Effects of Field Pea Usage in Growing and Finishing Diets for Beef Cattle

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EFFECTS OF FIELD PEA USAGE IN GROWING AND FINISHING DIETS FOR
BEEF CATTLE

by

Hannah L. Greenwell

A THESIS

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The value of field peas (FP) as a feedstuff has not been thoroughly assessed and compared to other feeds, such as corn, to better establish an economic value. Field peas are characterized by a high CP content (23-26%), a large portion (80%) being rumen degradable protein (RDP), and containing almost a third less starch (31-40%) than corn. Three research trials were performed to better understand the value of FP as a grazing supplement, finishing diet component, and any effects on digestion. Experiment 1 assessed the value of FP as a grazing supplement compared to corn. Grazing was followed by a finishing period with or without FP inclusion at 20% (DM basis). Cattle supplemented FP on pasture had greater ending BW and ADG than those cattle that were not supplemented and lower gains than those cattle supplemented a mixture of DRC, solubles and urea. Finishing performance and carcass characteristics were similar across treatments other than those cattle that were not supplemented on pasture experienced compensatory gain during finishing through increased ADG and G:F.

Two digestion trials were conducted to compare FP to corn in high forage diets and to assess rumen undegradable protein (RUP) of FP. In Exp. 1 cattle were fed either a
high (HQ) or low quality (LQ) forage with no supplement (CON), supplemented with FP (PEAS), or supplemented with dry-rolled corn, solubles, urea mixture (CORN) at 0.43% of BW (DM basis). Field peas increased DMI, DM digestibility, OMI, OM digestibility, and NDF digestibility when measured at 24 hours in situ. Feeding FP resulted in VFA concentrations similar to the CON treatment. In Exp. 2, FP were ruminally and duodenally incubated to evaluate RUP content and digestibility. Results show that the specific field peas that were evaluated ranged in CP content from 22 – 26.5% with an RUP content that was significantly affected by rumen incubation duration. As rumen incubation time increased, RUP content decreased. Digestibility of RUP of FP ranged from 97.4 – 98.9%. These studies suggest that if appropriately priced, FP would be a viable option for grazing supplementation or inclusion in finishing diets.

Keywords: field peas, cattle, beef
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Review of Literature

Protein

Metabolizable Protein

The shift from use of the crude protein (CP) system to the metabolizable protein (MP) system represents the extensive understanding that has developed in better defining protein requirements of ruminant animals (Burroughs et al., 1974; NRC, 1985, 2000). Being able to separate the nitrogen requirements of the microbes within the animal’s digestive tract and the amino acid requirements of the animal is a key concept for feeding ruminants and allows for more efficient use of feedstuffs and growth. The CP system made the assumption that all feedstuffs have equal protein degradation in the rumen. Increased information on bacterial crude protein (BCP) synthesis and digestive kinetics of rumen degradable protein (RDP) allow for improved prediction of protein metabolism (NRC, 2000). Metabolizable protein is the protein fraction which is digestible and accessible to the animal. Best defined as the quantity of true protein or amino acids absorbed by the small intestine (Wilkerson et al., 1993; NRC, 2000; NRBC, 2016), sources of MP include digestible rumen undegradable protein (RUP) and BCP (Burroughs et al., 1974; NRC, 1985, 2000; NASEM, 2016).

Rumen degradable protein is crucial in the metabolizable protein system because more than half of the MP is derived from BCP (NRC, 1985; Spicer et al., 1986). Initially, BCP production was determined by energy intake using total digestible nutrients (TDN) to calculate potential production (Burroughs et al., 1974), however further research by Wilkerson et al. (1993), Stokes et al. (1991), and Hoover and Stokes (1991) suggest there
are more factors that would aid in better defining BCP production. Wilkerson et al. (1993) suggest ruminal digestible organic matter (OM) is one of the additional factors related to microbial production. Others have also identified that RDP and nonstructural carbohydrates should be considered (Stokes et al., 1991; Hoover and Stokes, 1991).

Due to the complex system of ruminants and those microorganisms which inhabit the animal, there is uncertainty in the text of the 2000 NRC on protein calculations. Researchers have challenged the formulas for prediction of animal performance based on protein. This research has led to modified and improved methods for predicting animal performance. However, the majority of the methods also present their own limitations.

The seventh revised edition of the Nutrient Requirements of Beef Cattle (2000) formula uses total digestible nutrient intake (TDNI) multiplied by 0.13 for diets containing greater than 40 percent forage. BCP synthesis can be adjusted for higher grain diets that contain less than 40 percent forage, as the 0.13 value is representative of high fiber diets. It is suggested that the lower fiber diets should be adjusted by a 2.2 percent reduction in BCP synthesis for every 1 percent decrease in forage effective neutral detergent fiber (eNDF) less than 20% NDF (NRC, 2000). The current model has been challenged by multiple researchers who have developed alternative models or suggested changes in the MP system ranging from alterations in the formulas to suggestions for increased research to determine appropriate input values (Russell et al., 1992; Patterson et al., 2003; Lardy et al., 2004; Owens et al., 2014; Galyean and Tedeschi, 2014).

Galyean and Tedeschi (2014) assembled a database of 285 treatments from 66 published papers to evaluate the formula for predicting BCP synthesis against models
including more factors for BCP synthesis calculation. Total digestible nutrients, Fat-free TDN (FFTDN) concentration, CP intake (CPI), and true ruminal organic matter digested (TROMD) were included in the models. True ruminal OMD was highly related to BCP synthesis, and the new equations show minimal bias across the range of BCP synthesis and the variables used, unlike the NRC (2000). However, standard errors were 25 to 30 percent of mean values. Even though the standard errors of prediction were so high, the NRBC (2016) uses dietary ether extract values to correct TDNI when available due to accuracy of the models developed by Galyean and Tedeschi (2014) with a cut off at 3.99% fat diet content. Lardy et al. (2004) suggested use of 0.10 for microbial efficiency in low quality forage diets has also been adapted into the new Beef Cattle Nutrient Requirements Model (BCNRM). Other suggestions included that requirements and supply of nitrogen (N) in the ruminant system should be expressed on an amino acid basis. An understanding of how RDP and RUP may provide complementary amino acids to each other, would allow for lower N intakes due to more efficient digestion (Colombini and Broderick, 2010), leading to less excretion of excess N and consequently lower environmental impact.

Rumen Degradable Protein

An adequate supply of nitrogen to the microbes allows for the proper digestion of all other nutrients as well as the full contribution of BCP to the animal. Being able to properly estimate the amount of BCP production in the rumen is essential to the metabolizable protein system (Galyean and Tedeschi, 2014). Microbes require not only adequate rumen degradable protein supply, but also fermentable energy in order to digest
the nitrogen supplied to them. Ensuring adequate amounts of RDP are available allows for prevention of adverse effects on microbial growth (Satter and Slyter, 1974; Kang-Meznarich and Broderick, 1981). However, overfeeding of RDP will result in excreting excess nitrogen (Poos et al., 1979, Shain et al., 1998). Extent of degradation in the rumen depends on a list of factors: feed processing methods, ruminal pH, diet forage:concentrate ratios, protein structure, nutrient interactions, and ruminal dilution rate (NRC, 1985; Bach et al., 2005). In times when RDP levels are not adequate, the ruminant animal has the capability to recycle nitrogen through the saliva as urea as well as across the rumen wall as ammonium in the blood. The microbes are even able to adapt to asynchronous nitrogen and energy supply with the use of the recycling pathways (Reynolds et. al, 2008, Wickersham et. al, 2008). Wickersham et al. (2008) went on to specify that urea recycling plays a substantial role in steers supplemented infrequently with high levels of protein. This point of information can be applied to producers who operate under conditions which prevent consistent supplementation such as weather, terrain, distance, cost, etc.

A point of consideration related to the MP System and RDP supply is the efficiency that microbes convert supplied RDP to BCP. Research has proven that differences in microbial growth efficiency occur due to variable microbial community composition (Russell et al., 1992) and differences in diets (Galyean and Tedeschi, 2014). Review of the NRC (1985, 1996, 2000) shows variable estimates to this question, ranging from 100 percent efficiency to 90 percent to 85 percent. However, due to the ruminant’s ability to recycle excess N, the industry standard remains at 100 percent of RDP
converted to BCP due to a limited ability to measure recycled N in the animal (NRBC, 2016).

**Rumen Undegradable Protein**

The fraction of protein not hydrolyzed in the rumen, rumen undegradable protein (RUP), is partially available to be absorbed in the small intestine, depending on RUP digestibility. The importance of RUP is that the animal gets more access to amino acids that the microbes of the rumen were not able to digest. Quantifying the RUP component of feeds and more specifically, digestible RUP, is important because this component is not affected by the inefficiencies of rumen microbial N use (Buckner et al., 2013a). In order for an animal to produce a response from increased RUP, the RDP requirements must be met (Klopfenstein, 1996). The RUP required to meet MP demand is greatest in growing cattle and lactating cows (Klopfenstein, 1996).

Improved performance has been observed by supplementing rumen protected and slowly degraded protein on grazed forage diets (Stobbs et al., 1977; Penning and Treacher, 1982; Craig, 1983). The improved performance would suggest that even though grazed forages are high in crude protein, they do not meet the animal’s metabolizable protein requirements (Anderson et al., 1988). This theory has been evaluated in multiple seasons with smooth brome grass pasture (Anderson et al., 1988; Creighton et al., 2003), summer native range (Karges et al., 1992; Lardy et al., 2004), and big bluestem pastures (Blasi et al., 1991). Across all of these experiments, animal performance was improved by supplementing RUP when RDP requirements were met and MP was the first limiting nutrient.
Multiple research projects on RUP supplementation with animals grazing pasture suggests that differences exist in warm and cool season grasses. Compared to cool season grasses, warm season grasses tend to be more slowly degraded (Akin, 1989), therefore providing a greater proportion of RUP to the animal. Blasi et al. (1991) observed a greater response from supplemental RUP in lactating cows grazing smooth brome pastures when compared to those cows grazing big bluestem pasture. They concluded that the MP was limiting on the cool season pasture but not as limiting on the warm season pasture. A response was observed by Anderson et al. (1988) with RUP supplementation on smooth brome grass pastures. As RUP supplementation increased, gain of grazing steers increased.

The alteration in nutrient composition of plants as the growing season progresses also presents an opportunity for animals to become protein deficient, as biomass increases, altering percent composition of plants. As plants become more mature and move out of the vegetative stage, they typically decrease in CP content (NRC, 1996). The RDP:RUP ratio also changes with increasing amounts of RUP and decreasing amounts of RDP. As previously discussed, without adequate amounts of RDP, animals cannot benefit from increased amounts of RUP. Expressing RUP as a percentage of DM was proposed by Burken et al. (2013) as a better means of meeting MP requirements when discussing forage in cattle diets.

**Fiber Digestion**

Fiber is defined as the plant cell wall, and dietary fiber consist of polymers that are unavailable to mammalian digestive enzymes. These polymers make up 40 – 70% of
the dry matter in forages (Van Soest, 1994). In high forage diets, this would mean that a large proportion of an animal’s diet is inaccessible to the animal itself. In an effort to maximize digestibility and usage of feeds, it is important to understand those factors which affect the ruminal microbes. Four factors are the components of the calculation that make up fiber digestion in ruminants: plant structure and composition, fiber-digesting bacteria population density, microbial attachment and hydrolysis, and animal factors (i.e. mastication, salivation, digesta kinetics; Cheng et al., 1991).

Akin (1989) stated that the interaction of animal and plant factors affect extent of physical digestion promoting passage of plant residues and influencing forage intake. According to Allen and Mertens (1987), forage digestibility is a constant “competition” between passage rate and digestion rate. This is a reflection of how quality of forage can impact fiber digestion. The majority of differences between forages can be attributed to the differences in the fiber fraction, since the cell solubles are 98% digestible (Van Soest, 1967; Mertens and Ely, 1979). Those forages that are considered high quality are characterized by a high digestibility and a relatively higher passage rate, consequently increasing intakes. Low quality forages are observed to have lower extent of digestion, slower passage rates, and depressed intake (Mertens, 1994). Two factors that impact extent of digestion and rate of passage are plant maturity which consequently affects quality, and the composition of the rumen microorganism population.

The amount of lignin, an indigestible component, in a plant is representative of the plants digestibility (Waldo et al., 1972). Lignification has a direct relationship with plant maturity. However, this can be altered during high-stress growing situations (i.e.
lack of water) where lignification is accelerated (Akin, 1989). Rumen bacteria have an enormous capacity for breaking down forages (Hungate, 1966) since these bacterial species possess cellulases, hemicellulases, or pectinases, with some species possessing multiple carbohydrate enzymes (Akin, 1986). Miura et al. (1983) and Wolin (1981) also addressed that there is synergy in the bacteria’s ability to cross feed and transfer H₂ between species. Being able to transfer hydrogen will prevent the potential for decreased rumen pH. Since cell solubles are 98% degraded (Van Soest, 1967), the limitations lie in the fibrous components primarily made up of structural carbohydrates (Akin, 1986).

