steers were vaccinated with the combination intranasal vaccine Inforce 3 (Zoetis, Parsippany, NJ) to protect against bovine rhinotracheitis (IBR), parainfluenza$_3$ (PI_3), and bovine respiratory syncytial virus (BRSV); One Shot BVD (Zoetis) to protect

against BVD and bovine pneumonia caused by *Mannheimia haemolytica* type A1; Ultrabac-7/Somubac (Zoetis) to protect agains *Clostridial* and *Haemophilus somnus* infections; and received doramectin (Dectomax, Zoetis) upon arrival. On d 132 all cattle were treated for lice with topical gamma-cyhalothrin (StandGuard, Elanco Animal Health, Greenfield, IN). Cattle were fed once daily at 0800 h and feed refusals were collected weekly, weighed, and a subsample was dried in a 60^{o}C forced-air oven for 48 h to calculate DM refusals and calculate accurate DMI for individual animals. Interim weights were collected at 0700 h on days 62 and 63, 132 and 133, and 194 and 195; interim weights were averaged and shrunk 4% to account for gut fill. After d 214, all steers were limit fed the NONE diet at approximately 1.8% of estimated individual BW for 4 days to reduce variation in gut fill. Weights were collected on 3 consecutive days and averaged to obtain a final BW. Interim weight and final BW were used to calculate ADG for each feeding phase and overall. Dry matter intake and ADG were used to calculate gain to feed ratios (G:F) for each feeding phase and overall.

Data were analyzed using the Glimmix procedure of SAS as a randomized complete block design with the Tukey adjustment applied. The experimental unit was individual steer and block was a fixed effect. Treatment averages were calculated using the LSMEANS option of SAS. Significance was determined at an α value of less than or equal to 0.10.

Results and Discussion

Experiment 1

Values for CP, RUP content as a percent of CP, RUP digestibility, digestible RUP as a percent of DM, and percent of CP that disappeared from the bag during the wash

cycle are presented in Table 4. Significant differences between feed samples were observed for all variables examined ($P < 0.01$). There was no effect of day and no interaction between sample and day for RUP content or washout as a percent of CP ($P \geq 0.08$). Not enough residue was available for analysis of day after duodenal incubation, so day and interaction of sample and day were removed from the model for RUP digestibility and digestible RUP content as a percent of DM.

No differences were observed for RUP content between ensiled alfalfa, organic DEHY, or conventional DEHY for RUP content, but all were significantly lower in RUP content than heat damaged DEHY at 10.5%, 15.0%, 16.6%, and 53.4% of CP, respectively. Significant differences were observed between all alfalfa samples for digestible RUP, where organic DEHY had the greatest proportion of digestible RUP at 70.5% of RUP followed by conventional DEHY at 44.2% of RUP, heat damaged DEHY at 17.7% of RUP, and finally alfalfa haylage at 9.5% of RUP. This influenced the differences observed in digestible RUP content where organic DEHY was greatest at 2.4% of DM, heat damaged DEHY was second at 1.9% of DM, and alfalfa haylage was lowest at 0.2% of DM, with conventional DEHY intermediate and not different from any other alfalfa source at 1.2% of DM. Alfalfa haylage had greatest proportion of CP washout at 58.3% of CP, while all other DEHY samples ranged from 25.2% to 36.8% of CP.

Forage maturity may have influenced these differences in RUP content and digestibility, because as forage maturity increases, digestibility of RUP tends to decrease linearly (Buckner et al., 2013). Forage digestibility can vary due to not only maturity but fertilization, soil type, and weather (Von Keyserlingk et al., 1996). Because forage

maturity at time of harvest was not known for these samples, more organic and conventional DEHY samples were examined in experiment 2 to examine the potential differences further. The differences in CP washout may be due to differences in soluble N content between ensiled forages and those that have not been ensiled. Forages that have undergone silage fermentation are subject to changes in the protein fraction of the feed as bacterial and plant enzyme activity results in proteolysis, resulting in releasing N from proteins (Tremblay et al, 2001).

Among the corn and corn co-products, high protein DDGS had the greatest RUP content with DDGS lowest in RUP content and dry rolled corn in between the two at 59.9%, 28.5%, and 38.1% of CP. High protein DDGS was also highest in RUP digestibility at 93.5% with DDGS second at 84.2% and dry rolled corn was lowest at 67.0%. High protein DDGS was therefore highest in digestible RUP as a percent of DM at 18.7% of DM while DDGS was second at 7.5% of DM and dry rolled corn was lowest at 2.1% of DM.

While the RUP content of 59.9% of CP estimated for high protein DDGS is reasonable given the RUP content of dried DGS is estimated to be 67.9% of CP by the NASEM (2016), the RUP content value of 28.5% of CP is much lower. Using an *in situ* procedure, Kelzer et al (2010) estimated the RUP content of DDGS to be 33.2% of CP, significantly lower than the RUP content of high protein DDGS at 55.2% of CP. Mjoun et al. (2010) found low fat DGS to have a higher RUP content than other DGS at 60.4% of CP, while DDGS and high protein DDGS had similar RUP content at 52.3% and 54.5% of CP and higher RUP content than modified wet DGS at 38.3% RUP as percent of CP after a 16 h rumen incubation period. Paz et al. (2014) conducted a similar *in situ*

study and found low fat DDGS to have an RUP content of 38.3% of CP. This variability in measured RUP content indicate that another look at the RUP content of DDGS and other DGS products may be valuable to producers that use DGS as a protein source.

Among the field peas, roasted field peas had the lowest RUP content and digestible RUP as a percent of DM at 25.9% of CP and 4.5% of DM, respectively, while organic field peas had the greatest RUP content and digestible RUP as a percent of DM at 41.0% of CP and 8.6% of DM, respectively and conventional field peas were intermediate with 33.6% RUP as percent of CP and 6.1% digestible RUP as a percent of DM.. No difference between field pea types were observed for digestible RUP. Heating of field peas in this study did not improve RUP content. This may be due to inadequate execution of the heating procedures. Gilbery et al. (2005) found no effect of heat treatment on field peas until they were roasted at 149^{o}C for 12 min, and Ljkjel et al. (2003) found RUP content of field peas was maximized when roasted at 150^{o}C for 30 min. However, Aguilera et al. (1992) found roasting at 64^{o}C for 30 min resulted in an increase in RUP content. While the roasted field peas in this experiment were roasted for 30 min at 150^{o}C, it is apparent that the method of roasting performed in this experiment did not result in an increase in RUP content.

Organic fish meal had significantly greater RUP content than conventional fish meal at 46.8% and 16.5% of CP respectively; however the conventional fish meal had significantly greater washout of CP than organic fish meal at 79.2% and 49.6% of CP respectively, which in this case may have influenced the measured RUP content. Because the RUP content of fish meal is heavily influenced by processing method and fish species

(Mehrez et al., 1980; Hussein and Jordan, 1991), a further look at RUP content of fish meals was examined more thoroughly in experiment 2.

Among the conventional whole soybeans, no differences were observed between raw or roasted whole soybeans for RUP content at 44.9% and 50.5% of CP respectively, RUP digestibility at 96.7% and 97.3% respectively, or digestible RUP as a percent of DM at 14.9% and 16.3% of DM respectively. This indicates inadequate heating in the roasting procedure, potentially due to either insufficient heating time or temperature. Contrary to these results, Hsu and Satter (1995) found that roasting whole soybeans increased RUP content when the beans were roasted using a drum roaster at temperatures of 123^{o}C or above regardless of roasting time using an *in situ* procedure with 16 h of rumen incubation. Furthermore, Stern et al. (1985) found that extrusion of whole soybeans at 149^{o}C resulted in an increase in RUP content compared to whole soybeans. Given that no increase in RUP was observed after roasting in experiment 1, it is likely that the roasting procedure utilized was inadequate to influence rumen degradability of the CP.

Among the soybean meals, SoyPass was ranked greatest in RUP content at 78.5% of CP and digestible RUP as a percent of DM at 33.9% of DM and was greater than any other sample examined. Conventional solvent-extracted soybean meal was lowest in RUP content and digestible RUP as a percent of DM at 27.3% of CP and 12.5% of DM respectively while organic expeller soybean meal was second highest in RUP content and digestibility at 60.0% of CP and 26.7% of DM, respectively. No differences were observed between any type of soybean meal for RUP digestibility and values were 98.9%, 98.5%, and 98.7% of RUP for SoyPass, conventional solvent-extracted soybean meal, and organic expeller soybean meal, respectively. Of all samples examined in this

study, organic expeller soybean meal was second only to SoyPass in RUP content and digestible RUP as a percent of DM.

The differences in RUP content between expeller and solvent soybean meals can be attributed to the expeller process, which utilizes heat and pressure to press oil from the soybeans (Erickson, 1995). The heat from processing results in an increase in RUP content compared to solvent soybean meal (Mjoun et al., 2010; Paz et al., 2014). Because the comparison of conventional solvent soybean meal and organic expeller soybean meal alone may be inadequate to compare organic and conventional soybean meals, further investigation was done in experiment 2 with conventional expeller processed soybean meal compared to conventional and organic soybean meal. These comparisons will allow for comparison of organic and conventional soybean meal that does not vary in processing method.

Experiment 2

Values for CP, RUP content as a percent of CP, RUP digestibility, digestible RUP as a percent of DM, and percent of CP that disappeared from the bag during the wash cycle are presented in Table 5. Significant differences between feed samples were observed for all variables examined ($P < 0.01$). There was no effect of day on RUP content, digestible RUP content as a percent of DM, or percent CP washout ($P \geq 0.09$) but there was an effect of day on RUP digestibility ($P < 0.01$). There was no interaction between sample and day for any variable examined ($P \geq 0.33$).

When comparing the fish meals, all three organic fish meals had greater RUP content than the four conventional fish meals. Of the fish meals, organic fish meal 2 was greatest in RUP content at 57.2% of CP and organic fish meal 3 was lowest in RUP

content at 47.6% of CP. Of the conventional fish meals, conventional fish meal 2 was lowest in RUP content at 19.5% of CP and conventional fish meal 3 and 4 had the greatest RUP content at 31.5% and 29.8% of CP, with conventional fish meal 1 intermediate 24.8% of CP. As with experiment 1, the RUP content of these fish meals may have been influenced by CP washout. For example, the fish meal with the lowest RUP content was conventional fish meal 1 at 19.5% of CP and also had the greatest washout of CP at 77.9% of CP. Furthermore, the fish meal with the greatest RUP content was organic fish meal 2 at 57.2% of CP and also had the least CP washout at 38.6% of CP.

A large amount of variation can be observed in the RUP content of fish meal in experiments 1 and 2 from 16.5% to 57% of CP. A review by Hussein and Jordan (1991) also found a high degree of variability in estimated RUP content with a range of between 30% and 70% of CP. The variation in RUP content can be due to fish species and processing. In particular, factors in processing such as storage time of raw fish, type of dryer, type of preservative applied, heating duration and temperature, and amount of added condensed fish solubles all influence RUP content (Hussein and Jordan, 1991; Mehrez et al., 1980). It is also likely that processing method influences the proportion of CP washed out of the bag, particularly differences in particle size and amount of added condensed fish solubles which is largely water-soluble protein. Studies that estimate total tract CP digestibility of fish meal in ruminants found it to be 95% or greater (Erasmus et al., 1994; England et al., 1997). The lack of residue at the end of duodenal incubation in experiments 1 and 2 agree with a high estimate of post-ruminal and total tract CP digestibility. Because the fish meals examined in experiment 1 and 2 came from different

sources, differences in RUP content may be influenced by differences in processing or fish species and not necessarily due to differences between conventional and organic sources.

No differences were observed between any DEHY sample for RUP content, and RUP content ranges between 37.9% and 46.0% of CP. For RUP digestibility, organic DEHY 1 was greatest at 83.4% while conventional DEHY 3 and organic DEHY 2 were lowest at 74.5% and 75.2% and all other DEHY samples intermediate. Digestible RUP as a percent of DM was thus greatest for organic DEHY 1 at 8.4% of DM and lowest for organic DEHY 2, Organic DEHY 3, and conventional DEHY 3 at 2.2%, 5.5%, and 5.2% of DM respectively while conventional DEHY 1 and 2 were intermediate at 6.7% and 6.2% of DM. Ensiled alfalfa had the lowest RUP content at 18.5% of CP, RUP digestibility at 43.7%, and digestible RUP as a percent of DM at 1.6% of DM compared to any other alfalfa sample. Ensiled alfalfa had the greatest proportion of CP washout at 70.6% of CP, while all DEHY samples ranged from 34.7% to 42.1% of CP.

Although some variation between samples in organic and conventional DEHY were observed there was no significant difference between the majority of the organic and conventional DEHY samples, particularly in RUP content and digestible RUP as a percent of DM. The RUP digestibility of DEHY measured in experiments 1 and 2 are somewhat greater than the NASEM (2016) recommendation of 60% for forages. Orskov and McDonald (1979) indicated that RUP content was sensitive to passage rate. It is likely that RUP digestibility is also influenced by passage rate. The 16 h incubation time used in experiments 1 and 2 may be appropriate to estimate RUP values of forages in diets that are low in roughage, such as a finishing diet with only 10% of the diet as a

forage source, but not for diets that are almost entirely roughage with a slower passage rate (Von Keyserlingk et al., 1996). This may explain the relatively high RUP digestibility values observed in experiments 1 and 2.

When comparing soybean meals, no differences were observed between any expeller soybean meal for RUP content, which ranged from 56.1% to 61.5% of CP while RUP digestibility ranged from 96.2% to 98.2%. Both conventional expeller soybean meals had greater digestible RUP as a percent of DM at 28.5% and 28.0% of DM when compared to the organic expeller soybean meals, with organic expeller soybean meal 3 having the lowest digestible RUP as a percent of DM at 23.5% of DM and organic expeller soybean meal 1 and 2 being intermediate at 27.6% and 27.1% of DM. Solvent extracted soybean meal 1 and 2 were lower in RUP content at 41.9% and 42.8% of CP and digestible RUP as a percent of DM at 21.8% and 21.8% of DM than any other soybean meal, although organic expeller soybean meal was intermediate between the solvent soybean meals and the other expeller soybean meals at 23.5% of DM. All soybean meals examined were similar in RUP digestibility, and RUP digestibility ranged from 96.2% to 98.2%. Of all samples examined, the expeller soybean meals were generally highest in RUP content, RUP digestibility, and digestible RUP as a percent of DM.

Mjoun et al. (2010) performed an *in situ* experiment comparing RUP content and rumen degradability of amino acids of solvent and expeller soybean meals. The RUP content measured by Mjoun et al., (2010) was estimated at 53.7% and 32.3% of CP for expeller and solvent soybean meal, respectively, and intestinal digestibility of expeller and solvent soybean meals were 98.5% and 97.0% of RUP, respectively. Paz et al. (2014)

performed a similar *in situ* study comparing expeller and solvent soybean meals and found the RUP content to be 60.3% and 31.2% of CP, respectively, and found similarly high RUP digestibility. The RUP content and digestibility observed for the solvent and expeller soybean meals examined in experiment 1 and 2 agree with those values. Furthermore, Mjoun et al. (2010) found expeller and solvent soybean meal samples had similar amino acid composition after 16 h of rumen incubation and that intestinal digestibility of the amino acids was similar between soybean meals, indicating that processing differences did not affect protein quality.

While no differences were observed between organic and conventional field peas, the values for RUP content in field peas found in experiments 1 and 2 are somewhat greater than those reported in a review by Anderson et al. (2007). Anderson et al. (2007) reported a range of between 6% and 22% RUP as a percent of CP, while field peas examined in experiments 1 and 2 ranged from 33.6% to 47.3% of CP. However, the peas examined in those studies were ground through either a 1- or 2-mm screen while in the studies described above, incubated field peas were ground through a 6-mm screen to imitate masticate particle size, which may have influenced the results. Chen et al. (2003) examined the RUP content of field peas ground to pass through 1 mm, 2 mm, and 4 mm screens and reported RUP content as a percent of CP as 12.7%, 19.7%, and 20.2%, respectively with peas ground to 1 mm having significantly lower RUP content than those ground through the larger screens. Michalet-Doureau and Cerneau (1991) found that *in situ* rumen degradability of feed nitrogen decreases when screen size increases from 0.8-mm to 3-mm to 6-mm with a 12.3% decrease in rumen degradability of field pea nitrogen and a 10.6% decrease in corn grain nitrogen degradability when screen size

increased from 0.8-mm to 6-mm. Greenwell et al. (2018) measured RUP content and digestibility of two different samples of field peas using an *in situ* method and reported values of 32.6% of CP and 35.2% of CP for RUP content and 97.4% and 98.9% for RUP digestibility, and those peas were ground to pass through a 6-mm screen prior to incubation.

Very little research has been done comparing the nutrient digestibility of conventional and organic feed ingredients. When lambs were fed diets of cowpea hay and barley grain grown on the same facility under conventional or organic management, intake of DM, CP, and metabolizable energy (ME) were not different and apparent digestibility of DM, organic matter (OM), CP, neutral detergent fiber (NDF), acid detergent fiber (ADF), cellulose, and hemicellulose were not different (Singh et al., 2010). A similar study utilizing Tharparkar (*Bos indicus*) heifers fed organic or conventional sorghum hay harvested at half bloom stage and a concentrate mixture of barley grain, linseed grain, and mineral mixture resulted in no differences between crop management in DMI or apparent digestibility of DM, CP, NDF, ADF, and cellulose. However, the organic diet had higher NDF and hemicellulose digestibility compared to the conventional diet (Singh et al., 2012). While this may not be enough to draw a definitive conclusion, it does indicate that nutrient digestibility is similar between organic and conventional crops.

Experiment 3

Initial BW was significant ($P = 0.03$) between treatment groups with calves in the NONE group having the lowest initial BW and calves in the SP group having the heaviest initial BW, with calves in SBM, FPFM, and FP intermediate in initial BW (Table 6).

While these differences were statistically significant, the difference of between one to three kg of initial BW between treatment groups was likely not biologically significant. In the first feeding phase, significant differences were observed between dietary treatments for BW, ADG, and G:F on d 63 ($P \leq 0.04$). Cattle fed NONE had the lowest BW on d 63, while those fed FP, FPFM, SBM, and SP were similar in BW. Steers fed SP had the highest ADG in the first phase while steers fed NONE had the lowest ADG and those fed FP, FPFM, and SBM were intermediate. Steers fed NONE had the lowest G:F in the first feeding phase, while steers fed FP, FPFM, SBM, and SP were similar in G:F.

The differences observed in ADG and G:F during the first feeding phase may be attributed to the MP deficiency imposed upon the calves in the NONE treatment group. Hilscher et al. (2019) and Oney et al. (2019) found that calves in a negative MP balance had lower ADG and G:F compared to those receiving adequate MP, while increasing supplemental MP into a positive MP balance continued to increase ADG and G:F.

Due to lack of significant differences, data for feeding phases 2-4 are summarized together (Table 5). No difference in ending BW, ADG, or G:F were observed between dietary treatment groups ($P \geq 0.25$). Dry matter intake was significantly different between groups ($P = 0.02$), with calves fed SP having the greatest DMI at 9.7 $kg \cdot d^{-1}$ and those fed FP and FPFM having the lowest DMI at 8.2 $kg \cdot d^{-1}$ and 8.3 $kg \cdot d^{-1}$ respectively, with calves fed NONE and SBM having intermediate DMI at 9.1 $kg \cdot d^{-1}$ to 8.6 $kg \cdot d^{-1}$ respectively.

Across the entire feeding period, no significant effect of protein source was observed on final BW or ADG ($P \geq 0.25$). Live BW gain in $kg \cdot animal^{-1}$ was not significantly different ($P = 0.28$) between treatment groups but when compared to steers fed NONE, those fed FP, FPFM, SBM, and SP had a 3.2%, 9.8%, 13.0%, and 14.2%

increase in live BW gain, respectively. Dry matter intake was significantly different over the entire feeding period (*P* = 0.02) with steers fed SP having the greatest DMI at 9.3 kg d^{-1} and those fed FP and FPFM consuming the least at 8.0 kg·d^{-1}, with steers fed NONE and SBM having intermediate DMI at 8.9 kg·d^{-1} and 8.7 kg·d^{-1}, respectively. Steers fed FPFM had greater (*P* = 0.06) G:F than those fed NONE with steers fed FP, SBM, and SP having intermediate G:F (0.120, 0.098, 0.112, 0.113, 0.107, respectively).

Compensation appears to have occurred after a period of MP deficiency for steers in the NONE treatment group. Compensatory gain has been observed in cattle after a period of nutrient restriction (Carstens et al., 1991; Drouillard et al., 1991; Hersom et al, 2003). While the cattle fed NONE were not deficient in energy, they were deficient in MP. Drouillard et al. (1991) found that after a period of MP deficiency cattle experience a period of compensatory growth and that compensatory growth appeared to be influenced more by severity of the deficiency than the duration of the deficiency.

Inclusion of field peas in feedlot diets has largely proven to have no effect on G:F (Carlin et al., 2006; Jenkins et al., 2011). In experiment 3, Holstein steers fed diets containing field peas that replaced the corn portion of the diet had significantly lower DMI than steers fed diets without field peas but maintained ADG and G:F similar to the other dietary treatment groups, which contradicts most of the existing data. A review by Anderson et al. (2007) found that the use of field peas in growing and finishing cattle diets resulted in either no change or an increase in DMI in most studies. Chen et al. (2003) found that replacing barley grain with increasing proportions of field peas resulted in no difference in DMI or ADG. Reed et al. (2004) examined the effect of replacing corn grain with field peas on DMI and rumen fermentation parameters and found no effect of

field pea inclusion on DMI, but that replacing corn grain with field peas resulted in increased total VFA concentration, increased ruminal and total tract disappearance of N, and increased total tract disappearance of OM. These data indicate that the net energy values of field peas may need to be re-evaluated. Because field peas are a legume and fit well in a crop rotation system, organic field peas may be easy to obtain for an organic beef producer.

The calves fed FPFM had the greatest G:F over the entire study, although the MP balance of this diet was equal to that of the FP, SBM, and SP diets. Davenport et al. (1990) compared the effect of supplementing 220 kg calves fed a corn silage based diet with ground soybeans, ground soybeans and fish meal, ground soybeans and rumen protected lysine, and a combination of ground soybeans, fish meal, and rumen protected lysine. Supplements were formulated to be isonitrogenous and were fed at a rate to provide .40 kg CP per animal per day. Supplemental fish meal improved ADG and G:F while no difference in DMI was observed. No effect of rumen protected lysine was observed suggesting that an amino acid other than lysine, provided by the fish meal, was limiting. Davenport et al. (1990) also measured plasma amino acid concentrations and found that calves supplemented with fish meal had increased total essential amino acid concentrations, which likely contributed to the increase in performance observed.

Sanderson et al. (1992) fed 110 kg Holstein calves diets containing ryegrass silage and 0%, 5% 10%, or 15% fish meal and found that increasing fish meal concentrations resulted in a linear increase in DMI and ADG. While this study does not compare fish meal to other protein sources, it does indicate that fish meal is a good source of protein for growing cattle if it is priced reasonably.

Although organic soybean meal is always expeller processed, the soybean meal used in experiment 3 was solvent soybean meal. However, an *in situ* experiment performed by Mjoun et al. (2010) found that the residue of both expeller and solvent soybean meal after 16 h rumen incubation had similar amino acid composition and similar intestinal digestibility of both RUP and amino acids. This indicates that as long as MP is balanced, amino acid supply would be similar and supports the use of solvent soybean meal in experiment 3 as an accurate indication of performance of expeller soybean meal.

Steers fed SBM did not have different ADG or G:F compared to those fed other protein sources. A study comparing the performance of Holstein heifers fed diets formulated to contain equal amounts of CP, RUP, and RDP using low fat dried DGS, high fat DGS, or a 50:50 blend of solvent and expeller soybean meal found no difference between source of protein on final BW, ADG, DMI, or G:F even though inclusion of each protein source was different as a percent of DM to balance for the desired CP, RUP, and RDP levels (Anderson et al., 2015). In growing animals, solvent or expeller soybean meal may be a viable alternative to DGS as a source of protein provided it can be obtained at a competitive price. In an organic system, the use of expeller soybean meal appears to be a reasonable option.