A significant factor to fiber digestion is the use of starch in formulating ruminant diets. The presence of starch and sugars in the diet reduces fiber digestion, which can also decrease intake of the diet (Hoover, 1986; Olson et al., 1999). The addition of starch into diets can also increase lag time, also known as attachment period, or the amount of time it takes for rumen microbes to reach the fiber, attach, and initiate digestion. However, Mertens et al. (1980) observed that rate of digestion was not affected but extent of degradation was decreased. These effects are hypothesized to be a result of change in rumen pH which suppresses microbial population and activity leading to decreases in intake (Ørskov, 1986). The same author summarized starch digestion research from Karr et al. (1966), Ørskov et al. (1969), and Beever et al. (1970) concluding that the starch content of barley, oats, and wheat is 90% digested in the rumen, while corn starch can be found in levels up to 40% postruminally. The associative effects of starch and other components on fiber digestion can be crucial factors to consider when supplementing high forage diets and will be discussed in following sections.
Forage Quality

It is difficult to discuss fiber digestion and forage quality as two separate sections when they are conceptually synonymous. As Ulyatt (1981) expressed, forage quality can be evaluated in terms of the digestibility or fermentation of plant constituents and in terms of the amount of feed that ruminants consume. Therefore, the purpose of this section is to address the concepts of digestibility and quality in terms of evaluating different types of forage.

Plant species, stage of maturity, management practices, and weather conditions all factor into forage quality and specifically affect parameters such as DM digestibility, CP, and palatability (Von Keyserlingk et al., 1996; Bohnert et al., 2011). The first characterization of grasses tends to be the grouping into either cool season (C3) or warm season (C4) grasses. The general assumption is that cool season grasses are of greater nutritional value than warm season grasses (Galyean and Goetsch, 1992; Barbehenn et al., 2004) because of differences in photosynthetic products and growing temperatures leading to differences in tissue makeup (Akin, 1986a, 1989).

Although there are multiple factors contributing to quality, plant physiological and morphological development has the greatest impact on nutrient composition of plants (Watson, 1950; Meyer et al., 1957; Morrison, 1956) and consequently, quality. As growing season progresses, temperature alters, and water and nutrients dwindle, a decline in forage quality is observed. Structural components increase, altering the leaf-to-stem ratio (Blaser et al., 1964), highly digestible portions of the plant decrease, and nutrients such as protein, decrease as percent of plant DM.
While it always beneficial when producers have access to high quality forages, sometimes the only option is to use lower quality forages that are more economical. There is also opportunity for compensation of lower quality forages with protein supplementation in order to achieve desired performance results while still maintaining economics.

Ultimately it is difficult to develop a broad generalized model to measure forage quality. Initially, proximate analysis attempted to quantify the nutritive value of individual feed components (Van Soest, 1994), however faltered due to compounding error, leading to the development of the Van Soest Fiber System (Goering and Van Soest, 1970). While this is an improved method of determining neutral detergent fiber (NDF) and acid detergent fiber (ADF) components, there are still limitations to evaluating feedstuffs, such as starch content requiring amylase for digestion (Buckner et al., 2013b).

### High Forage Diet Supplementation

Since cattle have the potential to be protein deficient when grazing dormant or low quality forages, Bonhert et al. (2011) evaluated protein supplementation on both warm season and cool season grasses. Intake and digestibility of C4 forages increased more than C3 grasses as a response to protein supplementation.

Studies have shown an increase in total digestible organic matter intake (TDOMI) with increasing RDP supplementation levels (Guthrie and Wagner, 1988; Scott and Hibberd, 1990; Köster et al., 1996). Köster et al., (1996) evaluated supplementation of RDP for cattle on low quality forage. At the greatest, there was a 58% increase in the intake of low quality forage when RDP was supplemented in the diet. Church et al.
(1981) evaluated the forage intake response to CP supplementation for soybean meal or from a liquid supplement containing non-protein nitrogen (urea). They determined that an increase in forage intake was observed when supplementing organic proteins such as the soybean meal, but the same increase in response was not as likely with a urea containing liquid supplement. The use of the liquid supplement can be quite expensive; however in cases that require the use of low quality forage, the increased input may improve the forage quality enough to make the increase in animal performance economical. This study demonstrates that while supplemented RDP can produce more desirable results, there are situations where limitations occur and point of diminishing returns is present, as with the liquid supplement.

Shain et al. (1998) supplemented steers with urea to adequate levels of rumen degradable protein as well as no supplementation (deficient) and showed that the cattle were more efficient with an adequate RDP supply only to a certain level. While this study used finishing diets, it demonstrates that using urea as a source of RDP for supplementation is plausible, showing that adequate levels of rumen protein could be achieved through inexpensive N sources such as urea when other RDP sources are not economically feasible.

**Compensatory Gain**

Compensatory gain is defined as the accelerated growth an animal experiences after a time of limited nutritional availability (NRC, 1996). Osborne and Mendel (1915, 1916) observed the effect of a period of inhibited growth on the subsequent gain succeeding when an animal’s nutritional plane becomes improved. Since then numerous
Researchers have looked to better understand the mechanisms surrounding compensatory gain in an effort to find when accelerated growth could best fit production systems. This would be applicable in times of limited nutrient availability or when low quality feeds are available.

Typically accelerated growth is seen after a growing period between weaning and finishing has been implemented. The growing period potentially allows cattle to increase body development before fattening, providing the ability to reach a finishing point at a desirable carcass weight (Sainz et al., 1995). Once cattle are placed on full feed after backgrounding, they experience accelerated growth rate and compensate for their time on a lower plane of nutrition that would have occurred during the growing period. Those cattle that are perceived to have been on a lower plane of nutrition attract premiums during sale because producers see the potential for improved efficiency (Sainz et al., 1995).

The alterations in cattle performance that develop the equation to create compensatory gain are increased BW gain (Fox et al., 1972; Carstens et al., 1991; Sainz et al., 1995) and DMI (Fox et al., 1972; Drouillard et al., 1991; Sainz et al., 1995) with lower ME requirements for the animal or increased efficiency of metabolizable energy used for gain (Fox et al., 1972; Carstens et al., 1991; Hersom et al., 2003).

Studies evaluating the effects of tall fescue grazing, more specifically endophyte fungus, on subsequent feedlot gains have been consistent. Cattle that have grazed tall fescue pastures during the summer have compensated in the feedlot compared to those cattle that were grazing endophyte free fescue (Cole et al., 1987; Coffey et al., 1990;
The same accelerated gain has been seen when calves are wintered on a low plane of nutrition and turned out onto range in the summer (Nelson and Campbell, 1954; Bohman and Torrell, 1956). Compensatory gain has also been observed when cattle are in a feedlot on concentrate based diets that are limit fed and followed by full feed (Carstens et al., 1991; Sainz et al., 1995).

The difficulty with compensatory gain is that it is typically unpredictable (Sainz et al., 1995). The parameters surrounding the mechanism are not well defined and therefore make use of the change in growth difficult to predict. Parameters such as the length of growing phase, level of nutrition, and severity of restriction have not been properly quantified, making compensatory gain unpredictable and variable. However, it has been indicated that the magnitude of compensation is proportional to the intensity of the previous growth restriction (Coleman and Evans, 1986; Horton and Holmes, 1978).

**Growing Field Peas**

Over the past 5 years, there has been a large increase in field pea (*Pisum sativum*) production, increasing the need for a market for the product. A large increase has been seen primarily in the Great Plains region, more specifically the Northern portion (i.e. Colorado, Montana, Nebraska, North Dakota, South Dakota, and Wyoming). The increase in North Dakota has been measured regularly each year and in 1994 the total production was 5,600 ha of peas that increased to 55,800 ha in 2003 (Reed et. al, 2004). On a national scale, the number of hectares planted increased from 146,496 in 2011 to 513,141 in 2016 (NASS, 2016). The majority of field peas are routed for the human consumption, dry pea market, and for seeds used by fresh garden growers (Oelke et al.,
1991). However, those market outlets are limited in the amount of product in which they can take due to their mechanized processing steps, as well as maintaining high quality standards. Therefore, feeding field peas to livestock, more specifically cattle, started as a cropping surplus with no outlet, where the surplus is priced competitively enough to compete as a livestock feed (Fendrick et al., 2006).

Field peas provide numerous benefits to a cropping system including pest management, weed control, nitrogen fixation, and soil microbe diversity. With a similar planting and harvesting seasons to wheat, peas can serve as an alternative in a crop rotation. Planting occurs in late March to early April and harvest occurs in the middle of June to the middle of July (McKay et al., 2003). A shorter growing season than other cereal grains enables farmers to naturally increase weed and pest management and improve soil health without interfering with other cash crops such as corn. Increased weed occurrence in crop fields also decreases available soil nutrients for crops as it has been demonstrated that weeds tend to accumulate higher concentrations of nitrogen, phosphorous, potassium, calcium, and magnesium (Di Tomaso, 1995). Field peas naturally help with weed control by decreasing biomass production and population density in a monoculture planting system through increased temporal diversity (Liebman and Dyck, 1993). By decreasing occurrence of weeds, the cost of herbicides, and consequently overall production cost are decreased. Having a succession of different crops increases ability to combat pest problems (Allen et al., 1970; Roberts and Thomason, 1981; Flint and Roberts, 1988) as well as potentially preventing plant diseases (Butterfield et al., 1978; Krupinsky et al, 1980; Conner and Atkinson, 1989). These
advantages also potentially lead to lower production costs with less need for pesticides while also increasing sustainability. Because field peas are a legume, they have a nitrogen fixation characteristic which improves soil health and potentially decreases inorganic fertilizer needs. Use of leguminous crops such as field peas also encourages microbial diversity in the soil which contributes to improved crop production (Krupinsky et al, 1980).

**Field Pea Usage in Beef Cattle Diets**

*Industry Shifts*

The beef industry must always strive to be dynamic, adaptable, and just as important, sustainable. Because of this, the industry goes through trends and shifts on a regular basis to maintain and improve production and profitability. Feedstuff options tend to be one of those dynamic factors that encourage producers to choose options best fit to their geographical and economical situations. Record corn prices, ethanol production, as well as land competition (Corah, 2008) lead to increased distillers grains use and increased value of land. The use of field peas as a livestock feed developed out of the decision to plant field peas for farmers to improve their cropping system as previously discussed. The result was a new, potentially highly valuable livestock feed for ruminants. While there are agronomic advantages to planting field peas, there is limited research on feeding field peas to ruminants compared to other widely used grain feedstuffs.

Ever since the ethanol boom in the United States, there has been an increased amount of distillers grains included in cattle rations that has led to high protein levels in finishing diets. Before distiller’s grains, diet formulation would have consisted of
balancing on a protein basis with protein being the expensive component of the diet costs. Post-distillers grains, diets can typically be formulated on an energy basis. The by-products of ethanol production have historically been cheaper than corn, therefore allowing the use of cheap feedstuffs on a dollar per unit of energy basis. These by-products are also a good source of protein, but research at the University of Nebraska suggest that optimal levels of inclusion for distillers grains means feeding them on an energy basis rather than a protein basis, which leads to over-feeding protein (Bremer et al., 2011). The ethanol production facilities are also looking at new technologies that allow them to pull more nutrients out of the by-products of their production processes to increase profitability and overall amount of product. This is changing the product that cattle feeders are purchasing and altering diet composition in a negative way (Carlson et al., 2016 Nebraska Beef Reports). There are also limited distillers grains in the areas in which field peas are grown.

**Nutrient Composition**

On a nutrient composition basis, field peas are characterized by a high degradability of the crude protein fraction (Focant et al., 1990, Aguilera et al., 1992). Crude protein levels have typically ranged between 23 – 25% (Anderson et al., 2007). The levels of ruminally degradable protein are greater than that of corn with estimates ranging from 78 – 94% of CP (Anderson et al., 2007). In experiments where field peas were compared to corn, field peas have been reported to be similar in energy content (Loe et al., 2004) while others reported a lower energy content (Fendrick et al., 2005). Field peas have less starch than corn (approximately a third less; Fendrick et al., 2005) and
starch fermentation is slower than barely or wheat, but approximately the same as corn (Anderson et al., 2007). Corn does have lower neutral detergent fiber content than field peas (Gilbery et al., 2007). Field peas do contain antinutritional factors such as trypsin inhibitors, chymotrypsin inhibitors, amylase inhibitors, lectins, tannins, phytate, and oligosaccharides (Hanbury et al., 2000). With a nutrient composition competitive with other cereal grains, field peas are a viable option for inclusion in diets that are not only forage-based, but also grain based such as growing and finishing diets.

**Performance Results**

The majority of previous research evaluating the performance characteristics of cattle fed field peas has revealed similar results of average daily gain (ADG) and feed conversions (G:F) among studies. Several studies report consistent results that display inclusion of field pea has no effect on G:F (Loe et al., 2004; Fendrick et al., 2005; Carlin et al., 2006; Jenkins et al., 2011). Contradictory results were produced by Flatt and Stanton (2000) where inclusion of field peas at 20% replacement of corn increased G:F with a decrease in DMI and a steady ADG. Previous research has also shown that field peas are capable of providing the same performance results as other cereal grains such as corn, wheat, millet, barley, etc. up to certain levels (Reed et. al, 2004, Jenkins et. al, 2011).

The effect of field peas on DMI has been inconsistent. Fendrick et al. (2005), included peas in dry rolled corn finishing diets up to 59% of the diet. A quadratic response in DMI with the highest DMI occurring at 40% inclusion of whole peas was observed. Opposing results are found in several studies that did not see a difference in
DMI with inclusion of field peas. However none of those studies had rates of inclusion as high as the aforementioned study (Loe et al., 2004; Lardy et al., 2009; Jenkins et al., 2011, Pesta et al., 2012). The same opposing results were found in studies that looked at the replacement of barely with field peas. While Lardy et al. (2009) showed no changes in DMI, Anderson et al. (1999) reported an increased DMI as inclusion of peas increased. Field peas degrade in the rumen at a similar rate to dry rolled corn (Corbett, 1994), and a slower rate than barely. This could explain why the majority of results in DRC diets suggest no changes in DMI, where barely based diets have a tendency to increase in DMI with inclusion of field peas in finishing diets (Jenkins et al., 2011).