Experimental diets consisted of 30% alfalfa haylage (17.4% CP, 10% RUP as % of CP) and 5% supplement with protein source displacing dry rolled corn (8.8% CP, 60% RUP as % of CP). All diets containing a protein source were balanced for MP, but protein source inclusions were different between diets because the different protein sources had different proportions of CP and RUP content: field peas were assumed to be 23% CP and

42% RUP as % of CP, fish meal was assumed to be 70% CP and 60% RUP as % of CP, solvent extracted soybean meal was assumed to be 52% CP and 30% RUP as % of CP, and SoyPass was assumed to be 50% CP and 75% RUP as % of CP. The assumptions of RUP content for ensiled alfalfa, solvent soybean meal, field peas, and SoyPass are fairly close to the RUP content measured in experiments 1 and 2, which averaged to be 14.5%, 37.3%, 40.6%, and 78.5% of CP, respectively. However, the assumed RUP content of dry rolled corn and fish meal were greater than those measured in experiments 1 and 2, which averaged 40.5% and 35.9% of CP, respectively although the RUP content measured for fish meal *in situ* may not reflect the true RUP content. Expeller soybean meal had an average RUP content of 59.3% of CP in experiments 1 and 2. Based on this value, inclusions of expeller soybean meal would have been 12.5% of DM in phase 1 of experiment 3, compared to solvent soybean meal which was included at 32% of DM in phase 1.

Applications

Given the present data, there is no difference in RUP content or digestibility between conventional and organic feeds. The use of RUP content and digestibility values established using conventional feeds should be appropriate when formulating diets for organic beef cattle. The performance observed in growing Holsteins fed fish meal suggests that it may be a valuable protein source if available at a competitive price. Because cattle fed field peas achieved similar growth to those fed no supplemental protein while consuming less feed, energy value of field peas may be greater than what has been previously established and should be investigated further. Expeller soybean meal has an average RUP content of 59.3% of CP and digestibility of 97.6% of RUP, and

may be a valuable source when DGS are not readily available. These data suggest that a variety RUP supplements may be used as alternatives to DGS in organic beef production.

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Tables

Table 1. Number of feed ingredients analyzed for RUP content and digestibility using in situ procedures in Exp. 1 and Exp. 2

	Number of Samples[1]			
	Experiment 1		Experiment 2	
Item	CON	ORG	CON	ORG
Dry Rolled Corn	1	-	1	-
DDGS[2]	1	-	-	-
High Protein DDGS	1	-	-	-
Field Peas	1	1	1	-
Roasted Field Peas	1	-	-	-
Solvent Extracted Soybean Meal	1	-	2	-
Expeller Pressed Soybean Meal	-	1	2	3
SoyPass	1	-	-	-
Raw Whole Soybeans	1	-	-	-
Roasted Whole Soybeans	1	-	-	-
Fish Meal	1	1	4	3
Alfalfa Haylage	1	-	1	-
Dehydrated Alfalfa[3]	1	1	3	3
Heat Damaged Dehydrated Alfalfa[3]	1	-	-	-
Flax Meal	-	-	-	1

[1] CON = Conventional, ORG = Organic; any feed with multiple samples had samples procured from different sources and/or from different production runs from the same facility
[2] DDGS = Dried Distillers Grains Plus Solubles
[3]All dehydrated alfalfas were pelleted

Table 2. Experiment 3. Diets fed to Holstein steers in four phases to simulate an organic production system

	Dietary Treatment[1]				
Ingredient, %DM[2]	NONE	FP	FPFM	SBM	SP
Phase 1, d1 to d63					
Dry Rolled Corn	65	11	35	33	55.25
Alfalfa Haylage	30	30	30	30	30
Fish Meal	-	-	4	-	-
Field Peas	-	54	30	-	-
Soybean Meal	-	-	-	32	-
SoyPass	-	-	-	-	9.75
Supplement	5	5	1	5	5
Phase 2, d64 to d132					
Dry Rolled Corn	65	26	43	42	57.75
Alfalfa Haylage	30	30	30	30	30
Fish Meal	-	-	3	-	-
Field Peas	-	39	22	-	-
Soybean Meal	-	-	-	23	-
SoyPass	-	-	-	-	7.25
Supplement	5	5	2	5	5
Phase 3, d133 to d194					
Dry Rolled Corn	65	43	55	52	61
Alfalfa Haylage	30	30	30	30	30
Fish Meal	-	-	2	-	-
Field Peas	-	22	10	-	-
Soybean Meal	-	-	-	13	-
SoyPass	-	-	-	-	4
Supplement	5	5	3	5	5
Phase 4, d195 to d214					
Dry Rolled Corn	65	65	65	65	65
Alfalfa Haylage	30	30	30	30	30
Fish Meal	-	-	-	-	-
Field Peas	-	-	-	-	-
Soybean Meal	-	-	-	-	-
SoyPass	-	-	-	-	-
Supplement[2]	5	5	5	5	5

[1]NONE = no supplemental protein, FP = Field Peas, FPFM = Field Peas + Fish Meal, SBM = Soybean Meal, SP = SoyPass

[2]Supplement contained limestone, vitamins A-D-E, and trace minerals in a fine ground corn carrier

Table 3. Experiment 3. Calculated metabolizable protein balance of diets fed to Holstein steers in four phases to simulate an organic production system

	Dietary Treatment[1]				
Item[2]	NONE	FP	FPFM	SBM	SP
Phase 1, d1 to d63					
MP Balance[3]	-134	3	-1	-1	0
RDP Balance	-47	415	296	634	81
Phase 2, d64 to d132					
MP Balance	-134	-2	1	-1	0
RDP Balance	30	361	267	539	76
Phase 3, d133 to d194					
MP Balance	-85	1	1	2	0
RDP Balance	35	250	171	367	64
Phase 4, d195 to d214					
MP Balance	-38	-1	3	2	0
RDP Balance	41	134	106	193	54

[1]NONE = no supplemental protein, FP = Field Peas, FPFM = Field Peas + Fish Meal, SBM = Soybean Meal, SP = SoyPass

[2]MP = metabolizable protein, RDP = rumen undegradable protein

[3]For Phases 1 through 4, DMI was estimated to be 6.1 $kg \cdot d^{-1}$, 7.3 $kg \cdot d^{-1}$, 8.4 $kg \cdot d^{-1}$, 10.0 $kg \cdot d^{-1}$, respectively. Estimated initial BW for each phase was 227 kg, 263 kg, 320 kg, and 337 kg, respectively. ADG was assumed to be 1.0 kg across the entire feeding period. Microbial efficiency was assumed to be 13%.

Table 4. Experiment 1. Comparison of in situ RUP content and digestibility of organic and conventional feeds

	Item[1]				
Sample[2]	Initial CP, % of DM	RUP Content, % of CP	RUP Digestibility, % of RUP	Digestible RUP Content, % of DM	Washout, % of CP
Alfalfa					
Haylage	18.1	10.5[i]	9.5[h]	0.2[j]	58.3[b]
DEHY CON	18.1	15.0[i]	44.2[f]	1.2[ij]	31.0[de]
DEHY ORG	23.0	16.6[i]	70.5[e]	2.4[hi]	36.8[d]
HD DEHY CON	21.2	53.4[bc]	17.7[g]	1.9[i]	25.2[ef]
Corn and Corn Byproducts					
DRC	9.2	38.1[gh]	67.0[e]	2.1[i]	10.8[gh]
DDGS	35.2	28.5[i]	84.2[d]	7.5[fg]	27.3[e]
HP DDGS	37.1	59.9[b]	93.5[bc]	18.7[c]	5.3[ij]
Field Peas					
CON	22.4	33.6[fgh]	91.5[cd]	6.1[fg]	18.6[f]
ORG	25.0	41.0[def]	93.4[bc]	8.6[ef]	7.3[hi]
RST CON	22.3	25.9[h]	91.6[cd]	4.5[gh]	11.2[gh]
Fish Meal[3]					
CON	69.7	16.5[efg]	-	-	79.2[a]
ORG	68.1	46.8[cde]	-	-	49.6[c]
CON Soybeans					
Raw	37.5	44.9[cde]	96.7[abc]	14.9[cd]	5.7[ij]
Roasted	37.0	50.5[bcd]	97.3[ab]	16.3[cd]	3.1[j]
Soybean Meal					
SoyPass	48.9	78.5[a]	98.9[a]	33.9[a]	9.5[ghi]
SOLV CON	51.2	27.3[h]	98.5[a]	12.5[de]	11.6[gh]
EXP ORG	47.0	60.0[b]	98.7[a]	26.7[b]	12.3[g]
SEM	-	2.08	2.00	1.05	1.58
P-Value					
Sample	-	< 0.01	< 0.01	< 0.01	< 0.01
Day	-	0.08	-	-	0.54
Sample·Day	-	0.54	-	-	0.96

[1] CP = Crude Protein, RUP = Rumen Undegradable Protein
[2] CON = Conventional, ORG = Organic, DDGS = Dried Distillers Grains plus Solubles, DEHY = Dehydrated, DRC = Dry Rolled Corn, HD = Heat Damaged, HP = High Protein, SOLV = Solvent Extracted, EXP = Expeller Pressed; all feeds are conventional unless otherwise specified
[3] Fish meal had no residue remaining after retrieval from feces for crude protein analysis
[a-j] Means within a column with different superscripts are different ($P < 0.05$)

Table 5. Experiment 2. Comparison of in situ RUP content and digestibility of organic and conventional feeds

	Item[1]				
Sample[2]	Initial CP, % of DM	RUP Content, % of CP	RUP Digestibility, % of RUP	Digestible RUP Content, % of DM	Washout, % of CP
Dry Rolled Corn	8.9	42.8^{cde}	73.3^{d}	2.8^{g}	19.8^{ij}
Field Peas	24.7	47.3^{cd}	88.2^{b}	10.2^{d}	34.0^{fgh}
Flax Meal ORG	39.8	19.7^{h}	76.0^{d}	6.00^{ef}	26.1^{hi}
Fish Meal[3]					
CON 1	66.7	24.8^{gh}	-	-	66.4^{b}
CON 2	71.9	19.5^{h}	-	-	77.9^{a}
CON 3	64.5	29.8^{g}	-	-	53.1^{c}
CON 4	67.4	31.5^{fg}	-	-	49.5^{cd}
ORG 1	69.0	49.8^{bc}	-	-	47.3^{cde}
ORG 2	72.4	57.2^{ab}	-	-	38.6^{ef}
ORG 3	68.0	47.6^{cd}	-	-	51.3^{cd}
Alfalfa					
Haylage	20.3	18.5^{h}	43.7^{e}	1.6^{g}	70.6^{ab}
DEHY CON 1	19.1	46.0^{cde}	77.2^{cd}	6.7^{ef}	35.5^{fg}
DEHY CON 2	19.6	40.5^{de}	78.6^{cd}	6.2^{ef}	39.4^{ef}
DEHY CON 3	17.3	40.7^{de}	74.5^{d}	5.2^{f}	34.7^{fg}
DEHY ORG 1	22.8	44.7^{cde}	83.4^{bc}	8.4^{de}	42.1^{def}
DEHY ORG 2	16.9	43.7^{cde}	75.2^{d}	5.5^{f}	38.0^{f}
DEHY ORG 3	18.9	37.9^{ef}	76.2^{cd}	5.5^{f}	35.2^{fg}
Soybean Meal					
SOLV CON 1	53.5	41.9^{cde}	97.3^{a}	21.8^{c}	25.4^{i}
SOLV CON 2	53.1	42.8^{cde}	96.3^{a}	21.8^{c}	26.9^{ghi}
EXP ORG 1	48.0	59.1^{a}	97.6^{a}	27.6^{ab}	15.4^{j}
EXP ORG 2	46.6	59.3^{a}	98.2^{a}	27.1^{ab}	15.3^{j}
EXP ORG 3	43.7	56.1^{ab}	96.2^{a}	23.5^{bc}	16.8^{j}
EXP CON 1	47.7	61.5^{a}	97.5^{a}	28.5^{a}	20.8^{ij}
EXP CON 2	48.5	59.7^{a}	97.2^{a}	28.0^{a}	22.4^{ij}
SEM	-	2.62	4.20	1.53	1.74
P-Value					
Sample	-	< 0.01	< 0.01	< 0.01	< 0.01
Day	-	0.09	< 0.01	0.15	0.92
Sample·Day	-	0.33	0.59	0.87	0.98

[1] CP = Crude Protein, RUP = Rumen Undegradable Protein
[2] CON = Conventional, ORG = Organic, DRC = Dry Rolled Corn, DEHY = Dehydrated, SOLV = Solvent Extracted, EXP = Expeller Pressed
[3] Fish meal had no residue remaining after retrieval from feces for crude protein analysis
[a-j] Means within a column with different superscripts are different (P < 0.05)

Table 6. Experiment 3. Performance of Holstein steers individually fed diets with different sources of RUP in a simulated organic production system

	Dietary Treatment[1]						
Item	NONE	FP	FPFM	SBM	SP	SEM	*P*-Value
Phase 1, d1 to d63							
Initial BW, kg	211^{a}	213^{ab}	214^{b}	213^{ab}	214^{b}	0.6	0.03
d63 BW, kg	252^{a}	264^{b}	266^{b}	265^{b}	268^{b}	3.6	0.03
ADG, $kg \cdot d^{-1}$	0.65^{a}	0.80^{ab}	0.83^{ab}	0.84^{ab}	0.87^{b}	0.053	0.04
DMI, $kg \cdot d^{-1}$	6.8	6.5	6.5	6.8	7.1	0.21	0.20
G:F	0.093^{a}	0.124^{b}	0.128^{b}	0.123^{b}	0.122^{b}	0.0066	<0.01
Phases 2-4, d63 to d214							
d63 BW, kg	252^{a}	264^{b}	266^{b}	265^{b}	268^{b}	3.6	0.03
Final BW, kg	396	405	418	422	425	11.4	0.25
ADG, $kg \cdot d^{-1}$	1.04	1.03	1.03	1.02	1.08	0.075	0.97
DMI, $kg \cdot d^{-1}$	9.1^{ab}	8.2^{a}	8.3^{a}	8.6^{ab}	9.7^{b}	0.35	0.02
G:F	0.112	0.125	0.123	0.117	0.112	0.0063	0.43
Overall, d1 to d214							
Initial BW, kg	211^{a}	213^{ab}	214^{b}	213^{ab}	214^{b}	0.6	0.03
Final BW, kg	396	405	418	422	425	11.4	0.25
Live BW gain, $kg \cdot animal^{-1}$	186	191	204	210	212	11.2	0.28
ADG, kg d^{-1}	0.87	0.89	0.95	0.98	0.99	0.052	0.28
DMI, kg d^{-1}	8.9^{ab}	8.0^{a}	8.0^{a}	8.7^{ab}	9.3^{b}	0.33	0.02
G:F	0.098^{b}	0.112^{ab}	0.120^{a}	0.113^{ab}	0.107^{ab}	0.0054	0.06

Means within a row with different superscripts are different ($P \leq 0.10$)
[1]NONE = no supplemental protein, FP = Field Peas, FPFM = Field Peas + Fish Meal, SBM = Soybean Meal, SP = SoyPass

Chapter III: Evaluation of two implant strategies on performance and carcass characteristics of finishing heifers

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Abstract

A commercial feedlot study utilizing 1,737 crossbred heifers (initial BW 313 kg) compared two implant strategies on growth performance and carcass characteristics. Treatments were: 1) Synovex ONE Feedlot (day 0, **ONE**) or 2) Synovex Choice (day 0) followed by Synovex Plus (day 93-95, **CH/PLUS**). The CH/PLUS strategy involved treatment with a total of 300 mg trenbolone acetate (TBA) and 42 mg estradiol benzoate (EB), while total active ingredient doses for cattle treated with ONE were 200 mg TBA and 28 mg EB over the 182-d trial. No differences ($P \geq 0.11$) were observed in final body weight, hot carcass weight, carcass gain, or ADG but heifers implanted with ONE had lower ($P < 0.01$) carcass-adjusted deads-out feed efficiency than heifers implanted with CH/PLUS. Heifers implanted with the CH/PLUS strategy had lower ($P \leq 0.02$) marbling score and calculated yield grade but similar ($P = 0.15$) 12^{th}-rib fat thickness and greater ($P < 0.01$) DP and LM area compared to heifers implanted with ONE. No differences ($P \geq 0.16$) were observed between treatments in morbidity, mortality, or removals. Although the implant strategies were unequal in TBA and EB content, heifers in both treatment groups achieved similar growth and performance with heifers implanted with Synovex ONE Feedlot having greater marbling scores and quality grades while those implanted with Synovex Choice/Synovex Plus had lower calculated yield grade and greater LM area. These results indicate flexibility in implant strategy, allowing producers to utilize a single implant strategy to improve operational efficiency.

Key Words: reimplanting, finishing heifers, implants

Introduction

The use of growth-promoting implants in both steers and heifers has been shown to increase growth performance and lean meat yield when compared to nonimplanted cattle (Preston, 1999; Folmer et al., 2009; Hilscher et al., 2016). There are many different implant strategies common in the industry. Because most cattle require more than 120 days to reach slaughter weight and most implants available lose effectiveness between 60 and 120 days, a dual-implant strategy with an implant given upon arrival and a terminal implant given a number of days later has become common. The level of trenbolone acetate (TBA) and estradiol-17β (E) or analogue estradiol benzoate (EB) provided in those implants determines the strength of the implant, with the highest concentration of TBA or E/EB typically found in the terminal implant. These dual implant strategies have proven successful for improving performance over an extended feeding period (Preston, 1999). Depending on the combination of implants, cattle can show a 20% improvement in ADG and a 13.5% increase in gain efficiency compared to cattle with no implant (Duckett and Pratt, 2014). However, re-implanting cattle requires that they be processed again. Handling and processing can result in stress and reduced performance, although using good practices minimizes this effect (Grandin, 1984; Petherick et al., 2009). There is also a labor cost associated with processing. A single implant that can cover the entire feeding period may be appealing to producers that need to minimize labor costs or wish to reduce handling of the animals. Synovex ONE Feedlot is a single implant that is coated with a polymer film that results in a slow release of TBA and EB. This slow release allows the implant to remain active up to 200 d. The objective of this study was to evaluate effects of implanting heifers with Synovex ONE Feedlot compared to a dual

implant strategy of Synovex Choice followed by Synovex Plus on finishing heifer performance and carcass characteristics.

Materials and Methods

Animals and Treatments

Crossbred heifers (n = 1737) weighing 313 kg of initial body weight (BW) were fed at a commercial feedyard in central NE. Heifers were fed an average of 182 days (range 180-189 days) from April 2017 to November 2017. Heifers were sourced from sale barns located in Nebraska, Kansas, and Oklahoma. The study was designed as a randomized block design with blocking factor being arrival date at the feedyard. Treatments were 1) Synovex ONE Feedlot (200 mg of TBA + 28 mg EB; Zoetis, Parsippany, NJ; **ONE**) at initial processing and 2) Synovex Choice (100 mg TBA + 14 mg EB) at initial processing followed by Synovex Plus 93 to 95 days later (200 mg TBA + 28 mg EB; Zoetis; **CH/PLUS**).

Heifers were randomly allotted to pen (n = 24) as follows: using acquisition pay weight and historical data from records of similar cattle at the feedlot, an estimated range of 2 standard deviations (SD) above and below the pay weight was established. Within that range a series of randomization sheets were created, one for each 22.7-kg increment. Each sheet contained a random assignment to pen such that the first animal weighed that fell within a stratum was assigned to one pen while the next animal within that weight range was assigned to the other treatment. This continued until a replication was filled. There were 12 replications enrolled over 9 calendar dates. Treatments were assigned to pens within replicates using a random number generator, for a total of 24 pens. Within each study start date, heifers were processed, weighed, and assigned to pen and treatment

in one event. At initial processing, heifers received the combination intranasal vaccine Inforce 3 (Zoetis) to protect against bovine rhinotracheitis (IBR), parainfluenza$_3$ (PI$_3$), and bovine respiratory syncytial virus (BRSV). In addition, heifers received vaccination with One Shot BVD (Zoetis) to protect against BVD and bovine pneumonia caused by *Mannheimia haemolytica* type A1; and an implant based on the assigned treatment. Internal and external parasites were controlled by dosing animals with albendazole (Valbazen, Zoetis) oral suspension and doramectin (Dectomax, Zoetis) pour-on. Additionally, all heifers were pregnancy checked using rectal ultrasound, and if pregnant, were administered dinoprost tromethamine (Lutalyse HighCon, Zoetis) to induce abortion or both Lutalyse HighCon and dexamethasone to induce abortion and control inflammation in heifers that were in the second or third trimester of pregnancy. Following treatment on Day 0, implant sites were examined 27 to28 d after initial implant on a random subsample of 10 animals from 12 pens, with the subsample representing 6 blocks (2 pens per block). Heifers assigned to the CH/PLUS treatment were re-implanted 93 to 95 d after initial treatment, and 27 to 31 d after re-implanting was completed implants on a random subsample of 10 animals from the 6 pens not originally examined were checked (d 122 to 127 after the start of the study).

Cattle were housed in open lots with ad libitum access to water and feed. Diets were consistent across all treatments. Heifers were started on a diet consisting of 21.42% high moisture corn (HMC), 30% wet distillers grains (WDG), 35% alfalfa hay, 10% corn stalks, 3.5% supplement meal, and 0.08% microingredients on a DM basis. Three intermediate diets were used to step up heifers onto a final finishing diet that contained 59.46% corn (dry rolled, high moisture, or a blend), 30.0% WDG or modified distillers

grains plus solubles (MDGS), 3.0% alfalfa hay, 5.0% corn stalks, 2.5% supplement meal, 0.04% microingredient premix on a DM basis (Table 1). Ration formulation changes were the same for all cattle on feed throughout the trial. The supplement and microingredient premixes were formulated to target 9.81 $mg \cdot kg^{-1}$ DM tylosin phosphate (Tylan, Elanco Animal Health) and 33.07 $mg \cdot kg^{-1}$ DM monensin (Rumensin; Elanco Animal Health) on a dry matter basis. Melengestrol acetate (MGA, Zoetis) was fed at a rate of 0.45 $mg \cdot heifer^{-1}$ daily throughout the feeding period. Actogain 45 (Zoetis) was fed at a targeted rate of 300 $mg \cdot animal^{-1}$ for an average of the last 36 days of the feeding period (range 35-42 d). Diet samples were obtained monthly and analyzed for dry matter, crude protein, crude fiber, calcium, phosphorous, potassium, sulfur, zinc, and copper. Diets provided were formulated to meet or exceed NRC (1996) requirements for protein and minerals.

Carcass Evaluation

Harvest date was set at no less than 180 d from initial implant date across all treatments. Cattle were loaded onto trucks by pen and loaded trucks were weighed and shrunk 4% to get the average final live weight. Cattle were processed at JBS in Grand Island, NE and individual carcass data were collected. Individual hot carcass weight (HCW) was collected at slaughter. Following a 24 h chill 12^{th}-rib fat depth, LM area, marbling scores, USDA quality grade (QG), and USDA yield grades (YG) were collected. Yield grade was calculated using the equation YG = 2.50 + (6.35 × 12th-rib fat depth, cm) -(2.06 × LM area, cm^2) + (0.2 × KPH, %) + (0.0017 × HCW, kg) where KPH fat was assumed to be 2.5% (Boggs and Merkel, 1993). It is important to note that the number of observations used for the analysis of carcass characteristics is not the same as

those used for the analysis of performance due to missed observations at time of carcass data collection. Out of 853 heifers shipped in the ONE treatment and 846 heifers shipped in the CH/PLUS treatment, carcass data were complete for 819 heifers in the ONE treatment and 809 heifers in the CH/PLUS treatment (Table 2).

Deads-In, Deads-Out, and Animal Health Calculations and Statistical Analysis

Deads-In Calculations. Initial BW was calculated as the average of individual BW of heifers enrolled in the study with a 4% shrink applied. Final average live BW was determined by shrinking the total weight of each pen of cattle measured at the time of shipping by 4%, then dividing by the number of animals shipped. Live average daily gain (ADG) was calculated by subtracting shrunk initial BW of heifers enrolled from the shrunk final live BW and dividing by total number of deads-in animal days. Total dry matter intake (DMI) was calculated by dividing total feed delivered to the pen by the number of animal days. Live gain efficiency (G:F) was determined by dividing live ADG by average daily DMI/heifer. Carcass-adjusted final BW was determined by dividing the treatment average HCW by the average DP of 62.13%. Carcass-adjusted ADG was calculated by subtracting shrunk initial BW of enrolled heifers from the carcass-adjusted final BW, then dividing by the number of deads-in animal days. Carcass-adjusted G:F was calculated by dividing carcass-adjusted ADG by average DMI/heifer. Carcass-adjusted F:G was determined by taking the inverse of carcass-adjusted G:F.