Processing Method Effects

As is the case with most grains fed to beef cattle, processing method is crucial to the efficiency of digestion. Processing methods proven to improve metabolizable energy of cereal grains include rolling, ensiling, steam flaking, or grinding (Owens et al., 1997). However, field pea performance is not altered when the processing method of coarse rolling is compared to feeding whole field peas Fendrick et al. (2006). In the trial, finishing cattle were fed either whole field peas or coarse rolled field peas at 15 or 30% of diet dry matter. Statistically, no differences were observed between the processing types for DMI, ADG, or F:G. Birkelo et al. (2000) also examined including field peas at 10% dry matter in finishing diets as either whole peas or dry rolled peas. The results concluded that in a whole corn and silage diet, the two processing methods did not differ in performance results.
Focant et al. (1990) evaluated processing field peas by heat treating two different ways, steam flaking and extrusion. In a metabolism study with six fistulated dairy heifers, the two methods were evaluated in a diet consisting of 40% peas. Steam flaking did not affect any of the measured in vivo parameters, however, extrusion had a significant affect in N related parameters, typically increasing N availability in treatments that included extruded peas.

Effects on Carcass Characteristics, Sensory Attributes, and Tenderness

Analysis of carcass characteristics of cattle fed field peas produces varying results. While the majority of research observed no differences in carcass characteristics, there are some studies with differing results. Lardy et al. (2009) observed a quadratic increase in 12th rib fat, and a linear increase in marbling score as field pea levels increased. Jenkins et al. (2011) saw a quadratic response for KPH. Fendrick et al. (2009) reported a linear decrease in LM with increased field pea concentrations reaching as high as 59% of diet DM. In dry rolled corn based diets, Lardy et al. (2009) and Jenkins et al. (2011) reported no difference in yield grade; however, there was a tendency for an increase in yield grade in barley based diets. While Jenkins et al. (2011) reported no effects on marbling score with increasing field pea levels, Anderson (1999) observed increased marbling scores, followed by an expected increase in number of carcasses graded USDA Choice.

Jenkins et al. (2011) also evaluated the sensory attributes and tenderness of the beef product of cattle fed increasing levels of field peas. Feeding up to 30% of the diet as field peas increased desirability of the beef product. Carlin et al. (2006) found shear force
was decreased and juiciness ratings increased linearly with increasing concentration of field peas. No differences in flavor or off flavor were observed. Magolski et al. (2008) evaluated steaks from steers fed field peas during just the finishing period, or for the entire feeding period (receiving and finishing) and compared them to steaks from steers fed corn throughout the entire feeding period. Shear force was less for steers fed field peas throughout the entire finishing period. However, in contrast to Carlin et al. (2006), there were no differences noted in tenderness, juiciness, or off flavor were observed. Panelists reported that the corn-fed steaks had a stronger beef flavor than the pea-fed steaks.

**Conclusion**

The initial priority for field pea production is the human consumption market. However, the human consumption market has high quality standards that will not accept all of the field peas produced. Livestock producers are at an advantage to be able to give a salvage value to a wasted product that may otherwise have no value. The bigger advantage comes from the potential of this medium-protein, high-energy feedstuff which fits very well into beef cattle diets in various production settings. Advantages have been seen in feeding field peas as a protein supplement to grazing cattle. Also in growing and finishing diets, field peas produce similar results to commonly used cereal grains. The majority of studies show no negative effects with increasing amounts of field pea inclusion rates. There is also the reduced risk of acidosis in high grain diets since field peas are similar to energy in corn, but have a third less starch. Peas are also advantageous as a supplement in high forage diets due to the lack of negative associative effects of
digestion. Continued research will be highly beneficial to produce more consistent results to truly hone in on the nutritive values of field peas and their value to the ruminant animal.

The currently published literature on field peas included in this review of literature provides results that are contradictory. A large portion of this contradiction seems to be attributed to the difference in basal diets between trials, there is still more to uncover within each of those avenues. The greatest benefit of field peas is being able to have a cheap, locally sourced, feedstuff with a dependable supply. In order for producers to be able to put into practice the use of field peas as a corn or protein replacement, having a base of knowledge with results that are not confounded would be a large benefit. Another area with little research on field peas is the use as a protein supplement for grazing cattle, since field peas are a cheap protein source, there is potential for them to be used as a protein supplement on pasture where field peas can be locally sourced to keep prices economically advantageous.

From the beef product side, there seems to be a potential for increased value of the beef product from cattle consumption of field peas. While it is not known at what point the increase and tenderness and overall appeal occurs in the feeding period for field peas, a narrowed window would allow for exploitation of increased marbling scores and consequently increased USDA quality grades. With the advantages to cropping systems and as well as to various avenues in the beef production cycle, field peas may be a viable replacement for common cereal grains in growing and finishing diets.
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CHAPTER I. EVALUATING THE FEEDING VALUE OF FIELD PEAS FOR GROWING AND FINISHING CATTLE

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Abstract: A two year experiment was conducted to determine the effects of field pea supplementation during grazing and finishing phases on cattle performance and carcass characteristics. In year one, 114 steers (initial BW = 348 kg; SD = 22 kg) and in year two, 114 heifers (initial BW = 249 kg; SD = 11 kg) were used in a randomized complete block design. Treatments were arranged in a 3 × 2 factorial, the first factor was supplementation during grazing, consisting of three treatments: 1) control group receiving no supplement (CON); 2) a mixture of dry rolled corn (70.8%), corn condensed distillers solubles (24%), and urea (5.2%; CORN); and 3) whole field peas (PEAS). Cattle grazed crested wheatgrass pastures and were supplemented at 0.5% BW (DM basis). The second factor was finishing treatment where cattle were fed a DRC-based finishing diet with or without 20% field peas (DM basis). During the growing phase ending BW and ADG ($P < 0.01$) were greatest for calves supplemented CORN (416 ± 4.2 kg, 0.99 ± 0.08 kg, respectively) followed by field peas (402 ± 4.2 kg, 0.87 ± 0.08 kg, respectively) and the CON treatment (382 ± 4.2 kg, 0.69 ± 0.08 kg, respectively). There were no interactions of finishing and growing treatments on any of the finishing or carcass variables ($P \geq 0.20$). Finishing treatment had no significant effect on performance parameters ($P \geq 0.25$). Feedlot ADG was affected by growing treatment ($P < 0.01$). Cattle in the CON treatment had greater ADG (1.93 ± 0.06 kg) than cattle supplemented CORN (1.79 ± 0.06 kg) or PEAS (1.79 ± 0.06 kg), which were not different. Cattle fed the CON treatment had greatest G:F (0.145 ± 0.014 kg), followed by CORN and PEAS (0.135, 0.138 ± 0.014, respectively), which were not different ($P = 0.55$). Final BW and HCW tended ($P = 0.07$) to be affected by growing treatment in a similar manner to feedlot ADG. Inclusion of
field peas in the finishing diet had no impact on carcass characteristics. In conclusion, cattle supplemented CORN during grazing had greater ADG than cattle supplemented PEAS or CON. However, in the finishing phase, CON cattle compensated in feedlot ADG. Inclusion of field peas in grower supplement or finishing diets may be advantageous if appropriately priced and cattle are marketed after grazing.

Keywords: cattle, field peas, finishing, grazing

Introduction

On a national scale, the number of acres of field peas planted increased from 362,000 in 2011 to 1.268 million in 2016 (NASS, 2016). A 71% increase in production in five years suggests a large increase in field pea grain legume for a market which has not realized a concomitant increase in processing capacity. While a large component of this production is directed to the human consumption and pet food market, there has also been an increase in the availability of commodity peas for the livestock feed market. The majority of field peas are routed for the human consumption, dry pea market, and for seeds used by fresh garden growers (Davis et al., 1991). However, those market outlets are limited by the amount of product they can purchase due to limitations in processing, as well as maintaining quality standards. Therefore, feeding field peas to livestock, specifically cattle, began because of a surplus of low quality field peas with no outlet (Fendrick et al., 2006). Petit et al. (1997) suggested that field peas could be used as both a protein and energy source in livestock diets. Previous research has shown that field peas are capable of providing similar or improved performance compared to other cereal
grains such as corn and barley at moderate inclusion rates (Reed et. al, 2004, Jenkins et. al, 2011).

Peas provide a viable rotation in wheat production because they fix nitrogen in the soil and naturally break up pest cycles. Determining the best use of field peas for the livestock sector is important for both the cattle producer and field pea producer. This study was designed to determine the efficacy of field peas as a supplement to cattle grazing pasture, in comparison to cattle supplemented dry rolled corn with supplemental RDP. Following grazing, a second phase either included or excluded field peas from the finishing phase. Therefore, the objective of this study was to determine the effects of feeding field peas during growing and finishing phases on the cattle performance and carcass characteristics.

**Materials and Methods**

In Yr. 1, 114 crossbred steers (initial BW = 348 ± 22 kg) were used, and in Yr. 2, 114 crossbred heifers (initial BW = 249 ± 11 kg) were used in randomized complete block with a 3 × 2 factorial arrangement of treatments. Cattle were weighed on d -1 and d 0 and sorted into three BW blocks and assigned to pasture. Cattle were implanted with 40mg trenbolone acetate and 8mg estradiol (REVALOR®-G, Merck Animal Health, Kenilworth, N.J.), given a 5-way respiratory viral vaccination (Year 1: Express® FP 5, Boehringer Ingelheim, St. Joseph, MO; Year 2: Titanium 5, Elanco Animal Health, Greenfield, IN), and poured with Eprinomectin endectocide (IVOMEC®, Merial Limited, Duluth, GA). The first factor of the trial was the three supplementation treatments applied
during a summer grazing season. Supplementation occurred at a rate of 0.5% BW (DM Basis) pro-rated for six days in a 7-d period and was fed at approximately 0800.

The three treatments consisted of: 1) Whole, unprocessed field peas; (PEAS); 2) a mixture of dry rolled corn (DRC; 70.8%), condensed distillers solubles (24%), and urea (5.2%; CORN; the mixture was balanced to ensure RDP was not limiting); and 3) control group receiving no supplement (CON). There were 4 replications per treatment per year to give total of 8 replications per treatment across two years. Cattle grazed 12, 40.47-hectare crested wheatgrass pastures at the High Plain Agriculture Lab (HPAL) near Sidney, NE. Stocking rate was 4 hectares per animal. The 12 groups were rotated through pastures biweekly to ensure that pasture differences did not affect treatments. Cattle had ad libitum access to 14% magnesium content mineral blocks (Rancher’s Choice Hi Mag 14% Pressed Block, Consumers Supply, North Sioux City, S.D.). In year 1 the grazing period was 117 days and in year 2, 142 days.

The second factor in the experiment was the two treatments assigned during finishing that occurred at the Panhandle Research and Extension Center (PREC) feedlot near Scottsbluff, NE. At the conclusion of the grazing period, cattle were shipped to the feedlot where they remained in their respective grazing groups in 1 of 12 pens. Upon arrival cattle were limit fed for 5 days with a diet consisting of 35% wheat straw, 35% corn silage, 20% wet distillers grains, and 10% distillers condensed solubles (DM basis). On the fifth day cattle were weighed, implanted with 200 mg of trenbolone acetate and 40 mg of estradiol in year 1 (REVALOR®-XS, Merck Animal Health), and 200 mg of trenbolone acetate and 20 mg of estradiol in year 2 (REVALOR®-200, Merck Animal
Health), given a 7-way bacterial-toxoid vaccine (Vision 7 Somnus, Merck Animal Health), a 5-way respiratory vaccine (Year 1: Express® FP 5, Boehringer Ingelheim; Year 2: Titanium 5, Elanco Animal Health), and poured with Eprinomectin endectocide (IVOMEC®, Merial Limited).

The finishing diets were a DRC-based finishing diet with or without 20% whole, unprocessed field peas (DM basis). The complete composition of the finishing treatments and mineral supplement are in Table 1. Monensin was fed at 360 mg / head daily and tylosin at 90 mg / head daily (Rumensin and Tylan, Elanco Animal Health). Cattle were fed once daily in the morning and diets were provided ad libitum. Days on feed were 119 and 131 days for year 1 and year 2, respectively. Cattle were slaughtered and carcass data were collected at Tyson Foods (Lexington, N.E.).

Pasture samples were collected at the beginning of the grazing period (June) and at the end of the grazing period (August) in year 2. Three pastures were selected at random to be the representative samples for the twelve pastures. Six random collection sites within each pasture were used to clip total area samples measuring 61 cm by 61 cm in area. Samples were then dried in a forced air oven at 60°C (model LBB2-21-1; Despatch Industries, Minneapolis, MN) for 48 hours (AAOC, 1965; method 935.29), and ground through a 1-mm screen using a Wiley mill (number 4; Thomas Scientific). Processed samples were analyzed for OM, in vitro DM digestibility (IVDMD), in vitro OM digestibility (IVOMD), CP, NDF, and ADF. Ash was determined by placing samples in a muffle furnace for 6 h at 600°C (AOAC, 1999; method 4.1.10). Both in vitro OM and DM digestibilities were determined with the use of the in vitro method described by
Till and Terry (1962). Crude protein was determined using a combustion chamber (TruSpec N Determinator; Leco Corporation, St. Joseph, MI; AOAC, 1999; method 990.03). Neutral detergent fiber and acid detergent fiber analysis were conducted using the procedure described by Van Soest et al. (1991).