Deads-Out Calculations. Initial BW was calculated as the average initial shrunk weight of heifers enrolled in the study minus the initial shrunk weight of heifers that died or were removed from the study. Deads-out final live BW was computed by dividing the total weight of heifers at shipping (shrunk 4%) by the number of heifers shipped. Live

ADG was calculated by subtracting the shrunk initial BW of heifers that completed the study from the final live weight and dividing by the total number of deads-out animal days. Deads-out DMI was calculated the same as deads-in DMI. Live G:F was calculated by dividing live ADG by DMI. Carcass-adjusted ADG was determined by subtracting shrunk initial BW of heifers that completed the study from the carcass-adjusted final BW and dividing by the number of deads-out animal days. Carcass-adjusted G:F was calculated as carcass-adjusted ADG divided by DMI. Dressing percentage (DP) was calculated by dividing HCW by final shrunk live BW. Carcass-adjusted final BW was calculated by dividing treatment average carcass weight by the average DP of 62.13% across all animals enrolled in the study. Carcass-adjusted gain efficiency was calculated by dividing carcass-adjusted ADG by DMI.

Initial HCW was estimated from initial BW using the formula: initial HCW, kg = 0.2598 X (initial BW, kg ^ 1.1378). Carcass ADG was determined by subtracting estimated initial HCW from the measured HCW and dividing by deads-out animal days.

Animal Health. Percent morbidity was determined by dividing the number of cattle treated for illness or injury by the total number enrolled. Categories within percent morbidity were calculated as the number of animals that were treated for respiratory illness, lameness, pinkeye, or other reasons divided by the total number of animals enrolled. Percent mortality was calculated by the total number of cattle that died or were euthanized divided by the total number of cattle enrolled. Percent removals was determined by dividing the total number of cattle removed from the study due to injury, chronic illness, or structural unsoundness divided by the total number of cattle enrolled. Total percent removed from study was determined by dividing the number of cattle that

died or were removed from the study by the total number of animals enrolled. Categories within the total percent removed from study were calculated as the number of animals that died or were removed for respiratory disease, lameness, metabolic illness such as founder or acidosis, and other reasons such as injury or death and dividing by the total number of animals enrolled.

Statistical Analysis

Live performance and carcass data were analyzed as a randomized complete block design using the Mixed procedure of SAS (9.3, SAS Institute Inc., Cary, NC). Pen was the experimental unit. Treatment and block were considered fixed effects. Performance and carcass data were analyzed with initial BW as a covariate. A tendency for a difference in initial BW was detected as a result of allocation method in 22.7-kg BW increments leading to low variation in initial BW. Treatment averages were calculated using the LSMEANS option of SAS. Frequency data were analyzed using the Glimmix procedure of SAS. Means of proportions for the frequency data were determined using the ILINK option of SAS. Treatment differences were significant at $\alpha \leq 0.05$.

Results and Discussion

Performance

Over the entirety of the study heifers implanted using ONE tended to have greater ($P = 0.09$) DMI than those implanted with the CH/PLUS strategy (Table 2). Over the first 96 days of the study, DMI was not different ($P = 0.34$). After re-implanting DMI of CH/PLUS heifers was reduced ($P < 0.01$) compared to cattle treated with ONE. Differences were not observed between treatments for deads-in or deads-out carcass-

adjusted final BW, live final BW, live ADG, and carcass-adjusted ADG ($P \geq 0.13$). Heifers implanted using the CH/PLUS strategy showed an increase ($P < 0.01$) in deads-out carcass-adjusted G:F over those implanted with the ONE strategy. On a deads-out live basis, heifers implanted with the CH/PLUS strategy tended (P = 0.09) to have greater feed efficiency as well. Heifers implanted using both strategies had similar ($P \geq 0.11$) initial HCW, final HCW, and carcass ADG. Implant strategies did not have an impact ($P \geq 0.22$) on deads-in live or carcass-adjusted G:F and ADG. These results are consistent with Samber et al. (1996) and Nichols et al. (2014), who reported no differences in final BW, ADG, or G:F when comparing implant strategies of increasing potency. These data suggest that these two implant strategies did not affect growth performance of heifers measured on a live basis, but did influence G:F when measured on a carcass-adjusted basis as heifers implanted with CH/PLUS were more efficient than those implanted with ONE.

Carcass Characteristics

Heifers implanted with CH/PLUS had greater ($P = 0.02$) DP than those implanted using the ONE strategy (Table 2). Cattle implanted with ONE had greater ($P \leq 0.02$) marbling score and calculated YG than those implanted using the CH/PLUS strategy. Heifers implanted with the CH/PLUS strategy had 2.9 % greater ($P < 0.01$) LM area than heifers implanted with ONE. Heifers implanted with ONE had similar ($P = 0.15$) 12^{th}-rib fat thickness compared to those implanted with the CH/PLUS strategy. Samber et al. (1996), Schneider et al. (2007), and Hilscher et al. (2016) reported a similar increase in DP, calculated YG, and LM area and a decrease in marbling score in response to

increased implant potency. However, Samber et al. (1996) found that increased implant TBA and E concentration resulted in decreased 12th-rib fat thickness.

A tendency (*P* = 0.06) for a difference in the overall QG distribution was observed between treatments (Table 3). Heifers implanted using the ONE strategy had a QG distribution that tended to shift towards a greater percent of carcasses to grade Prime and upper 2/3 Choice compared to heifers implanted with the CH/Plus strategy. Furthermore, heifers implanted with the CH/PLUS strategy had a QG distribution that tended to shift towards increased proportions of carcasses grading in the lower 1/3 of Choice and grading Select compared to cattle implanted with the ONE strategy. Parr et al. (2011) reported a decrease in percent of carcasses grading Choice and an increase in percent of carcasses grading Select as implant potency increases. Hilscher et al. (2016) also found that increasing implant potency resulted in reduced QG.

A tendency (*P* = 0.09) for a shift in yield grade distribution was also observed between implant strategies. The YG distribution of Heifers implanted using the CH/PLUS strategy tended to shift towards greater proportion of YG3 carcasses and lower, while heifers implanted with the ONE strategy had a tendency for greater proportions of YG4 and YG5 carcasses. Parr et al. (2011) and Hilscher et al. (2016) reported a similar shift in YG distribution in response to increasing implant potency, with greater doses of TBA and E resulting in greater percent YG@ and below and lower percent YG3 and above.

These data suggest that implanting with ONE results in lower DP and YG but improved marbling score and QG compared to implanting with CH/PLUS, and that these differences are likely due to the difference in TBA and EB between the two implant

programs. It is possible that, if fed for a longer number of days, the heifers implanted with CH/PLUS may achieve similar marbling scores to those implanted with ONE.

Animal Health

No differences ($P \geq 0.16$) were observed between treatments for percent morbidity or for the sub-categories of morbidity that included animals treated for respiratory disease, lameness, pinkeye, or other reasons such as calving or injury (Table 4). No differences ($P \geq 0.53$) were observed between treatments for percent mortality or percent removed from the study. There were no significant differences ($P \geq 0.21$) observed between treatments for percent total heifers removed from study or for the reasons for the removals or death resulting from respiratory disease, lameness, metabolic illness such as founder or acidosis, and other reasons such as injury. Hilscher et al. (2016) found that increased implant potency did not affect morbidity or mortality. Furthermore, Gruber et al. (2011) and Munson et al. (2012) both reported no differences in morbidity or mortality due to increased implant potency. These data imply there are no differences between these two implant strategies on animal health outcomes.

Applications

Heifers implanted with the ONE strategy had similar final BW, ADG, HCW, and carcass gain as heifers implanted with the CH/PLUS strategy but lower deads-out feed efficiency. Heifers implanted with ONE showed higher marbling scores and calculated yield grade but similar 12th-rib fat thickness, lower DP, and reduced LM area compared to heifers implanted with the CH/PLUS strategy. The CH/PLUS strategy provided greater total TBA and EB. Despite this difference, these data suggest that heifers implanted once on d 0 with Synovex ONE Feedlot achieved growth rates comparable to cattle

administered a Synovex Choice/Synovex Plus re-implant program while conceding only in yield grade, feed efficiency, and LM area. Potential differences in yield grade and quality grade distribution should be considered when determining marketing strategy. Use of Synovex One Feedlot provides an opportunity to improve operational efficiency by reducing costs of labor and animal productivity losses associated with processing cattle.

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Tables

Table 1. Composition of the finishing diet fed to heifers implanted with two different strategies

Ingredient	**Inclusion, % of DM**
Corn[1]	59.46
Distillers Grains[2]	30.00
Alfalfa Hay	3.00
Corn Stalks	5.00
Supplement Meal	2.50
Microingredients[3]	0.04

[1]Corn was either dry rolled corn, high moisture corn, or a blend of the two based on availability.

[2]Distillers Grains was either wet distillers grains or modified distillers grains plus solubles based on availability.

[3]Micros were formulated to provide 0.45 $mg \cdot heifer^{-1}$ MGA (Zoetis), 9.81 $mg \cdot kg^{-1}$ tylosin phosphate (Tylan, Elanco Animal Health) and 33.07 $mg \cdot kg^{-1}$ monensin (Rumensin; Elanco Animal Health) on a dry matter basis throughout the feeding period. Actogain (Zoetis) was included at the rate of 300 $mg \cdot animal^{-1}$ for the last 36 days.

Table 2. The effect of using one slow-release implant compared to a dual implant strategy on heifers fed 181 d

	Treatment [1]			
Item	**ONE**	**CH/PLUS**	**SEM**	***P*-Value**
No. of heifers (pens)	869 (12)	868 (12)	-	-
Initial BW, kg	313	314	4.6	0.08
DMI, kg·d^{-1}	10.7	10.6	0.05	0.09
Initial 96 d, kg·d^{-1}	9.9	10.0	0.07	0.34
Final 85 d, kg·d^{-1}	11.7	11.3	0.08	<0.01
Live performance, Deads out				
Final BW, kg[2]	621	620	1.4	0.90
ADG, kg·d^{-1}	1.70	1.70	0.007	0.97
G:F	0.158	0.160	0.0007	0.09
Carcass-adjusted performance, Deads-out [2]				
Final BW, kg	619	622	4.0	0.13
ADG, kg·d^{-1}	1.69	1.71	0.021	0.13
G:F	0.157	0.161	0.0007	<0.01
Carcass weight performance				
Initial HCW, kg	179.7	179.8	0.06	0.18
HCW, kg	384.1	386.7	0.99	0.11
Carcass ADG, kg·d^{-1}	1.13	1.14	0.005	0.13
Carcass characteristics				
No. of heifers	819	809	-	-
Dressing Percentage, %	61.96	62.30	0.001	0.02
Marbling score	534.7	509.4	4.45	<0.01
LM area, cm^2	85.2	87.7	0.45	<0.01
12th-rib fat thickness, cm	1.96	1.91	0.025	0.15
Calculated Yield Grade	3.92	3.76	0.04	0.02
Live performance, Deads in				
ADG, kg·d^{-1}	1.65	1.63	0.017	0.77
G:F	0.153	0.155	0.0018	0.64
Carcass-adjusted performance, Deads-in [2]				
ADG, kg·d^{-1}	1.63	1.65	0.016	0.55
G:F	0.152	0.156	0.0017	0.22

[1]ONE = Synovex One Feedlot on d 0; CH/PLUS = Synovex Choice on d 0 and Synovex Plus on d 93-95.

[2]The mean dressing percentage of 62.13% was used for all carcass-adjustment calculations.

Table 3. A comparison of the distribution of quality grade and calculated yield grade between heifers implanted with two different strategies

	Treatment [1]			
Item	**ONE**	**CH/PLUS**	**SEM**	***P*-Value**
USDA Quality Grade, %			-	0.06
Prime	8.40	5.79	0.90	-
Upper 2/3 Choice	47.81	41.79	1.56	-
Low Choice	35.37	39.15	1.21	-
Select	8.42	13.27	0.71	-
<Select	0	0	-	-
USDA Yield Grade, %			-	0.09
1	1.61	2.45	0.53	-
2	11.51	14.52	1.21	-
3	39.23	47.00	1.44	-
4	38.48	29.11	2.38	-
5	9.16	6.91	1.10	-

[1]ONE = Synovex One Feedlot on d 0; CH/PLUS = Synovex Choice on d 0 and Synovex Plus on d 93-95.

Table 4. Analysis of morbidity, mortality, and removals between heifers implanted with two different strategies

	Treatment [1]			
Item[2]	**ONE**	**CH/PLUS**	**SEM**	***P*-Value**
Morbidity, % [3]	15.69	19.82	3.903	0.38
Respiratory	4.00	2.91	0.860	0.28
Lameness	6.18	10.24	3.753	0.20
Pinkeye	2.27	4.02	0.986	0.16
Other [4]	0.79	0.67	0.377	0.82
Mortality, % [5]	0.78	0.90	0.348	0.79
Removals, % [6]	0.99	1.32	0.426	0.53
Total removed from study, % [7]	1.80	2.25	0.560	0.51
Respiratory	0.57	0.57	0.269	0.99
Lameness	0.16	0.47	0.271	0.21
Metabolic [8]	0.22	0.32	0.205	0.72
Other [9]	0.81	0.69	0.303	0.79

[1]ONE = Synovex One Feedlot on d 0; CH/PLUS = Synovex Choice on d 0 and Synovex Plus on d 93-95.
[2]Statistical means were used to generate this table, and proportions of the subcategories may not sum to equal the proportions of the main categories.
[3]Morbidity was determined as the percent of animals treated in the duration of the study with subsequent categories expressed as a percent of total animals enrolled.
[4]This category included heifers treated after calving or due to injury.
[5]Mortality was calculated as the percent of heifers that died while on trial.
[6]Removals were determined as the percentage of heifers that were taken off study due to chronic illness, injury, or structural unsoundness.
[7]Total removed from study was calculated as the percent of heifers that died or removed from the study with subsequent categories expressed as a percent of total animals enrolled.
[8]Metabolic reasons for cattle death or removal included acidosis and founder.
[9]This category includes heifers removed from the study due to injury or death that did not fit into the other categories.

Running head: serial slaughter of Holstein bulls and steers

Chapter IV: Serial slaughter of Holstein bulls and steers to evaluate and compare live performance and cutability of cattle pen-fed organic diets

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Abstract

Performance, carcass characteristics, and total meat yield of Holstein bulls and steers were compared in a simulated organic production system with the goal of producing ground beef. Holstein bulls (*n* = 120, initial BW = 221 kg, SD = 16) and steers (*n* = 120, initial BW = 214 kg, SD = 12) of the same age were blocked by BW and assigned randomly to be harvested at 308, 343, 378, and 413 days on feed (DOF). Cattle were fed a diet of 30% alfalfa haylage and 5% supplement with dry rolled corn, field peas, and fish meal included to meet metabolizable protein requirements over time. After harvest, all meat off the carcass was considered trim and was collected and weighed to calculate total trim yield (TY). Bulls had greater ADG, DMI, live BW, HCW, and TY than steers ($P \leq 0.05$). Steers showed greater linear increases in marbling scores and fat composition of TY as DOF increased than bulls, indicating a linear interaction ($P \leq 0.02$). Increasing DOF linearly increased DMI, live BW, HCW and MY ($P < 0.01$). Bulls had greater DMI and feed costs per animal than steers ($P < 0.01$) but castration had no effect on feed cost of gain ($P \geq 0.40$). Feed cost of gain per kg BW gain increased at a decreasing rate as DOF increased, while cost of gain per kg TY increased linearly as DOF increased. These data suggest potential for improved animal performance feeding Holstein bulls in an organic system.

Key Words: serial slaughter, Holstein, bulls, organic beef production

Introduction

The use of steroidal hormones in beef cattle production has been approved since the 1950s (Duckett and Andrae, 2001). Use of hormonal implant inserted subcutaneously in the back of the ear can increase average daily gain (ADG) and feed efficiency by up to

20% and 13.5%, respectively (Duckett and Pratt, 2014). This is due to the anabolic effect steroidal hormones like estrogen and testosterone or synthetic analogues of those compounds have on muscle tissue. Steroidal hormones activate and encourage proliferation of quiescent satellite cells and promoting the production of growth hormones such as insulin-like growth factor-1 (IGF1; Johnson and Chung, 2007; Bryant et al., 2010; O'Connell and Wu, 2014). Testosterone is an androgen that has an anabolic effect on muscle tissue. Increased androgen levels increase expression of androgen receptors and stimulate satellite cell activation and proliferation, resulting in increased protein deposition and muscle hypertrophy (O'Connell and Wu, 2014). Because of this, hormonal implants are administered to 91% of steers and 94% of heifers entering feedyards surveyed by the USDA National Animal Health Monitoring System (2013).

However, use of hormonal implants and other growth promoting technologies are banned in an organic beef production system. To compensate for the loss of technology and therefore a loss in performance, one option may be to leave male calves intact, allowing the testes to produce testosterone. When compared to steers, bulls have greater hot carcass weight (HCW) and longissimus muscle (LM) area but less tender meat and reduced marbling scores (Steen and Kilpatrick, 1995; Mach et al., 2009;).

The hypothesis is that bull calves would have increased muscle mass thereby increasing body weight (BW), ADG, and LM area compared to steers but that both steers and bulls would increase in final live BW, hot carcass weight (HCW), and LM area as the length of the feeding period increased. The objective of this study was to compare the performance, carcass characteristics, and total meat yield of Holstein bulls and steers fed an increasing number of days in a simulated organic production system.

Materials and Methods

The facility and management procedures described in the following experiment were approved by the University of Nebraska-Lincoln Institutional Animal Care and Use Committee.

Animals and Treatments

Holstein bulls (*n* = 120, initial BW = 221 kg, SD = 16) and steers (*n* = 120, initial BW = 214 kg, SD = 12) were fed at the research feedlot at the Eastern Nebraska Research and Extension and Education Center (ENREEC) located near Ithaca, NE. All calves were born at dairies in IA, were similar in age, and were raised at the same facility in SD until study initiation. Calves were assigned to be castrated or left intact by the facility that raised them by castrating every other animal in the group. Calves assigned to castration were castrated using elastic bands at 4 wk of age and were weaned off of milk at 8 wk of age. Cattle were processed upon arrival and were given an individual identification number. Calves were vaccinated with the combination intranasal vaccine Inforce 3 (Zoetis, Parsippany, NJ) to protect against bovine rhinotracheitis (IBR), parainfluenza$_3$ (PI$_3$), and bovine respiratory syncytial virus (BRSV); One Shot BVD (Zoetis) to protect against BVD and bovine pneumonia caused by *Mannheimia haemolytica* type A1; Ultrabac-7/Somubac (Zoetis) to protect agains *Clostridial* and *Haemophilus somnus* infections; and received injectable doramectin (Dectomax, Zoetis).

Bulls and steers were blocked by body weight into three blocks and assigned randomly to be harvested at 308, 343, 378, and 413 days on feed (DOF) such that each body weight block was represented for bulls and steers for each harvest time point. The initial harvest date of 308 DOF was selected to achieve a minimum live BW of 499 kg,

and successive harvest dates were spaced at 35 d intervals to ensure consistency in handling the cattle at the feedyard and in the abattoir. Cattle were housed in earthen pens with 10 calves per pen. Treatments imposed were therefore arranged in a 2×4 factorial with castration status (CAST) and DOF, with each of the three BW blocks represented once for bulls and steers within each assigned harvest date.

Before trial initiation, cattle were limit-fed a diet of 50% alfalfa and 50% Sweet Bran (Cargill Corn Milling, Blair, NE) at 2% of BW from d -4 to d 0 to reduce variation in gut fill (Watson et al., 2013). Cattle were then weighed on d 0 and d1 of the study in the morning before feeding and those weights were averaged to determine initial BW (Stock et al., 1983). Interim weights were collected over two consecutive days on d 65 and 66, d 126 and 127, d 189 and d 190, and d 252 and 253, averaged, and shrunk 4% to account for gut fill and calculate interim BW. Final live BW was collected at approximately 1630 h using a pen scale, shrunk 4%, and averaged over the number of animals in the pen. Pens scheduled to ship on a particular day were fed half of their called feed delivery for that day. Final live BW was calculated only using the weights of the pens that were scheduled to harvest in that event. Final BW was used to calculate average daily gain (ADG).

All cattle were moved and processed by students and employees on foot until d 252, after which cattle were moved using horses in the interest of safety for students and employees. The water source for the pens was located in the fence line of each pair of pens. When assigned to pens, the randomization was set for each pair of pens so that pens of bulls did not share a water source to ensure the safety of the employees cleaning and maintaining the waterer.

All cattle were fed a common diet with 30% alfalfa haylage and 5% supplement with dry rolled corn, field peas, and fish meal included at differing proportions to meet metabolizable protein requirements as BW increased over time (Table 1). The supplement was a dry meal with fine ground corn as a carrier and contained only limestone, salt, vitamins A-D-E, and trace minerals. Feeds used were conventionally grown and processed; however, the diet was designed to mimic the requirement of organic beef production where grazed forage needs to be a minimum of 30% of diet dry matter during the grazing season. In this study, cattle were fed in pens and forage maintained at 30% of diet DM to represent a worst-case scenario of cattle requiring delivered feed year-round. No ionophores or tylosin were included in the diet. Feed was delivered once daily at approximately 0730 h and feed refusals were collected as needed, weighed, and a subsample was dried in a forced-air oven at 60°C for 48 h to calculate dry matter refusals and accurately estimate dry matter intake (DMI). Dry matter intake and ADG were used to calculate gain to feed ratio (G:F).

Carcass Evaluation

Cattle were harvested at JBS in Omaha, NE over a period of 3 days for each harvest event in the order of heavy block, middle block, and light block so that identification of individual carcasses could be preserved through fabrication. Individual HCW was collected at harvest. Dressing percentage (DP) was calculated using the pen average of HCW and final live BW. Following a 24 h chill, 12th-rib fat depth, longissimus muscle (LM) area, and marbling score were collected. Kidney-pelvic-heart (KPH) fat was assumed to be 1.5% for all animals in all harvest events. At fabrication, carcasses from each pen were deboned and all meat was treated as boneless trim,

collected in combo bins, and weighed to obtain trim yield. Samples of each combo bin of trim were collected by JBS employees and were used to measure fat and lean composition of the trim, which was also used to calculate yields of fat trim and lean trim. Preliminary yield grade was used to calculate 12th-rib fat thickness using the equation PYG = 2.0 + (2.5 $\times$ fat thickness). Yield grade was calculated using the equation YG = 2.50 + (6.35 × 12th-rib fat depth, cm) - (2.06 × LM area, cm^2) + (0.2 $\times$ KPH, %) + (0.0017 × HCW, kg) where KPH fat was assumed to be 1.5% (Boggs and Merkel, 1993).

Feed Cost of Gain Analysis

A feed cost of gain analysis was conducted using the prices of organic feed applied to the DMI to calculate total feed costs for each treatment group. Prices used for calculation on a DM basis: fish meal was \$2131.63 MT^{-1} after a 5% shrink; field peas were \$686.07 MT^{-1} after a 5% shrink; dry rolled corn was \$444.98 MT^{-1} after a 2% shrink; alfalfa haylage was \$320.48 MT^{-1} after a 15% shrink. Feed costs were expressed on a per animal basis. Total live BW gain (BWG) and trim yield in kg·animal^{-1} were then utilized to calculate feed cost of gain per kg of BWG or trim yield. Data such as yardage, veterinary cost, and death loss were not included in this analysis.

Statistical Analysis

Data were analyzed as a randomized complete block design using the GLIMMIX procedure of SAS (9.3, SAS Institute Inc., Cary, NC) and means were estimated using the LSMEANS option of SAS. Means of proportions were estimated using the ILINK option of SAS with the exception of DP, which fit a gaussian distribution and was treated as normal data. Pen was the experimental unit and block was considered a fixed effect. Linear and quadratic interactions between DOF and castration and linear quadratic, and

cubic effect of DOF were examined using contrasts. Treatment differences were considered significant at $\alpha \leq 0.05$.