Economic Analysis

An economic analysis was conducted to estimate the value of field peas as a feedstuff compared to a corn, solubles, and urea supplement mixture on an energy basis. To calculate cost of the animal, data accumulated by the Livestock Marketing Information Center was used to develop ten year averages (2004-2014). In year 1, medium to large frame #1 steer prices were used for the month in which the steer was purchased or sold, and in year two, medium to large frame #1 heifers were used. Initial cost of the animal, predicted cost of the animal after the grazing phase, and the slaughter cattle price were all gathered from the reports that summarized prices from all Nebraska auction markets. Prices were used from the weight ranges that corresponded with each transition in the trial. For example, initial cost of the animal price for year 1 used the price per 45.5 kg for 341 to 364 kg steers, and 409 to 432 kg steers for end of grazing/initial feedlot price. For year two, prices were used for heifers instead of steers due to gender differences between the two years. For the initial cost of the animal, weekly averages from the month of May were used to determine accurate seasonal average. The month of September was used for the end of the grazing period. Slaughter prices were taken from the month of January for year 1 and February for year 2. Animal value was calculated on the same $ / kg for the average individual animal weight per pen.
Using the *Nebraska Farm Real Estate Market Highlights Report* (2014, 2015) a grazing rental value for pasture was determined by using the average pasture rental rate of 2014 and 2015 for 250-273 kg stockers in the Northwest Region of Nebraska. This calculated value was $11.75 / .40 hectare.

Supplement cost for cattle fed field peas was calculated based on the human consumption market ($4.50 / 27.24 kg) since there is no established price for livestock feed grade peas. To determine the cost of the CORN supplement, the ten year average corn price from 2004 to 2014 was used based on the USDA Agriculture Marketing Service of $4.40 / bu. Corn condensed distillers solubles were evaluated at the same price as corn. The price of urea was also a ten year average of prices reported for the month of April from 2004 to 2014. Finishing diet cost was also formulated using the same corn and field pea prices with corn silage price being set at nine times the value of corn per ton. A ten year average from the USDA Agriculture Marketing Service was also used to price wet distiller’s grains. Mineral supplement cost was collected from the University of Nebraska-Lincoln Feed Production facility.

Labor costs for both grazing and finishing were adapted from Warner et al. (2015). During grazing, the CON treatment was charge $0.10 / head daily, PEAS was charged $0.20 / head daily, and CORN was charged $0.25 / head daily, reflecting differences in labor requirements for each supplement strategy. Equal yardage for all treatments was applied during the finishing phase at $0.45 / head daily. Cost of transporting the cattle from pasture to the feedlot was based on $4.00 / loaded 1.61 kilometers with a 114-kilometer trip.
In order to determine interest cost on the live cattle, an annual rate of 4.5% was applied to the initial cost of the animal and then pro-rated to the number of months the cattle were owned (Interest Months = [Grazing Days + Days on Feed] / 30). Feed interest was calculated based on a 4.5% annual rate for half the amount of time on feed applied to the total feed costs for the finishing period.

Analysis of sensitivity was conducted on the price of field peas relative to the price of corn. All cost assumptions previously discussed remained the same and price of field peas was evaluated at corn prices of 3, 5, and 7 dollars per 25.42 kg. Field pea price was determined by having equal profitability between corn and field pea supplementation on grazing, as well as inclusion of field peas or not in the finishing period.

Statistical Analysis

Data were analyzed as a randomized complete block design using PROC MIXED procedure of SAS (SAS Inst Inc., Cary, NC). The treatments were analyzed as a 2 x 3 factorial arrangement. The grazing and finishing models included treatment as a fixed effect with block, year, and block within year as random effects. The nutrient composition analysis was analyzed with month and pasture as fixed effects. The experimental unit for animal performance and economic analysis was pasture / pen and pasture for nutrient analysis.

Results and Discussion

Pasture nutrient composition analysis in Table 2 suggests that OM, NDF, and ADF did not vary ($P \geq 0.38$) across the grazing season for the predominately crested wheatgrass pastures. However, IVDMD and IVOMD declined from June to August ($P =$
0.03 and \( P < 0.01 \), respectively). This difference is to be expected as plants mature in the growing season and biomass increases (Von Keyserlingk et al., 1996; Bonhert et al., 2011). Therefore, plant physiological and morphological development have the greatest impact on nutrient composition of plants (Watson, 1950; Meyer et al., 1957; Morrison, 1956).

There was no interaction between year and treatments, main effects of grazing treatment are presented for the growing period results. During the grazing phase ending BW and ADG (\( P < 0.01 \)) were greatest for calves supplemented CORN, followed by PEAS, and CON (416 kg, 402 kg, and 382 kg, respectively; SED = 4.19; 0.99 kg, 0.87 kg, and 0.69, respectively; SED = 0.08 kg; Table 3). The CON cattle also had lower ADG than what has been observed in continuous grazing systems (Daugherty et al., 1982). Additionally, cattle receiving supplement had gains less than previous observations for cattle receiving supplement while grazing crested wheatgrass pasture (William and Post, 1945; Vogel et al., 1993; Ojowi et al., 1996).

There were no interactions between growing and finishing treatments on cattle performance during the feeding period or carcass characteristics. There was not a significant effect of finishing treatment for animal performance and carcass characteristics observed (\( P \geq 0.20 \); Table 4).

Analysis of the main effects of growing treatment on finishing performance show that initial BW for the feedlot period was affected by growing treatment (\( P < 0.01 \); Table 5) as a reflection of ending BW for the grazing period. Feedlot ADG was also affected by growing treatment (\( P < 0.01 \)). Cattle in the CON treatment had greater ADG (1.93 ± 0.06
kg; $P < 0.01$) than cattle supplemented CORN (1.70 ± 0.06 kg) and PEAS (1.79 ± 0.06 kg), which were similar ($P = 0.085$). Final BW and HCW tended ($P = 0.07$) to be affected by growing treatment in a similar manner to feedlot ADG.

Cattle were most efficient when they did not receive supplement on pasture, the CON treatment had greater G:F ($P \leq 0.01$) compared to CORN and PEAS (0.145, 0.135, 0.138 ± 0.014 kg, respectively). The differences in G:F are the result of consistent DMI across treatments ($P = 0.27$) and differences in ADG due to growing period treatment. A biological explanation for the increased G:F during finishing for the CON cattle may be compensatory gain (Osborne and Mendel, 1915, 1916). CON cattle compensated 54% compared to cattle supplemented CORN and 90% compared to cattle supplemented PEAS during grazing.

The present study had differences in feedlot performance due to the effects of treatments applied prior to the cattle entering the feeding period. The effect of supplement applied during grazing on animal performance during the finishing period is inconsistent with some published literature. Elizalde et al. (1998) observed no effect of grazing supplement on subsequent feedlot performance when supplementing multiple levels of protein and energy. Similarly, Coleman et al. (1976) observed no effect on subsequent feedlot performance when cattle were fed supplemental energy during grazing. The authors also saw no differences in carcass quality grade, but increased dressing percent, estimated percent yield (not measured in present study) and LM area. However, the results of the current study agree with published literature on the result of compensatory gain. Researchers have observed compensatory gain when cattle
previously were on a low plane of nutrition are then placed on a higher plane of nutrition. (Carstens et al., 1991; Drouillard et al., 1991; Hersom et al, 2003).

There was no significant effect of finishing treatment on animal performance or carcass characteristics during the finishing phase ($P \geq 0.25$). No differences were observed for DMI, however the literature is inconsistent with the effect of field peas in finishing diets on DMI. Fendrick et al. (2005) observed that DMI increased with increasing inclusion of field peas for feedlot steers, with peak DMI being at 40% inclusion. Jenkins et al. (2011) saw no differences in DMI, however field peas were only included up to 30% of diet DM. The results observed by Jenkins et al. (2011) agree with other studies with similar inclusion rates (Loe et al., 2004; Lardy et al., 2009).

Similar to the current study, others have reported that inclusion of field peas in finishing diets has no effect on G:F (Fendrick et al., 2005; Carlin et al., 2006; Jenkins et al., 2011). Contradictory results were observed by Flatt and Stanton (2000) when 20% field peas replaced corn. Those authors observed increased G:F, decreased DMI, and similar ADG for cattle fed 20% field peas compared to corn. A decrease in DMI was also observed when field peas were used as a substitute in by-product-based medium concentrate diets (Soto-Navarro et al., 2004). In growing diets, improved feed efficiency was observed when field peas replaced barley and soybean meal (Okine, 2001). However, some studies showed no effect on DMI when using field peas to replace other cereal grains in growing diets (Poland et al., 1996; Anderson, 1999).

Inclusion of field peas in the finishing diet had no impact on carcass characteristics (HCW, 12$^{th}$ rib fat, LM area, marbling, calculated YG) which is similar to
observations by Jenkins et al. (2011). The effects of field peas on carcass characteristics have been inconsistent. Lardy et al. (2009) observed a quadratic increase in 12th rib fat, and an increase in marbling score as field pea levels increased. In dry-rolled corn-based diets, Lardy et al. (2009) and Jenkins et al. (2011) reported no difference in yield grade, however, there was a tendency for an increase in yield grade in barley-based diets. Also, Fendrick et al. (2009) reported a linear decrease in LM area with increased field pea levels up to 59%. While Jenkins et al. (2011) reported no effects on marbling score with increasing field pea levels, Anderson (1999) observed increased marbling scores, followed by an expected increase in number of carcasses graded USDA Choice.

**Economic Analysis**

During the grazing period, a treatment effect on the value of the animal at the conclusion of grazing as well as the costs during grazing were observed ($P < 0.01$; Table 6). Those cattle supplemented CORN on pasture had an average value of $1,150.25 per head which was greater than those supplemented with PEAS ($1,113.36/hd) which was also greater than the CON ($1,057.27/hd). This would be expected as it mirrors the results of ending BW for the grazing period. However, this is calculated on an even dollars / kg basis as opposed to a price slide for individual animals. Costs ($ / head) during the grazing period were also greatest for CORN, then PEAS, with CON having the cheapest costs ($195.96, $182.66, $128.77, respectively). Similar results were found by Rolfe et al. (2011) where steers supplemented on pasture during the summer increased returns after grazing over those cattle that were not supplemented.
There were no interactions of grazing and finishing treatment nor an effect of finishing treatment observed for any of the measured feedlot period related costs, values, or profits ($P \geq 0.30$; Table 7). However, growing treatment had an effect on cost of gain, live net profit, and dressed net profit, with a tendency to for the finished live and dressed animal value to be different. Cost of gain favored the CON growing treatment which was less than CORN and PEAS ($P \leq 0.01$) which did not differ ($P = 0.64$). Both live net profit and dressed net profit ($$/hd$) were more desirable for the CON cattle with positive returns that were significantly different from the PEAS ($P \leq 0.01$). CORN cattle were similar to both the CON and PEAS ($P > 0.06$, $P \geq 0.06$, respectively). Gillespie et al. (2014) had a winter grazing period preceding the summer grazing portion of the study where compensatory gain was observed and there was no final economic benefit from summer supplementation.

While the supplemented cattle tended to be more profitable at the end of the grazing period, even with costs associated with labor and feed, the amount of compensatory gain the CON cattle experienced during finishing offset the increased value of the supplemented cattle without having the associated increased costs. However, for this analysis, the field pea price was determined by the human consumption market and therefore price could be altered to account for animal performance relative to corn. Drouillard and Kuhl (1999) suggested that knowing when compensatory gain will occur can allow for better allocation of high and low value inputs at the proper time into the production system. Analysis of sensitivity for the grazing period (Table 9) and the
finishing period (Table 10) show that the price of field peas is sensitive to the price of corn when corn price is 3, 5, or 7 dollars / 25.42 kg.

**Overall Conclusion**

Field peas can be an alternative protein supplement option for grazing cattle on cool season pasture as cattle will potentially perform better than those cattle receiving no supplement. In finishing diets, field pea inclusion did not affect performance up to 20% inclusion rate. However, cattle receiving supplement on grass may gain less during the finishing phase, demonstrating the impacts of compensatory gain.
Literature Cited


**Table 1.** Finishing Diet Composition (DM Basis)

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<tr>
<td></td>
<td>No Peas</td>
</tr>
<tr>
<td>Dry-Rolled Corn</td>
<td>60.0</td>
</tr>
<tr>
<td>Field Peas</td>
<td>0.0</td>
</tr>
<tr>
<td>WDGS</td>
<td>20.0</td>
</tr>
<tr>
<td>Corn Silage</td>
<td>14.0</td>
</tr>
<tr>
<td>Mineral Supplement&lt;sup&gt;1,2&lt;/sup&gt;</td>
<td>6.0</td>
</tr>
<tr>
<td>Crude Protein, %</td>
<td>8.0</td>
</tr>
<tr>
<td>Crude Fat, %</td>
<td>0.5</td>
</tr>
<tr>
<td>Calcium, %</td>
<td>4.7</td>
</tr>
<tr>
<td>Phosphorus, %</td>
<td>0.06</td>
</tr>
<tr>
<td>Salt, %</td>
<td>3.5</td>
</tr>
<tr>
<td>Potassium, %</td>
<td>3.8</td>
</tr>
<tr>
<td>Vitamin A, IU/lb</td>
<td>10,820</td>
</tr>
</tbody>
</table>

<sup>1</sup>Supplement included Monensin at a rate of 360 mg/hd/d and Tylosin at 90 mg/hd/d

<sup>2</sup>Mineral composition of supplement is for both “No Peas” and “Peas”
Table 2. Nutrient Analysis of Pastures from Year 1¹

<table>
<thead>
<tr>
<th>Nutrient Analysis</th>
<th>June 2015</th>
<th>August 2015</th>
<th>SEM</th>
<th>$P$-value²</th>
</tr>
</thead>
<tbody>
<tr>
<td>OM</td>
<td>89.0%</td>
<td>88.9%</td>
<td>0.197</td>
<td>0.77</td>
</tr>
<tr>
<td>IVDMD</td>
<td>49.0%</td>
<td>40.3%</td>
<td>1.040</td>
<td>0.03</td>
</tr>
<tr>
<td>IVOMD</td>
<td>52.1%</td>
<td>43.0%</td>
<td>0.600</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>NDF</td>
<td>69.5%</td>
<td>68.8%</td>
<td>0.992</td>
<td>0.69</td>
</tr>
<tr>
<td>ADF</td>
<td>47.6%</td>
<td>48.0%</td>
<td>0.260</td>
<td>0.38</td>
</tr>
<tr>
<td>CP</td>
<td>8.74%</td>
<td>6.39%</td>
<td>0.134</td>
<td>&lt;0.01</td>
</tr>
</tbody>
</table>

¹Established, predominantly, crested wheatgrass pastures near Sidney, N.E. at the University of Nebraska-Lincoln High Plains Agriculture Lab. Samples were clipped by hand using a 61-cm × 61-cm quadrant.