Results and Discussion

Live Performance

There were no linear or quadratic interaction between DOF and castration status and no quadratic effect of DOF for any live performance variable measured ($P \geq 0.16$). No cubic effects were observed for any live performance, carcass characteristic, or economic variable, so cubic contrasts were removed ($P \geq 0.11$). Table 2 shows the simple effects of castration and DOF on the performance of Holstein bulls and steers while Table 3 shows the main effect of castration and Table 4 shows the main effect of DOF.

Bulls had significantly heavier initial BW and 6.0% greater final BW than steers ($P < 0.01$). Compared to steers, bulls had 7.5% greater ADG ($P < 0.01$) and greater DMI in kg d^{-1} ($P < 0.01$). However, no difference was observed in DMI between bulls and steers when expressed as a percent of average BW ($P = 0.44$). No difference in G:F was observed for castration status ($P = 0.31$). In studies comparing Holstein bulls and steers of the same age, differences in initial BW have been observed (Mach et al., 2008; do Prado et al., 2015). Holstein bulls have repeatedly been shown to have heavier final BW than Holstein steers due to an increase in ADG (Mach et al., 2009; Marti et al., 2013; do Prado et al., 2015). Mach et al. (2009) found that castration of Holstein bulls resulted in a decrease in concentrate feed intake but did not affect G:F. Marti et al. (2013) and do Prado et al. (2015) did not observe a difference between Holstein bulls and steers in DMI, but do Prado et al. (2015) did find that bulls had 13.0% greater G:F compared to steers.

As designed, there was no interaction of increasing DOF and castration status or effect of increasing DOF on initial BW ($P \geq 0.61$). Final BW and DMI in kg d^{-1} increased linearly for both bulls and steers across days on feed ($P \leq 0.05$). A linear decrease in G:F from 0.109 to 0.097 and a linear decrease in DMI as a percent of average BW from 2.49% to 2.37% was observed with increasing DOF ($P < 0.01$). A tendency for a linear decrease in ADG from 1.01 kg d^{-1} to 0.095 kg d^{-1} was observed as DOF increased (P = 0.09). Marti et al. (2013) compared Holstein bulls and steers harvested at 10, 12, and 14 mo of age and found that increasing age resulted in a linear increase in final BW and concentrate intake and a linear decrease in G:F, but ADG was unaffected by increasing age. Wilken et al. (2015) examined seven trials that utilized beef steers to evaluate the influence of increasing DOF on profitability and observed a linear increase in DMI and BW with a linear decrease in ADG and G:F as DOF increased. Vasconcelos et al. (2008) observed an increase in final BW and a decrease in ADG and G:F in response to increasing DOF in beef breed steers.

Carcass Characteristics

Linear interactions between castration status and DOF were observed for marbling score, trim fat percentage, and trim lean percentage ($P \leq 0.02$). A tendency for a linear interaction was observed for trim yield as a percent of HCW ($P = 0.09$) and lean trim in kg·animal^{-1} ($P = 0.10$). No other interactions were observed ($P \geq 0.12$). There were no quadratic effects of DOF on carcass characteristics ($P \geq 0.19$), although a tendency ($P = 0.07$) for a quadratic effect of increasing DOF on YG was observed. Table 2 shows the simple effects of castration and DOF on the carcass characteristics of

Holstein bulls and steers while Table 3 shows the main effect of castration and Table 4 shows the main effect of DOF.

Bulls had 5.9% greater HCW than steers ($P = 0.01$); however, DP was not different between bulls and steers ($P = 0.96$). Bulls had 21.1% greater LM area and 8.1% greater trim yield in kg·animal^{-1} than steers. Bulls also had greater trim yield as a percent of HCW than steers, averaging 72.2% and 70.8% respectively ($P \leq 0.05$). Steers had greater 12th-rib fat depth than bulls ($P < 0.01$). Trim lean in kg·animal^{-1} was 14.4% greater for bulls than for steers ($P < 0.01$). A tendency for an interaction between castration status and DOF was observed for trim yield as a percent of HCW ($P = 0.09$) as bulls tended to increase in trim yield as a percent of HCW over time while steers did not. A tendency for an interaction was also observed for trim lean in kg·animal^{-1} ($P = 0.10$) as bulls tended to increase in trim lean at a greater rate than steers as DOF increased. There was a linear interaction between castration status and DOF for marbling score, with both steers and bulls increasing in marbling score over time but steers increasing at a greater rate ($P < 0.01$). Linear interactions between castration status and DOF were observed for trim lean percentage, trim fat percentage, and trim fat in kg·animal^{-1} ($P \leq 0.02$) because steers increased in fat content of TY as DOF increased, while bulls appeared to maintain or decrease in trim fat content as trim lean percentage increased. Bulls had lower YG than steers ($P < 0.01$), which was driven by bulls having greater LM area and HCW and decreased 12th-rib fat depth compared to steers.

Marti et al. (2013) and do Prado et al. (2015) found Holstein bulls to have higher DP than steers. In most studies comparing bulls and non-implanted steers, bulls have between 2.8% and 19.6% heavier HCW (Jones et al., 1984; Steen and Kilpatrick, 1995;

Mach et al., 2009; Marti et al., 2013; do Prado et al., 2015). Steen and Kilpatrick (1995) observed greater LM area and reduced 12^{th}-rib fat depth and marbling scores for Friesian and crossbred Friesian bulls compared to steers. They estimated that bulls had greater proportions of the carcass as lean tissue and bone and lower proportion of carcass as fat than steers.

A similar increase in lean carcass composition in Holstein bulls compared to steers has also been observed by Mach et al. (2009), Marti et al. (2013) and do Prado et al. (2015). Do Prado et al. (2015) also found that Holstein bull carcasses had greater proportions of edible product than steer carcasses when harvested at the same DOF. Jones et al. (1984) compared carcass composition and yield of beef breed bulls and steers harvested at a common 12^{th}-rib fat depth of 6 mm and found that although bulls required more DOF to reach target fatness, bulls had a greater proportion of carcass as muscle and reduced proportion of carcass as bone compared to steers and found that bulls converted feed to muscle more efficiently than did steers.

Carcass weights increased linearly from 300.0 kg to 351.6 kg as DOF increased ($P < 0.01$), but no change in DP (P = 0.37) or YG ($P = 0.11$) was observed over time. Longissimus muscle area increased from 67.1 cm^2 to 72.3 cm^2 as DOF increased ($P = 0.01$). Trim yield as a percent of HCW did not change as DOF increased ($P = 0.61$); however, trim yield in $kg \cdot animal^{-1}$ increased from 214.1 kg to 253.4 kg as DOF increased ($P < 0.01$). No change in 12^{th}-rib fat depth was observed over DOF ($P = 0.24$). Lean trim in $kg \cdot animal^{-1}$ increased from 195.5 kg to 227.7 kg as DOF increased ($P < 0.05$). The interaction of DOF and castration observed for fat content of the trim was likely

influenced by the increase in marbling scores in steers and the increase in LM area observed in bulls as DOF increased.

Marti et al. (2013) observed an increase in HCW as DOF increased when comparing the performance of Holstein bulls and steers. Similar to the observations in this study, conventional beef cattle increase in HCW, LM area, and marbling score as DOF increase (Bruns et al., 2004; Vasconcelos et al., 2008; Streeter et al., 2012). However, increases in DP, 12^{th}-rib fat depth, and YG are also observed in conventionally fed beef cattle as DOF increase, which were not observed in this study (Bruns et al., 2004; Vasconcelos et al., 2008; Streeter et al., 2012). May et al. (2016) observed increases in HCW, 12^{th}-rib fat depth, LM area, marbling score, and YG in Holstein steers fed between 254 to 534 DOF and harvested in 11 groups. Using the same data as May et al. (2016), May et al. (2017) found that both trimmable fat and saleable meat yield increased linearly as DOF increased. Increase in saleable weight as DOF increase has also been observed in beef cattle by Wilkins et al. (2015), which ultimately increased profitability.

These differences in carcass characteristics of bulls compared to steers are in some ways similar to the differences between implanted and non-implanted cattle, or cattle implanted with different amounts of active ingredients. The use of hormonal implants increases HCW by 6% to 7.5% and increases LM area by 5.8% to 9% while decreasing marbling scores by 3% to 11% compared to non-implanted cattle fed the same number of days depending on the type and concentration of active ingredient provided (Duckett and Pratt, 2014). Increasing implant potency has been found to increase LM area and DP while reducing marbling score and YG in steers harvested at the same DOF

(Parr et al., 2011; Hilscher et al., 2016). However, when harvested at the same 12th-rib fat depth endpoint implanted cattle have similar carcass compositions to non-implanted cattle while maintaining an advantage in HCW and live BW (Nichols et al., 2002). In the present study, bulls had increased HCW and LM area and lower YG compared to steers while steers showed an increase in marbling scores at a greater rate than bulls did in response to increasing DOF. However, it did not appear that feeding bulls longer days would result in similar marbling scores to those observed in steers when fed from 308 DOF to 413 DOF because the highest marbling score observed for bulls at 413 DOF was 357, much lower than the lowest marbling score for steers of 433 at 308 DOF.

Feed Cost of Gain Analysis

No linear or quadratic interactions between castration status and DOF were observed for any variable examined in the cost of gain analysis ($P \geq 0.33$). Table 5 shows the simple effects of castration and DOF on the feed cost of gain of Holstein bulls and steers while Table 6 shows the main effect of castration and Table 7 shows the main effect of DOF.

Total feed cost, total BWG, and trim yield in kg·animal^{-1} increased as DOF increased, and bulls had higher total feed costs, BWG, and trim yield in kg·animal^{-1} than steers ($P < 0.01$). No difference due to castration status was observed for cost of gain expressed in terms of BWG or trim yield ($P \geq 0.40$). Feed cost of BWG increased in both a linear and quadratic fashion as DOF increased ($P \leq 0.02$). The feed cost of BWG and trim yield increased at a decreasing rate as DOF increased, and from 378 d to 413 d cost of BWG changed from \$4.63 kg^{-1} BWG to \$4.61 kg^{-1} BWG. Feed cost of trim yield increased linearly as DOF increased ($P < 0.01$). A tendency for a quadratic increase in

cost of trim yield was also observed (*P* = 0.09). This indicates that feed cost of trim yield increases as DOF increases, while the feed cost of BWG increases at a decreasing rate as DOF increases.

In an economic analysis on increasing DOF by Wilken et al. (2015), it was found that increasing DOF increased total costs but also increased profitability when cattle were marketed on a HCW basis. Increases in HCW have been shown to greatly influence profitability when feed prices are high (Wilken et al., 2015). Because cost of gain was not different between bulls and steers in this study when expressed per unit of BWG or trim yield, and bulls had greater BWG and trim yield compared to steers, there is potential for increased profitability using bulls to increase kg of saleable product.

Applications

Bulls had greater live BW, HCW, and trim yield than steers when fed the same number of days. Steers showed greater linear increase in marbling scores and proportion of trim fat as DOF increased compared to bulls. Bulls had leaner carcass composition over time. The increase in live and carcass weights and difference in carcass composition is likely due to the androgenic effect of testosterone in bulls. Increasing DOF linearly increased live BW, HCW, TY, and feed cost per kg TY. Castration had no effect on cost of gain. These data indicate that feeding bulls in an organic production system will result in an increase in saleable product without negatively impacting feed cost of gain. However, meat quality is significantly influenced. Feeding bulls may increase profitability in a production system that is not penalized for low quality beef. Feeding cattle longer will also increase saleable product and potentially increase profits.

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Tables

Table 1. Diets fed to Holstein bulls and steers in five phases to simulate an organic production system

	Feeding Phase				
Ingredient, %DM	d 1 to d 63	d 64 to d 126	d 127 to d 189	d 190 to d 252	d 253 to Harvest
Dry Rolled Corn	31.0	40.0	53.0	60.2	65.0
Alfalfa Haylage	30.0	30.0	30.0	30.0	30.0
Fish Meal	4.0	3.0	2.0	0.8	0.0
Field Peas	30.0	22.0	10.0	4.0	0.0
Supplement[1]	5.0	5.0	5.0	5.0	5.0

[1]Supplement consisted of fine ground corn carrier with trace minerals, vitamins A-D-E, and limestone

1

Table 2. Simple effects of castration and days on feed on performance and carcass characteristics of Holstein bulls and steers fed a common diet for different days

	Steers				Bulls					*P* - Value				
Item	308[1]	343	378	413	308	343	378	413	SEM	CAST[2]	L	Q	L×L	Q×Q
No. of animals (pens)	30(3)	30(3)	28(3)	30(3)	28(3)	26(3)	28(3)	30(3)	-	-	-	-	-	-
Initial BW, kg	215	214	215	214	220	222	220	221	1.6	<0.01	0.78	0.87	0.61	0.77
DMI, kg·d^{-1}	9.1	8.9	9.2	9.3	9.5	9.4	9.7	10.3	0.26	<0.01	0.05	0.25	0.36	0.73
DMI, % of average BW[2]	2.49	2.42	2.40	2.33	2.49	2.40	2.40	2.41	0.041	0.44	<0.01	0.16	0.24	0.52
Live Performance														
Final BW, kg	516	523	568	590	539	567	594	627	11.6	<0.01	<0.01	0.55	0.73	0.77
ADG, kg·d^{-1}	0.98	0.90	0.93	0.91	1.04	1.01	0.99	0.98	0.030	<0.01	0.09	0.38	0.97	0.81
G:F	0.108	0.101	0.102	0.097	0.110	0.107	0.102	0.096	0.003	0.31	<0.01	0.97	0.35	0.52
Carcass Characteristics														
Hot Carcass Weight, kg	289.4	298.9	329.8	342.0	310.7	328.9	334.7	361.1	9.21	0.01	<0.01	0.68	0.60	0.86
Dressing Percentage, %	56.1	57.1	58.0	58.0	57.6	58.0	56.3	57.5	0.81	0.96	0.37	0.91	0.12	0.44
Marbling Score	433	485	479	549	336	345	342	357	15.2	<0.01	<0.01	0.59	0.01	0.81
Fat Depth, cm	0.43	0.41	0.48	0.51	0.20	0.15	0.15	0.18	0.036	<0.01	0.24	0.19	0.17	0.73
LM Area, cm^2	60.0	60.6	67.1	67.1	74.2	78.1	79.4	77.4	2.32	<0.01	0.01	0.37	0.26	0.45
Calculated Yield Grade	2.7	2.7	2.7	2.8	1.9	1.8	1.8	2.1	0.09	<0.01	0.11	0.07	0.53	0.25
Trim Yield, kg·animal^{-1}	208.9	208.7	232.9	241.5	219.3	239.3	240.4	265.3	8.19	<0.01	<0.01	0.56	0.75	0.86
Trim Yield, % of HCW	72.2	69.7	70.6	70.6	70.8	72.7	71.8	73.4	0.91	0.05	0.61	0.46	0.09	0.31
Trim Fat, %	8.8	12.0	15.8	15.2	8.1	7.5	7.8	5.7	1.60	<0.01	0.35	0.19	0.01	0.77
Trim Lean, %	91.2	88.0	84.2	84.8	92.0	92.5	92.2	94.3	1.60	<0.01	0.35	0.19	0.01	0.77
Trim Fat, kg·animal^{-1}	18.3	26.2	36.7	36.4	16.9	18.3	18.1	15.0	4.76	<0.01	0.05	0.29	0.02	0.75
Trim Lean, kg·animal^{-1}	194.3	182.5	196.2	205.2	196.7	221.0	222.3	250.3	11.76	<0.01	<0.01	0.41	0.10	0.55

[1]Average days on feed

[2]BW = body weight, CAST = castration status; DOF = days on feed, DMI = dry matter intake, ADG = average daily gain, G:F = gain to feed, L = linear response, Q = quadratic response, L×L = linear interaction, Q×Q = quadratic interaction, LM = longissimus muscle, HCW = hot carcass weight, d = day

[3]This was calculated as the average lb of DMI over the feeding period divided by the average Live BW over the feeding period

Table 3. Main effect of castration on performance and carcass characteristics of Holstein bulls and steers fed a common diet for different days

Item	Steers	Bulls	SEM	*P*-Value
No. of animals (pens)	118(12)	112(12)	-	-
Initial BW, kg	214	221	1.1	<0.01
DMI, kg·d^{-1}	9.2	9.7	0.19	<0.01
DMI, % of average BW[2]	2.42	2.40	0.028	0.44
Live Performance				
Final BW, kg	549	582	8.2	<0.01
ADG, kg·d^{-1}	0.93	1.00	0.021	<0.01
G:F	0.102	0.104	0.002	0.31
Carcass Characteristics				
Hot Carcass Weight, kg	315.1	333.8	6.50	0.01
Dressing Percentage, %	57.3	57.3	0.57	0.96
Marbling Score	487	345	10.7	<0.01
Fat Depth, cm	0.46	0.18	0.025	<0.01
LM Area, cm^2	63.9	77.4	1.61	<0.01
Calculated Yield Grade	2.73	1.92	0.063	<0.01
Trim Yield, kg·animal^{-1}	223.0	241.1	5.79	<0.01
Trim Yield, % of HCW	70.8	72.2	0.58	0.05
Trim Fat, %	12.7	7.2	1.12	<0.01
Trim Lean, %	87.3	92.8	1.12	<0.01
Trim Fat, kg·animal^{-1}	29.4	17.1	3.45	<0.01
Trim Lean, kg·animal^{-1}	194.5	222.6	8.53	<0.01

[1]BW = body weight, DMI = dry matter intake, ADG = average daily gain, G:F = gain to feed, LM = longissimus muscle, HCW = hot carcass weight, d = day
[2]This was calculated as the average lb of DMI over the feeding period divided by the average Live BW over the feeding period

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Table 4. Main effect of castration on performance and carcass characteristics of Holstein bulls and steers fed a common diet for different days

	DOF[1]					*P*-Value	
Item	308	343	378	413	SEM	L	Q
No. of animals (pens)	58(6)	56(6)	56(6)	60(6)	-	-	-
Initial BW, kg	217	218	217	218	1.1	0.78	0.87
DMI, $kg \cdot d^{-1}$	9.3	9.2	9.5	9.8	0.19	0.05	0.25
DMI, % of average BW[2]	2.49	2.41	2.37	2.37	0.028	<0.01	0.16
Live Performance							
Final BW, kg	528	545	582	609	8.2	<0.01	0.55
ADG, $kg \cdot d^{-1}$	1.01	0.95	0.96	0.95	0.021	0.09	0.38
G:F	0.109	0.104	0.102	0.097	0.002	<0.01	0.97
Carcass Characteristics							
Hot Carcass Weight, kg	300.0	314.0	332.2	351.6	6.50	<0.01	0.68
Dressing Percentage, %	56.8	57.6	57.1	57.7	0.57	0.37	0.91
Marbling Score	385	411	415	453	10.7	<0.01	0.59
Fat Depth, cm	0.33	0.28	0.33	0.36	0.025	0.24	0.19
LM Area, cm^2	67.1	69.0	73.5	72.3	1.61	0.01	0.37
Calculated Yield Grade	2.3	2.27	2.25	2.25	0.063	0.11	0.07
Trim Yield, $kg \cdot animal^{-1}$	214.1	224.0	236.7	253.4	5.79	<0.01	0.56
Trim Yield, % of HCW	71.5	71.3	71.2	72.0	0.58	0.61	0.46
Trim Fat, %	8.4	9.5	11.2	9.4	1.12	0.35	0.19
Trim Lean, %	91.6	90.5	88.8	90.5	1.12	0.35	0.19
Trim Fat, $kg \cdot animal^{-1}$	17.6	22.2	27.4	25.7	3.45	0.05	0.29
Trim Lean, $kg \cdot animal^{-1}$	195.5	201.8	209.2	227.7	8.53	<0.01	0.41

[1]BW = body weight, DOF = days on feed, DMI = dry matter intake, ADG = average daily gain, G:F = gain to feed, L = linear response, Q = quadratic response, LM = longissimus muscle, HCW = hot carcass weight, d = day

[2]This was calculated as the average lb of DMI over the feeding period divided by the average Live BW over the feeding period

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Table 5. Simple effects of castration and days on feed on feed cost of gain of Holstein bulls and steers fed a common diet for different days

	Steers				Bulls					*P* - Value				
Item	308[1]	343	378	413	308	343	378	413	SEM	CAST[2]	L	Q	L×L	Q×Q
Total Feed Cost, $\$\cdot animal^{-1}$	1295	1396	1622	1724	1358	1641	1738	1886	47.3	<0.01	<0.01	0.33	0.59	0.33
Total BWG, $kg\cdot animal^{-1}$	301.6	308.9	353.7	375.9	319.5	344.9	374.5	405.8	10.80	<0.01	<0.01	0.51	0.76	0.77
Trim Yield, $kg\cdot animal^{-1}$	208.9	208.7	232.9	241.5	219.3	239.3	240.4	265.3	8.19	<0.01	<0.01	0.56	0.75	0.86
Feed COG, $\$\cdot kg^{-1}$ BWG	4.30	4.54	4.61	4.59	4.25	4.76	4.63	4.63	0.106	0.40	<0.01	0.02	0.90	0.40
Feed COG, $\$\cdot kg^{-1}$ TY	6.22	6.70	6.97	7.14	6.20	6.86	7.23	7.12	0.214	0.55	<0.01	0.09	0.95	0.48

[1]Average days on feed

[2]CAST = castration status; COG = cost of gain; DOF = days on feed, BWG = live body weight gained, TY = trim yield, L = linear response, Q = quadratic response, L×L = linear interaction, Q×Q = quadratic interaction, d = day

[3]Prices used for calculation on a DM basis: fish meal = \$2131.63 MT^{-1} after a 5% shrink, field peas = \$686.07 MT^{-1} after a 5% shrink, dry rolled corn = \$444.98 MT^{-1} after a 2% shrink, alfalfa haylage = \$320.48 MT^{-1} after a 15% shrink

Table 6. Main effect of castration on feed cost of gain of Holstein bulls and steers fed a common diet for different days

Item[1]	Steers	Bulls	SEM	*P*-Value
Total Feed Cost, $\$\cdot animal^{-1}$	1509	1656	33.4	<0.01
Total BWG[2], $kg\cdot animal^{-1}$	335.0	361.2	7.64	<0.01
Trim Yield, $kg\cdot animal^{-1}$	223.0	241.1	5.79	<0.01
Feed COG, $\$\cdot kg^{-1}$ BWG	4.50	4.56	0.075	0.40
Feed COG, $\$\cdot kg^{-1}$ TY	6.77	6.86	0.152	0.55

[1]Prices used for calculation on a DM basis: fish meal = \$2131.63 MT^{-1} after a 5% shrink, field peas = \$686.07 MT^{-1} after a 5% shrink, dry rolled corn = \$444.98 MT^{-1} after a 2% shrink, alfalfa haylage = \$320.48 MT^{-1} after a 15% shrink

[2]BWG = live body weight gained, COG = cost of gain, TY = trim yield, d = day

Table 7. Main effect of increasing days on feed on feed cost of gain of Holstein bulls and steers fed a common diet for different days

	DOF[1]					*P*-Value	
Item[2]	308	343	378	413	SEM	L	Q
Total Feed Cost, $\$\cdot animal^{-1}$	1326	1517	1680	1805	33.4	<0.01	0.33
Total BWG[2], $kg\cdot animal^{-1}$	310.6	326.9	364.1	390.9	7.64	<0.01	0.51
Trim Yield, $kg\cdot animal^{-1}$	214.1	224.0	236.7	253.4	5.79	<0.01	0.56
Feed COG, $\$\cdot kg^{-1}$ BWG	4.28	4.65	4.63	4.61	0.075	<0.01	0.02
Feed COG, $\$\cdot kg^{-1}$ TY	6.22	6.77	7.10	7.12	0.152	<0.01	0.09

[1]DOF = average days on feed, BWG = live body weight gained, TY = trim yield, L = linear response, Q = quadratic response d = day

[2]Prices used for calculation on a DM basis: fish meal = \$2131.63 MT^{-1} after a 5% shrink, field peas = \$686.07 MT^{-1} after a 5% shrink, dry rolled corn = \$444.98 MT^{-1} after a 2% shrink, alfalfa haylage = \$320.48 MT^{-1} after a 15% shrink

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