²$P$-value is representative of the comparison between the start of the grazing (June) and the end of grazing (August). Experimental unit was paddock.
Table 3. Effect of corn or field pea supplementation on performance of growing calves across 2 years of summer grazing

<table>
<thead>
<tr>
<th>Treatment(^1)</th>
<th>Control</th>
<th>Corn</th>
<th>Peas</th>
<th></th>
<th>SED</th>
<th>Treatment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Initial BW, kg</td>
<td>301</td>
<td>300</td>
<td>300</td>
<td>1.48</td>
<td></td>
<td>0.82</td>
</tr>
<tr>
<td>Ending BW, kg</td>
<td>382(^c)</td>
<td>416(^a)</td>
<td>402(^b)</td>
<td>4.19</td>
<td>&lt;0.01</td>
<td></td>
</tr>
<tr>
<td>ADG, kg/d</td>
<td>0.69(^c)</td>
<td>0.99(^a)</td>
<td>0.87(^b)</td>
<td>0.08</td>
<td>&lt;0.01</td>
<td></td>
</tr>
</tbody>
</table>

\(^{abc}\) Within a row, means without a common superscript differ.

\(^1\) Treatments: Cattle grazed 117 days (2014) or 142 days (2015) either without supplement or supplemented at 0.5% of body weight with either dry rolled corn (70.8%), solubles (24%), and urea (5.2%) or whole, unprocessed field peas.
Table 4. Effect of 20% field pea inclusion in finishing diets on animal performance and carcass characteristics

<table>
<thead>
<tr>
<th>Finishing Trt</th>
<th>No Peas</th>
<th>Peas</th>
<th>SED</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Growing Trt</td>
<td>Control</td>
<td>Corn</td>
<td>Peas</td>
<td>Growing</td>
</tr>
<tr>
<td>Initial BW, kg</td>
<td>387</td>
<td>414</td>
<td>402</td>
<td>6.3</td>
</tr>
<tr>
<td>Final BW, kg</td>
<td>623</td>
<td>636</td>
<td>626</td>
<td>9.8</td>
</tr>
<tr>
<td>ADG, kg</td>
<td>1.90</td>
<td>1.76</td>
<td>1.81</td>
<td>0.07</td>
</tr>
<tr>
<td>DMI, kg/d</td>
<td>13.4</td>
<td>13.3</td>
<td>13.0</td>
<td>0.27</td>
</tr>
<tr>
<td>G:F</td>
<td>0.143</td>
<td>0.134</td>
<td>0.140</td>
<td>0.004</td>
</tr>
</tbody>
</table>

Carcass Performance

| HCW, kg       | 393     | 400  | 394 | 6.2     | 0.07     | 0.63       | 0.87       |
| 12th Rib Fat, cm | 1.35   | 1.48 | 1.44| 0.12    | 0.68     | 0.61       | 0.36       |
| LM Area, cm²  | 90.9    | 88.6 | 88.9| 2.08    | 0.93     | 0.26       | 0.20       |
| Marbling³     | 3.15    | 3.43 | 3.31| 26.6    | 0.80     | 0.82       | 0.29       |
| Calculated YG⁷ | 3.15   | 3.43 | 3.31| 0.18    | 0.80     | 0.55       | 0.31       |

¹Within a row, means without a common superscript differ.
²Finishing Treatment: Cattle with peas in the diet had 20% of the dry matter of the diet as peas (by displacing dry rolled corn). The “No Peas” diet still included that 20% as dry rolled corn. The “No Peas” diet still included that 20% as dry rolled corn.
³Growing Treatment: Cattle were grazed for 142 days either without supplement or supplemented at 0.5% of body weight with either dry rolled corn or field peas depending on assigned treatment.
⁴Initial BW Main Effects of Growing Treatment: Corn > Field Peas > Control (P<0.01)
⁵Final BW: Calculated as HCW ÷ 0.63
⁶ADG and G:F Main Effect of Growing Treatment: Both measures favored Control over Corn and Field Peas (P<0.01); Corn and Field Peas were similar (P≥0.57).
⁷Marbling: 400 = Slight 000; 500 = Small 000
⁸Calculated Yield Grade: 2.50 + (2.5 × 12th Rib Fat, in.) – (0.32 × REA, in²) + (0.2 × 2.5) + (0.0038 × HCW, lb.) (USDA, 1997)
Table 5. Main effects of growing treatment on finishing and carcass performance parameters significantly impacted by treatment

<table>
<thead>
<tr>
<th>Growing Treatment¹</th>
<th>Control</th>
<th>Corn</th>
<th>Peas</th>
<th>SED</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Initial BW, kg</td>
<td>382c</td>
<td>416a</td>
<td>402b</td>
<td>25.4</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>Final BW, kg²</td>
<td>623</td>
<td>639</td>
<td>626</td>
<td>19.4</td>
<td>0.07</td>
</tr>
<tr>
<td>ADG, kg</td>
<td>1.93a</td>
<td>1.79b</td>
<td>1.79b</td>
<td>0.06</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>G:F</td>
<td>0.145a</td>
<td>0.135b</td>
<td>0.138b</td>
<td>0.014</td>
<td>0.01</td>
</tr>
<tr>
<td>HCW, kg</td>
<td>393</td>
<td>403</td>
<td>394</td>
<td>12.2</td>
<td>0.07</td>
</tr>
</tbody>
</table>

abc Within a row, means with different superscripts differ

¹Growing Treatment: Cattle were grazed for 142 days either without supplement or supplemented at 0.5% of body weight with either dry rolled corn or field peas depending on assigned treatment.

²Final BW: Calculated as HCW ÷ 0.63
Table 6. Economic analysis of grazing period for cattle supplemented CORN or PEAS across 2 summer grazing seasons

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Control</th>
<th>Corn</th>
<th>Peas</th>
<th>SED</th>
<th>P-value Treatment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Initial Animal Value, $/hd</td>
<td>867.04</td>
<td>864.51</td>
<td>864.70</td>
<td>4.34</td>
<td>0.81</td>
</tr>
<tr>
<td>End of Grazing Animal Value, $/hd</td>
<td>1,057.27&lt;sup&gt;c&lt;/sup&gt;</td>
<td>1,150.25&lt;sup&gt;a&lt;/sup&gt;</td>
<td>1,113.36&lt;sup&gt;b&lt;/sup&gt;</td>
<td>11.28</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>Costs, $/hd</td>
<td>128.77&lt;sup&gt;c&lt;/sup&gt;</td>
<td>195.96&lt;sup&gt;a&lt;/sup&gt;</td>
<td>182.66&lt;sup&gt;b&lt;/sup&gt;</td>
<td>0.59</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>Cost of Gain, $/kg</td>
<td>0.38</td>
<td>0.37</td>
<td>0.40</td>
<td>0.05</td>
<td>0.48</td>
</tr>
<tr>
<td>Net Profit, $/hd</td>
<td>60.84</td>
<td>89.15</td>
<td>65.37</td>
<td>12.01</td>
<td>0.06</td>
</tr>
</tbody>
</table>

<sup>abc</sup> Within a row, means without a common superscript differ.

<sup>1</sup> Treatments: Cattle grazed 117 days (2014) or 142 days (2015) either without supplement or supplemented at 0.5% of body weight with either dry rolled corn (70.8%), solubles (24%), and urea (5.2%) or whole, unprocessed field peas.
Table 7. Economic analysis of finishing period with or without 20% inclusion of field peas

<table>
<thead>
<tr>
<th></th>
<th>Finishing Trt(^1)</th>
<th>Growing Trt(^2)</th>
<th>No Peas</th>
<th>Peas</th>
<th>SED</th>
<th>Growing</th>
<th>Finishing</th>
<th>Interaction</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Control</td>
<td>Corn</td>
<td>Peas</td>
<td>Control</td>
<td>Corn</td>
<td>Peas</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Finishing Costs, $/hd</td>
<td>393.95</td>
<td>391.71</td>
<td>387.01</td>
<td>392.41</td>
<td>389.74</td>
<td>385.29</td>
<td>6.52</td>
<td>0.28</td>
</tr>
<tr>
<td>Finished Live Animal</td>
<td>1,377.53</td>
<td>1,405.51</td>
<td>1,383.95</td>
<td>1,379.61</td>
<td>1,421.31</td>
<td>1,384.36</td>
<td>22.54</td>
<td>0.07</td>
</tr>
<tr>
<td>Value, $/hd</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Finished Dressed</td>
<td>1,392.10</td>
<td>1,420.40</td>
<td>1,398.62</td>
<td>1,394.20</td>
<td>1,436.25</td>
<td>1,398.90</td>
<td>22.76</td>
<td>0.07</td>
</tr>
<tr>
<td>Animal Value, $/hd</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cost of Gain, $/kg(^3)</td>
<td>0.35</td>
<td>0.37</td>
<td>0.36</td>
<td>0.33</td>
<td>0.36</td>
<td>0.36</td>
<td>0.02</td>
<td>0.01</td>
</tr>
<tr>
<td>Live Net Profit,$/hd(^4)</td>
<td>-9.12</td>
<td>-48.05</td>
<td>-51.12</td>
<td>-11.74</td>
<td>-27.54</td>
<td>-47.61</td>
<td>21.05</td>
<td>0.03</td>
</tr>
<tr>
<td>Dressed Net Profit,$/hd(^4)</td>
<td>4.98</td>
<td>-33.69</td>
<td>-36.90</td>
<td>2.35</td>
<td>-13.04</td>
<td>-33.58</td>
<td>21.25</td>
<td>0.03</td>
</tr>
</tbody>
</table>

\(^1\) Finishing Treatment: Cattle with peas in the diet had 20% of the dry matter of the diet as peas (by displacing dry rolled corn). The “No Peas” diet still included that 20% as dry rolled corn.

\(^2\) Growing Treatment: Cattle were grazed for 142 days either without supplement or supplemented at 0.5% of body weight with either dry rolled corn or field peas depending on assigned treatment.

\(^3\) Main Effects of Growing Treatment: Control < Corn and Field Peas \((P \leq 0.01)\) which were not different \((P = 0.64)\)

\(^4\) Main Effects of Growing Treatment: Field Peas < Control \((P = 0.01)\); Corn was similar to both Control \((P > 0.06)\) and Field Peas \((P \geq 0.40)\)
Table 8. Main effects of growing treatment on economic analysis parameters significantly impacted by treatment

<table>
<thead>
<tr>
<th>Growing Treatment</th>
<th>Control</th>
<th>Corn</th>
<th>Peas</th>
<th>SED</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cost of Gain, $/kg</td>
<td>0.34&lt;sup&gt;b&lt;/sup&gt;</td>
<td>0.36&lt;sup&gt;a&lt;/sup&gt;</td>
<td>0.36&lt;sup&gt;a&lt;/sup&gt;</td>
<td>&lt;0.01</td>
<td>0.01</td>
</tr>
<tr>
<td>Live Net Profit,$/hd</td>
<td>-10.43&lt;sup&gt;a&lt;/sup&gt;</td>
<td>-37.80&lt;sup&gt;ab&lt;/sup&gt;</td>
<td>-49.36&lt;sup&gt;a&lt;/sup&gt;</td>
<td>13.64</td>
<td>0.03</td>
</tr>
<tr>
<td>Dressed Net Profit,$/hd</td>
<td>3.66&lt;sup&gt;a&lt;/sup&gt;</td>
<td>-23.37&lt;sup&gt;ab&lt;/sup&gt;</td>
<td>-35.24&lt;sup&gt;b&lt;/sup&gt;</td>
<td>13.77</td>
<td>0.03</td>
</tr>
</tbody>
</table>

<sup>abc</sup> Within a row, means with different superscripts differ

<sup>1</sup>Growing Treatment: Cattle were grazed for 142 days either without supplement or supplemented at 0.5% of body weight with either dry rolled corn or field peas depending on assigned treatment.
Table 9. Price of field peas relative to the price of corn to achieve equal profitability after grazing$^1$

<table>
<thead>
<tr>
<th>Corn Price, $/25.42$ kg</th>
<th>Corn Price, $/0.454$ kg, dry</th>
<th>Pea Price, $/25.42$ kg</th>
<th>Pea Price, $/0.454$ kg, dry</th>
<th>Pea Price, % of corn</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.00</td>
<td>0.062</td>
<td>0.37</td>
<td>0.007</td>
<td>10.91%</td>
</tr>
<tr>
<td>5.00</td>
<td>0.104</td>
<td>2.54</td>
<td>0.047</td>
<td>45.28%</td>
</tr>
<tr>
<td>7.00</td>
<td>0.145</td>
<td>4.70</td>
<td>0.087</td>
<td>59.94%</td>
</tr>
</tbody>
</table>

$^1$All assumptions for costs of production were kept the same between the economic analysis when adjustments of the price of corn were made.
Table 10. Price of field peas relative to the price of corn to achieve equal profitability after grazing and finishing periods

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>3.00</td>
<td>0.0623</td>
<td>3.3500</td>
<td>0.0620</td>
<td>0.0620</td>
</tr>
<tr>
<td>5.00</td>
<td>0.1038</td>
<td>5.4900</td>
<td>0.1016</td>
<td>0.1016</td>
</tr>
<tr>
<td>7.00</td>
<td>0.1450</td>
<td>7.6300</td>
<td>0.1410</td>
<td>0.1410</td>
</tr>
</tbody>
</table>

1 All assumptions for costs of production were kept the same between the economic analysis when adjustments of the price of corn were made.
CHAPTER II. EFFECTS OF FIELD PEA SUPPLEMENTATION ON DIGESTIBILITY OF DIETS CONTAINING HIGH AND LOW QUALITY FORAGES

H. L. Greenwell, J. L. Gramkow, M. L. Jolly-Breithaupt, J. C. MacDonald, K. H. Jenkins

A contribution of the University of Nebraska Agricultural Research Division, supported in part by funds provided through the Hatch Act
Abstract: Two experiments were conducted to determine the effect of feeding field peas in high- and low-quality forage diets on total tract digestibility, ruminal pH, VFA production, and RUP digestion kinetics of field peas. In Exp. 1, five ruminally fistulated steers; initial BW = 202 kg; SD = 20 kg were utilized in a 5 × 6 Latin rectangle. Treatments were set up as a 2 × 3 factorial (forage quality × supplement type). The first factor was high quality forage (HQ; 50% alfalfa, 50% sorghum silage, DM basis) or low quality forage (LQ; 50% brome grass hay, 50% wheat straw, DM basis). The second factor was one of three supplements: Control (CON), dry-rolled corn (CORN), or field peas (PEAS). Steers were supplemented at 0.43% of BW (DM basis). Periods lasted 14 days with a 9 day adaptation period and 4 day collection period. Data were analyzed using the mixed procedure of SAS and evaluating significance at α = 0.10. There were no interactions between forage quality and supplement type on digestibility ($P \geq 0.25$). Dry matter intake, DM digestibility (DMD), OM intake (OMI), and OM digestibility (OMD; $P < 0.01$) were greater with HQ forage (6.13 kg/d, 63.1%, 4.96 kg/d, and 64.2%, respectively) than diets containing LQ (4.71 kg/d, 49.1%, 3.60 kg/d, and 50.1%, respectively). The PEAS supplement ($P \leq 0.03$) increased DMI and OMD (6.14 ± 0.512 kg/d and 61.6% ± 1.94%, respectively) over steers receiving CORN (5.33 kg/d and 56.1%, respectively) or CON (4.80 kg/d and 53.8%, respectively). CORN and CON did not differ in intake or OMD. The acetate to propionate ratio (A:P) was affected by both forage quality and supplement where HQ was less than LQ (3.61 ± 0.05 and 4.09 ± 0.05, respectively) and CORN supplement produced lower A:P (3.58 ± 0.07) than PEAS and CON (3.99 and 3.97 ± 0.07, respectively), which were similar. In Exp. 2, ruminally and
duodenally fistulated steers were used to determine RUP digestibility of field peas compared to three other high protein feedstuffs. Rumen undegradable protein as a percent of crude protein and digestibility of RUP were measured in situ with three different rumen incubation durations. Rumen undegradable protein concentration, as a percent of CP, was significantly affected by time and sample \( (P < 0.01) \). Digestibility of RUP was significantly affected by sample \( (P < 0.01) \). Field peas had an RUP content (% of CP) of 32.6 ± 4.4% for year 1, and 35.2% ± 4.4% for year 2 with a digestibility of 97.4% and 98.9% ± 1.17% for year 1 and 2, respectively. Supplementing field peas in low or high quality diets increases DMI and OMD and may be an acceptable supplement for beef cattle with a high rumen undegradable protein digestibility.

Key Words: cattle, field peas, forage quality

### Introduction

With recent increases in availability of field peas (NASS, 2016) as a livestock feed, a renewed interest has developed in their use in beef production. Previous research has shown that feeding field peas in beef cattle finishing diets up to 30% of the diet (DM basis) produces similar results to starch grains, such as corn (Reed et. al, 2004; Jenkins et. al, 2011). The majority of the research has focused on including field peas in finishing diets with limited research on the use of field peas in high-forage diets. Accordingly, there are limited data available evaluating the effects of field peas on digestion parameters of fiber and protein in high forage diets.
Field peas are characterized by a high degradability of their crude protein fraction with a large portion being RDP (Focant et al., 1990, Aguilera et al., 1992). Supplementation of RDP in high forage diets has been extensively researched and consistently results in improved forage intake and digestion (Koster et al., 1996; Olson et al., 1999; Mathis et al., 2000; Klevesahl et al., 2003). While field peas are able to influence animal performance in a similar manner to other cereal grains, the potential for negative associative effects on fiber digestion are unknown. Corn has a negative impact on fiber digestion due to the starch content (Hoover, 1986; Olson et al., 1999), which may differ from that of field peas, which have approximately one third the amount of starch of corn (Fendrick et al., 2005). Corn supplementation also alters the proportion of acetate to propionate favoring propionate (Sharp et al., 1982). The impacts of field pea supplementation on volatile fatty acid (VFA) concentrations are not established.

The first objective of this study was to determine the effects of field pea supplementation on diet digestibility, VFA concentrations, and ruminal pH relative to corn when supplemented to cattle fed high and low quality forages. A second objective was to determine the RUP content and digestibility parameters for field peas relative to other high protein feedstuffs.

**Materials and Methods**

**Experiment 1**

Five ruminally fistulated steers (Initial BW = 202 ± 20 kg) were utilized in a 5 × 6 Latin rectangle designed study to evaluate the effects of field pea or corn supplementation on total tract digestibility of diets containing either high or low quality
forages. Treatments were designed as a 2 × 3 factorial (forage quality × supplement type). The design allowed for each of the five animals to be assigned randomly to each of the six treatments once across the six periods. The first factor was high quality forage (HQ; 50% alfalfa, 50% sorghum silage, DM basis) or low quality forage (LQ; 50% brome grass hay, 50% wheat straw, DM basis). The second factor was one of three supplements: Unsupplemented control (CON), dry-rolled corn (CORN), or ground field peas (PEAS). Those steers being supplemented CORN were dosed with 47 mL of urea solution (478.99 grams of urea per liter of water) to ensure that they were not deficient in rumen degradable protein in comparison to those being supplemented with PEAS. Both PEAS and CORN supplements were coated in molasses to increase palatability.

Forage was offered ad libitum through the entire study and steers were supplemented at 0.43% of BW (DM basis). Forage diets were mixed weekly in a stationary ribbon mixer (model S-5 Mixer; H.C. Davis Sons Manufacturing Co., Inc., Bonner Springs, KS) and stored in a cooler held at 4⁰ C to maintain diet quality. CORN and PEAS were mixed with molasses daily, immediately before feeding (95% grain, 5% molasses; DM basis). The non-supplemented cattle on the LQ forage are calculated to have received an adequate supply of RDP in their diet (LQ TDN: approximately 51.0; LQ CP: 7.73%). According to the 2016 NRBC, assuming a microbial efficiency of 9% and an 80% conversion to bacterial crude protein, the requirement for the animal was 57.38 g per kg DMI. Supply from the LQ forage was calculated as 70 g per kg DMI. Steers were weighed at the beginning of each period to adjust supplement amount accordingly. Supplement was fed at 0800 hours, steers were given two hours to consume supplement.
Any supplement not consumed was inserted into the rumen cannula. Forage was then fed at 1000 hours. Forage feed refusals were collected each morning prior to supplementation. Feed refusals collected on day 8 through 13 were retained and dried in a forced air oven at 60° C (model LBB2-21-1; Despatch Industries, Minneapolis, MN) for 48 h (AAOC, 1965; method 935.29) to determine DM content of refusals and accurately determine individual animal DMI. Periods lasted 14 days with a 9 day adaptation period and 4 day collection period. Animals were housed in individual slatted floor stalls with ad libitum access to water. Steers were ruminally dosed continuously with 5 g of TiO$_2$ twice daily at 0800 and 1600 hours. During collection, rumen fluid samples and fecal grab samples were taken at four time points including 0700, 1100, 1500, and 1900 hours.

Hourly fecal samples were composited by day by steer on a wet basis. Samples were lyophilized (Virtis Freezemobile 25ES; Life Scientific, Inc., St. Louis, MO), and ground through a Wiley Mill using a 1-mm screen (number 4; Thomas Scientific, Swedesboro, NJ). After grinding, daily composites were composited on a weekly basis by steer within collection period. Processed fecal samples were analyzed for TiO$_2$ concentrations per the method described by Myers et al. (2004). Determined TiO2 concentrations were used to calculated fecal DM output using the equation: g marker dosed per d / concentration of marker in feces (Cochran and Galyean, 1994).

Feed ingredient samples were taken each period and dried in a forced air oven at 60° C (model LBB2-21-1; Despatch Industries, Minneapolis, MN) for 48 h (AAOC, 1965; method 935.29) to adjust diet composition using accurate feed DM. Dried feed
samples were also ground through a 1-mm screen with a Wiley Mill (number 4; Thomas Scientific, Swedesboro, NJ).

Dried, ground samples were analyzed for OM, NDF, and CP to determine diet nutrient composition. Fecal samples were also analyzed for OM, NDF, and ADF. Ash was determined by placing samples in a muffle furnace for 6 h at 600° C (AOAC, 1999; method 4.1.10). Crude protein was determined by using a combustion chamber (TruSpec N Determinator; Leco Corporation, St. Joseph, MI; AOAC, 1999; method 990.03). Neutral detergent fiber analysis were conducted using the procedure described by Van Soest et al. (1991) with modifications to the analysis of corn described by Buckner et al. (2013). Summary of modifications used consisted of grinding the DRC through a 0.5 mm screen attached to a Tecator Cyclotec Mill (ThermoFisher Scientific, Eden Prairie, MN). Also, the addition of two doses (0.5 mL/dose) of α-amylase (catalog number FAA; ANKOM Technology, Macedon, NY) during the hour boil in NDF solution. Forage feed samples were also analyzed for in vitro DM and OM digestibility using the method describe by Tilley and Terry (1963).

Nutrient diet composition and feces nutrient compositions were used to determine total tract digestibility of DM, OM, and NDF. The equation given by Cochran and Galyean (1994) was used:

\[
\left( \frac{kg \ of \ nutrient \ fed - kg \ of \ nutrient \ refused - kg \ of \ nutrient \ in \ feces}{kg \ of \ nutrient \ fed - kg \ of \ nutrient \ refused} \right) \times 100
\]

Rumen fluid samples were taken using a suction strainer method to collect a representative 50-mL sample. After collection, samples were immediately frozen to store until processing could occur to measure for VFA concentration.Samples were thawed
and prepared according to Myers et al. (1961) and with the use of a Trace 1300 gas chromatograph (Thermo Fisher Scientific, Inc., Omaha, NE) fitted with a Zebron capillary column (Phenomenex Inc., Torrance, CA; catalog number 7HM-G009-22). Chromatograph and column settings and standards were set according to the methods described by Gramkow et al. (2016).

Ruminal pH was collected via wireless pH loggers (Dascor, Inc., Escondido, CA) for each collection period. Calibration of probes occurred prior to being placed in the rumen by use of pH 4 and 7 standard solutions. Probes were placed in the ventral sac of the rumen prior to start of the collection period and attached to weights to ensure steady placement throughout collection. Ruminal pH was measured and recorded every 60 seconds. Upon removal after collection period, probes were once again calibrated to use beginning and ending values for adjustment of ruminal pH measurements.

In situ bag procedures were used to analyze supplement effect on fiber digestibility. Both HQ and LQ forage diets were weighed into the nylon bags (5 × 10 cm; Ankom Technology Corp., Macedon, NY) at approximately 1.25 g of sample after being ground through a 6 mm screen for grains and a 2 mm screen of a Wiley Mill (number 4; Thomas Scientific) for forages. Bags were double sealed and incubated in the rumen for 24 hours. Individual bags were placed in a larger mesh bags all together with a weight to prevent regurgitation and passing of the bags to the lower parts of the digestive tract. Bags were removed and washed using the method described by Vanzant et al. (1998) and then placed in a Fiber Analyzer to be washed with NDF solution (Ankom Technology Corp, Macedon, NY). Bags were dried in a forced air oven at 60⁰ C (model LBB2-21-1;
Despatch Industries, Minneapolis, MN) for 24 hours and weighed back to determine remaining NDF after incubation.

Data were analyzed using the MIXED procedure of SAS (SAS Inst. Inc., Cary, NC) and probabilities were considered significant if \( P \leq 0.10 \) (\( P \leq 0.05 \) was used for pH data). Steer was the experimental unit with supplement type, forage type and their interaction as fixed effects. Steer and collection period were random effects. For pH and VFA concentration data, analysis was done as repeated measure using the MIXED procedure of SAS. Time within day was the repeated measure. Day, time, treatment, and their interactions were included in the model with period as a fixed effect.

**Experiment 2**

Rumen undegradable protein digestibility was evaluated using similar preparation to the in situ bag procedures described in Exp. 1. Two ruminally fistulated steers, and two duodenally fistulated steers were used in a completely randomized design to evaluate two different samples of field peas, soybean meal, and SoyPass (rumen protected soybean meal). Steers used for rumen incubation were randomly paired with duodenal steers to be evaluated as animal A and animal B. Composition of the common diet fed to the ruminally fistulated steers can is provided in Table 1. The diet fed to the duodenally fistulated steers is provided in Table 2. Field pea samples were ground through a 6-mm screen in a Wiley Mill (number 4; Thomas Scientific, Swedesboro, NJ). Bags were incubated in the ruminally fistulated steers for 8, 16, and 24 h in order to evaluate changes in digestibility and content over time. There were six bags per time point per feedstuff per animal. Bags were removed and washed according to the method described
by Vanzant et al. (1998). Half the bags from each time point for each feedstuff were then dried in a forced air oven at 60° C (model LBB2-21-1; Despatch Industries, Minneapolis, MN) for 24 h, air equilibrated for 24 h, and weighed back to determine remaining sample weight. Remaining feed was removed from the bags, composited within rumen incubation time point and steer to be analyzed for N content by a combustion chamber (TruSpec N Determinator; Leco Corporation, St. Joseph, MI; AOAC, 1999; method 990.03) to determine CP content of the samples.

The other half of the bags were immediately submersed in a solution of pepsin and hydrochloric acid at 37° C for three hours, the solution was stirred every 15 minutes to simulate digestive processes in the abomasum of the animal. Bags were removed, individually washed, and frozen. After being thawed, bags were directly placed in the duodenum through a duodenal cannula at a rate of 1 bag every 5 minutes. After the animal “passed” bags, and collected from feces, bags were rinsed, and frozen. After all bags were collected, bags were thawed, thoroughly washed for 5, 2-minute cycles, and dried in a forced air oven at 60° C (model LBB2-21-1; Despatch Industries, Minneapolis, MN) for 24 hours then air equilibrated for 24 hours and weighed back to determine remaining sample weight (Haugen et al., 2006). Remaining feed was removed from the bags, composited within rumen incubation time point and steer to be analyzed for N content by a combustion chamber (TruSpec N Determinator; Leco Corporation, St. Joseph, MI; AOAC, 1999; method 990.03) to determine CP content of the samples.
Data were analyzed using the MIXED procedure of SAS (SAS Inst. Inc., Cary, NC). Sample type, time, and their interaction were included in the model. Sample, steer, and time were fixed effects. Probabilities were considered significant if $P \leq 0.10$.

**Results and Discussion**

*Experiment 1*

**Digestibility**

There were no interactions between forage quality and supplement type on digestibility therefore main effects are presented ($P \geq 0.25$). Forage quality affected ($P < .10$) total dry matter intake (DMI), forage DMI, DM digestibility (DMD), OM intake (OMI), OM digestibility (OMD), and 24 hour in-situ NDF digestibility (NDFD; Table 3). Dry matter intake was increased by 1.43 kg for overall DMI (HQ: 6.41 ± 0.49 kg vs LQ: 4.71 ± 0.49) and 1.42 kg in forage DMI (HQ: 5.51 ± 0.49 kg vs LQ: 4.09 ± 0.49).

Organic matter intake resulted in a 1.36 kg increase (HQ: 5.56 ± 0.43 kg vs LQ: 4.20 ± 0.43), while NDF intake was not affected by forage quality ($P = 0.82$). Dry matter digestibility (HQ: 63.09 ± 1.65% vs LQ: 49.09 ± 1.65%) and OMD (HQ: 64.18 ± 1.61% vs LQ: 50.10 ± 1.61%) were 14% greater in digestibility with 24 hour in situ NDFD having a 4.78% increase (HQ: 38.59 ± 0.85% vs LQ: 33.81 ± 0.85%).

The different forage qualities compared in this study produced an expected response in measured parameters. This outcome was expected because of the increased value of higher quality forages for ruminants. Similarly, Adewakun et al. (1988) observed an increase in digestibilities over low quality forages when feeding sorghum silage in diets. While all measured intakes differed due to forage quality, it was noted that cattle
ate to the same NDF intake level, further proving where Arelovich et al. (2008) showed that NDF intake and DMI are positively related.

The effects of supplement type are presented in Table 4, showing PEAS supplement increased total DMI (6.14 ± 0.49 kg; \( P \leq 0.05 \)) over the CORN (5.34 ± 0.49 kg) and CON (4.80 ± 0.49 kg) supplemented steers, which were not different (\( P = 0.20 \)). Organic matter intake, DMD, and OMD were all affected by supplement type similar total DMI with increases for those steers consuming PEAS supplement (\( P \leq 0.09 \)) over steers consuming CORN or CON, which were not different (\( P \geq 0.14 \); Table 4). Forage DMI tended (\( P = 0.14 \)) to be least for CORN (4.40 ± 0.51 kg) while PEAS tended to increase forage DMI (5.20 ± 0.51 kg; \( P = 0.05 \)), but was similar to CON (4.80 ± 0.51 kg; \( P = 0.32 \)) which was also similar to CORN (\( P = 0.31 \)). The in-situ 24 hour NDFD is an indicator of the associative effects on fiber digestion that might occur when other feedstuffs are added to the diet such as supplements. While the level of supplementation was low (0.43% BW), there was still a change in forage NDF digestibility between the CORN and PEAS supplements, with PEAS having greater fiber digestibility (38.03 ± 1.06%) over the CORN supplemented cattle (34.48 ± 1.06%; \( P = .10 \)) with the CON treatment being similar to both supplement types (36.09 ± 1.06%; \( P \geq 0.25 \)).

There have been multiple reports of field peas having no impact on DMI in growing diets when using peas to replace other cereal grains (Anderson, 1999; Poland and Landblom, 1996). Reed et al. (2004) hypothesized for their digestion study that investigation of digestion kinetics would result in positive or no change, perhaps favoring inclusion of peas into beef cattle diets. The authors observed inclusion of field peas did
not alter DMI, similar to the previously mentioned studies which are all contradictory to the results displayed in the current study. Reed et al. (2004) did see an increase in OMD and NDFD with inclusion of field peas, also similar to the present study. This could suggest that in the present study, cattle were RDP deficient when assigned to the LQ treatment with no supplement (LQCON) even though the 2016 NRBC predict an adequate supply of RDP from the forage.

Alternatively, the effects of PEAS compared to CON and CORN could be associated with the lower starch level of PEAS as compared to CORN, providing a more favorable rumen environment for fiber digestion even with the lower levels of supplementation.

Rumen VFA Concentrations

Butyrate proportion was significantly affected by the interaction of forage quality and supplement type (Table 5). Cattle fed HQ forage had greater butyrate concentrations than LQ forage fed steers (12.16 ± 0.22%, 7.47 ± 0.22%, respectively). Supplementation also increased butyrate numbers over the CON treatment (CORN: 10.56 ± 0.275; PEAS: 10.52 ± 0.275%; \( P = 0.91 \); CON: 8.36 ± 0.27%; \( P < 0.01 \)). The interaction was observed due to the relative increase in butyrate concentration supplementation had a greater impact in steers fed HG forage compared to LQ forage.

Forage quality of the diet altered acetate and propionate proportions along with the acetate to propionate ratio (A:P). The proportion of acetate increased in the LQ (72.26 ± 0.58%) over HQ (64.1 ± 0.58), while propionate increased in the HQ (18.48 ± 0.22%) over the LQ (17.89 ± 0.225). The changes in relative proportions shifted the A:P in favor
of the propionate and produced lower values in the HQ diets than the LQ diets (3.61, 4.09, ± 0.05, respectively; Table 3).

Acetate and propionate proportions, as well as the A:P ratio were also affected by supplement type (Table 4). Acetate proportions were similar between \( P = 0.67 \) the CON and PEAS (68.82%, 69.38 ± 0.72), which were greater than CORN \( P < 0.01 \). Propionate proportions were greatest in the CORN supplemented cattle (18.93 ± 0.27; \( P \leq 0.02 \)) with CON and PEAS being similar (17.96 and 17.72 ± 0.27, respectively; \( P = 0.52 \)). The A:P ratio was decreased by CORN supplementation (3.58 ± 0.05) which was lesser than \( P < 0.01 \) PEAS and CON treatments that were similar (3.99, 3.97 ± 0.05, respectively; \( P = 0.83 \)).

VFA concentrations with field pea supplementation remain similar to the CORN treatment as opposed to having similar results to the CON treatments. Field peas did not appear to have the same negative associative effects on fiber digestibility as CORN, but resulted in similar A:P ratio as CORN. The changes in VFA concentrations for PEAS could be explained due to the shifts in microbial populations toward starch digesting bacteria which favors the production of propionate (Hoover 1986).

Reed et al. (2004) saw a cubic increase in total ruminal VFA concentrations as field pea inclusion increased, further concluding that replacement of corn with field peas increased ruminal fermentation. The present study, contradicts the observations of Reed et al. (2004), perhaps due to lower supplement inclusions in the total diet. They also saw that only acetate proportions were affected by increasing inclusion of field peas with a
decrease in mol/100 mol. This differs from the present study in that the VFA profile when peas were included resembled CON treatments rather than CORN supplement.

*Ruminal pH*

Treatment, hour of the day, and their interaction all significantly affected ruminal pH. Period, however did not have a significant effect \((P \geq 0.25)\) on ruminal pH. The results of the pH loggers can be seen in Figure 1 and Figure 2 where the effects are presented by supplement type within forage quality. Cattle were fed supplement at 0800 h and forage at 1000 h. In HQ diets, ruminal pH was similar across treatments from feeding until 1200 hours, where the CORN treatment decreased in pH enough to progressively become different from CON and PEAS, which were similar from 1500 to 1900 hours. At 2000 hours, all treatments differed, after that, all treatments increased ruminal pH back to no difference at 0400 hours through 0700 hours.

In Figure 2, the differences of each supplement treatment in LQ quality diets are shown. From the time of feeding at 0800 hours, all treatments differed until 1200 hours. From 1300 hours until 0400 hours CORN and PEAS treatments were similar, however both were significantly different from CON. All treatments differed again for 0500 and 0600 hours, and then returned to CON treatment being different than the supplementation treatments the hour before feeding.

Fiber digestion is typically depressed below a ruminal pH of 6.0 causing fibrolytic bacteria populations to decrease enough to affect overall fiber digestion. Sub-acute acidosis occurs when ruminal pH is between 5.2 and 5.6 (Slyter, 1976, Fulton et al., 1979). None of the treatments in the current study were below a pH of 6.4, suggesting
that fiber digestion was not altered by ruminal pH and cattle did not experience sub-acute acidosis.

It was hypothesized that field peas would have a more favorable ruminal pH pattern than corn due to decreased starch content. In the HQ diets, there are times when the field peas have an improved ruminal pH over the corn, however, there are times when the field peas are still comparable to corn. It is important to note that peas do not inflict the same range of change in rumen pH that corn does in this study for the HQ diets. In the LQ diets, PEAS remained similar to the CORN supplement which were always different than CON. Acidosis was not an issue for either forage quality due to the diet being primarily roughage with a small fraction as grain. It has been observed that as inclusion of field peas in growing diets increases, ruminal pH responds cubically (Reed et al., 2004). The current study only evaluated supplementing one rate of field peas. Results showed there was a difference from CON at times when PEAS were supplemented. Soto-Navarro et al. (2004) saw a decrease in ruminal pH with increasing inclusion of field peas, however this was in medium concentrate based diets. The effect of increasing RDP in finishing diets by means of urea was examined by Shain et al. (1998) with no effect on ruminal pH. Again, this was in finishing diets, and therefore the presence of more RDP from the field peas would be potentially more prone to altering ruminal pH in a diet with energy density lower than a finishing diet.

Experiment 2

Crude protein content of all feeds were determined and listed in Table 6 as a reference point for evaluating the results of RUP digestion kinetics. The two years of
field pea samples had a crude protein content ranging from 22.0% to 26.5%. There was not an interaction of sample by rumen incubation time for RUP nor RUP digestibility ($P \geq 0.35$).

The RUP portion of all the feeds as a percentage of crude protein content was variable across the feedstuffs and also significantly affected by sample incubation time in the rumen (Table 6). Field peas had an RUP content of 32.6% and 35.3 ± 4.395, which was similar to the RUP content of SBM (23.6 ± 4.39%; $P = 0.25$). The effect of time on amount of protein available in the lower digestive tract shows that the longer the samples were incubated in the rumen, the less RUP there was in the remaining sample. By using three time points, there is the opportunity to evaluate the feeds when they would be included in diets with different passage rates, while also evaluating the optimum time of incubation for desired digestibility of the feeds. All three time points were significantly different with 24 hours being the least amount of RUP across feedstuff followed by 16 and 8 hours, respectively ($P < 0.01$). Figure 3 also shows the change in RUP content for each feed across the incubation times.

RUP digestibility was affected by sample type ($P < 0.01$). Field peas had similar RUP digestibility to both SBM and SoyPass with a range of 97.4% for year 1 peas and 98.9% for year 2 (SEM = 1.17).

Field peas are high in RDP, leaving a smaller percent of CP to RUP. Chen et al. (2003) evaluated replacing barley with corn and concluded that the low RUP fraction was not a limiting factor to the heifer’s performance. Although the high RDP content of field peas has been hypothesized to be beneficial to rumen microbial development (Anderson,
2007), the digestibility of the RUP fraction is beneficial to the animal, and digestibility was very high across all rumen incubation times.

**Overall Conclusion**

Field peas are a highly digestible feed that in high forage diets, of any quality, do not negatively impact the rumen environment for fiber digestion and potentially increase intakes. However, field peas produce VFA concentrations more similar to diets without supplementation.
Literature Cited


Köster, H.H., R.C. Cochran, E.C. Titgemeyer, E.S. Vanzant, I. Abdelgadir, G. St-Jean. Effect of increasing degradable intake protein on intake and digestion of low-


Table 1. Composition of diet consumed by ruminally fistulated steers in Exp. 2

<table>
<thead>
<tr>
<th>Ingredient</th>
<th>% of Diet 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Brome Hay</td>
<td>70.51</td>
</tr>
<tr>
<td>Dried DGS</td>
<td>23.33</td>
</tr>
<tr>
<td>Dry Rolled Corn</td>
<td>5.81</td>
</tr>
<tr>
<td>Salt</td>
<td>0.28</td>
</tr>
<tr>
<td>Trace Mineral 2</td>
<td>0.05</td>
</tr>
<tr>
<td>Vitamin ADE 3</td>
<td>0.03</td>
</tr>
</tbody>
</table>

1 Two ruminally fistulated steers were used to incubate in situ bags for 8, 16, and 24 hours.
2 Premix contained 10% Mg, 6% Zn, 4.5% Fe, 2% Mn, 0.5% Cu, 0.3% I, and 0.05% Co.
3 Premix contained 1,500 IU vitamin A, 3,000 IU vitamin D, and 3.7 IU vitamin E per g.
4 DM basis
Table 2. Composition of diet consumed by duodenally fistulated steers in Exp. 2

<table>
<thead>
<tr>
<th>Ingredient</th>
<th>% of Diet&lt;sup&gt;4&lt;/sup&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>Brome Hay</td>
<td>50.0</td>
</tr>
<tr>
<td>Sweet Bran</td>
<td>44.5</td>
</tr>
<tr>
<td>Trace Mineral&lt;sup&gt;2&lt;/sup&gt;</td>
<td>4.0</td>
</tr>
<tr>
<td>Limestone</td>
<td>1.5</td>
</tr>
</tbody>
</table>

<sup>1</sup>Two duodenally fistulated steers were used to pass in situ bags that had previously been ruminally incubated for 8, 16, and 24 hours through the lower digestive tract.

<sup>2</sup>Premix contained 14% Ca, 4% P, 23% Salt, 12% Na, 0.5% Mg, 0.5% K, 775ppm Mn, 50ppm I, 10ppm Se, 750 ppm Zn, 12000IU/lb Vitamin A, 2000 IU/lb Vitamin D<sub>3</sub>, 25 IU/lb Vitamin E (Tractor Supply Company; Brentwood, TN)

<sup>3</sup>Premix contained 1,500 IU vitamin A, 3,000 IU vitamin D, and 3.7 IU vitamin E per g.

<sup>4</sup>DM basis
Table 3. Diet digestibility and concentration of rumen VFA’s in steers due to forage quality in Exp. 1

<table>
<thead>
<tr>
<th>Forage Trt¹</th>
<th>High Quality</th>
<th>Low Quality</th>
<th>SEM</th>
<th>P-value³</th>
</tr>
</thead>
<tbody>
<tr>
<td>DM</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Intake, kg/d</td>
<td>6.13</td>
<td>4.71</td>
<td>0.49</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>Excreted, kg/d</td>
<td>2.19</td>
<td>2.36</td>
<td>0.15</td>
<td>0.16</td>
</tr>
<tr>
<td>Total tract digestibility, %</td>
<td>63.09</td>
<td>49.09</td>
<td>1.65</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>Forage DM</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Intake, kg/d</td>
<td>5.51</td>
<td>4.09</td>
<td>1.07</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>OM</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Intake, kg/d</td>
<td>5.43</td>
<td>4.20</td>
<td>0.50</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>Excreted, kg/d</td>
<td>1.94</td>
<td>2.06</td>
<td>0.14</td>
<td>0.23</td>
</tr>
<tr>
<td>Total tract digestibility, %</td>
<td>64.14</td>
<td>50.04</td>
<td>1.61</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>NDF</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Intake, kg/d</td>
<td>3.08</td>
<td>3.16</td>
<td>0.36</td>
<td>0.75</td>
</tr>
<tr>
<td>Excreted, kg/d</td>
<td>1.31</td>
<td>1.42</td>
<td>0.11</td>
<td>0.17</td>
</tr>
<tr>
<td>Total tract digestibility, %</td>
<td>57.71</td>
<td>54.51</td>
<td>2.14</td>
<td>0.23</td>
</tr>
<tr>
<td>In-situ NDFD², %</td>
<td>38.59</td>
<td>33.81</td>
<td>0.85</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>VFA</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total, mMol</td>
<td>124.49</td>
<td>126.81</td>
<td>9.39</td>
<td>0.86</td>
</tr>
<tr>
<td>Acetate, %</td>
<td>64.10</td>
<td>72.26</td>
<td>0.58</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>Propionate, %</td>
<td>18.48</td>
<td>17.89</td>
<td>0.22</td>
<td>0.06</td>
</tr>
<tr>
<td>Butyrate, %</td>
<td>12.16</td>
<td>7.47</td>
<td>0.22</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>A:P</td>
<td>3.61</td>
<td>4.09</td>
<td>0.05</td>
<td>&lt;0.01</td>
</tr>
</tbody>
</table>

*abcd* Within a row, means without a common superscript differ.

1High Quality Forage Diet: 50/50 blend of sorghum silage and alfalfa hay. Low Quality Forage Diet: 50/50 blend of brome grass hay and wheat straw. Water was added to the Low Quality treatment to ensure equal amount of dry matter across both forage treatments.

2NDF digestibility: measured at 24 hours, in-situ. HQ and LQ forages were incubated in the rumen.

3Time × Treatment Interaction \( P \geq 0.25 \)
Table 4. Diet digestibility and concentration of rumen VFA’s in steers due to supplement type in Exp. 1

<table>
<thead>
<tr>
<th>Supplement Trt¹</th>
<th>Control</th>
<th>Corn</th>
<th>Peas</th>
<th>SEM</th>
<th>P-value³</th>
</tr>
</thead>
<tbody>
<tr>
<td>DM</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Intake, kg/d</td>
<td>4.80ᵃ</td>
<td>5.33ᵃ</td>
<td>6.14ᵇ</td>
<td>0.51</td>
<td>0.01</td>
</tr>
<tr>
<td>Excreted, kg/d</td>
<td>2.13</td>
<td>2.36</td>
<td>2.33</td>
<td>0.16</td>
<td>0.25</td>
</tr>
<tr>
<td>Total tract digestibility, %</td>
<td>53.05ᵃ</td>
<td>55.13ᵃ</td>
<td>60.10ᵇ</td>
<td>2.01</td>
<td>0.06</td>
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<tr>
<td>Forage DM</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Intake, kg/d</td>
<td>4.81</td>
<td>4.40</td>
<td>5.21</td>
<td>1.12</td>
<td>0.14</td>
</tr>
<tr>
<td>OM</td>
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</tr>
<tr>
<td>Intake, kg/d</td>
<td>4.28ᵃ</td>
<td>4.82ᵃ</td>
<td>5.35ᵇ</td>
<td>0.52</td>
<td>0.06</td>
</tr>
<tr>
<td>Excreted, kg/d</td>
<td>1.87</td>
<td>2.09</td>
<td>2.03</td>
<td>0.15</td>
<td>0.20</td>
</tr>
<tr>
<td>Total tract digestibility, %</td>
<td>53.76ᵃ</td>
<td>56.02ᵃ</td>
<td>61.48ᵇ</td>
<td>1.94</td>
<td>0.03</td>
</tr>
<tr>
<td>NDF</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Intake, kg/d</td>
<td>3.09</td>
<td>3.00</td>
<td>3.27</td>
<td>0.38</td>
<td>0.66</td>
</tr>
<tr>
<td>Excreted, kg/d</td>
<td>1.35</td>
<td>1.37</td>
<td>1.38</td>
<td>0.11</td>
<td>0.95</td>
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<tr>
<td>Total tract digestibility, %</td>
<td>55.43</td>
<td>53.81</td>
<td>59.09</td>
<td>2.50</td>
<td>0.25</td>
</tr>
<tr>
<td>In-situ NDFD² (%)</td>
<td>36.09ᵃᵇ</td>
<td>34.48ᵃ</td>
<td>38.03ᵇ</td>
<td>1.06</td>
<td>0.09</td>
</tr>
<tr>
<td>VFA</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total, mMol</td>
<td>128.56</td>
<td>120.12</td>
<td>128.27</td>
<td>11.55</td>
<td>0.84</td>
</tr>
<tr>
<td>Acetate, %</td>
<td>68.82ᵇ</td>
<td>66.39ᵃ</td>
<td>69.38ᵇ</td>
<td>0.72</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>Propionate, %</td>
<td>17.96ᵃ</td>
<td>18.93ᵇ</td>
<td>17.72ᵃ</td>
<td>0.27</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>Butyrate, %</td>
<td>8.36ᵇ</td>
<td>10.56ᵃ</td>
<td>10.52ᵃ</td>
<td>0.27</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>A:P</td>
<td>3.97ᵇ</td>
<td>3.58ᵃ</td>
<td>3.99ᵇ</td>
<td>0.05</td>
<td>&lt;0.01</td>
</tr>
</tbody>
</table>

ᵃᵇ Within a row, means without a common superscript differ.
¹ There were three supplement treatments, Control which consisted of no supplement, Peas which was 6 mm ground field peas, or Corn that was dry rolled corn. Supplements were coated in molasses to increase palatability (95% grain, 5% molasses; DM basis) and fed at 0.43% BW, DM basis.
²NDF digestibility: measured at 24 hours, in-situ. HQ and LQ forages were incubated in the rumen.
³Time × Treatment Interaction P ≥ 0.25
Table 5. Effect of forage quality and supplement type on butyrate proportion in Experiment 1

<table>
<thead>
<tr>
<th>Supp. Trt</th>
<th>High Quality</th>
<th>Low Quality</th>
<th>SEM</th>
<th>P - value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Forage Quality</td>
<td>Butyrate, %</td>
<td>Control</td>
<td>Corn</td>
</tr>
<tr>
<td>Control</td>
<td>11.31ᵇ</td>
<td>12.88ᵃ</td>
<td>12.28ᵃ</td>
<td>5.41ᵈ</td>
</tr>
<tr>
<td>Corn</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Peas</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

abcd Within a row, means without a common superscript differ.

¹High Quality Forage Diet: 50/50 blend of sorghum silage and alfalfa hay. Low Quality Forage Diet: 50/50 blend of brome grass hay and wheat straw. Water was added to the Low Quality treatment to ensure equal amount of dry matter across both forage treatments.

²Control consisted of no supplement, Peas was 6 mm ground field peas, and Corn was dry rolled corn. Supplements were coated in molasses to increase palatability (95% grain, 5% molasses; DM basis) and fed at 0.43% BW, DM basis.
Figure 1. Ruminal pH in high quality forage treatments in Experiment 1
Ruminal pH of cattle fed 3 different treatments was monitored over 6 collection periods. Cattle were given a High Quality Forage Diet (50/50 blend of sorghum silage and alfalfa hay) fed ad libitum. There were three supplement treatments, CON which consisted of no supplement, PEAS which was 6 mm ground field peas, or CORN that was dry rolled corn. Supplements were coated in molasses to increase palatability (95% grain, 5% molasses; DM basis) and fed at 0.43% BW, DM basis. There was a time × treatment interaction ($P < 0.01$). Treatment differences ($P < 0.05$) within time points are marked with a letter (a, b, c, d, e) to show statistical differences ($P < 0.05$) within time point. Those times marked with an “a” indicate there was no difference across treatments within time point ($P > 0.05$). Time points marked with a “b” indicates that PEAS were similar to CORN and CON, which differed. Time points marked with a “c” indicates that CON and PEAS were similar and both were different than CORN. Time points marked with “d” indicate that all treatments differed from each other. Time points marked with “e” indicate that CON differed from CORN and PEAS, which were similar.
Ruminal pH of cattle fed 3 different treatments was monitored over 6 collection periods. Cattle were given a Low Quality Forage Diet (50/50 blend of brome grass hay and wheat straw) fed ad libitum. Water was added to the Low Quality treatment to ensure equal amount of dry matter across both forage treatments. There were three supplement treatments, CON which consisted of no supplement, PEAS which was 6 mm ground field peas, or CORN that was dry rolled corn. Supplements were coated in molasses to increase palatability (95% grain, 5% molasses; DM basis) and fed at 0.43% BW, DM basis. There was a time × treatment interaction \( (P < 0.01) \). Treatment differences \( (P < 0.05) \) within time points are marked with a letter (a or b) to show statistical differences \( (P < 0.05) \) within time point. Those times marked with an “a” indicates that all treatments differed from each other. Time points marked with a “b” indicates that CON differed from CORN and PEAS, which were similar.

Figure 2. Ruminal pH in low quality forage treatments in Experiment 1

Ruminal pH of cattle fed 3 different treatments was monitored over 6 collection periods. Cattle were given a Low Quality Forage Diet (50/50 blend of brome grass hay and wheat straw) fed ad libitum. Water was added to the Low Quality treatment to ensure equal amount of dry matter across both forage treatments. There were three supplement treatments, CON which consisted of no supplement, PEAS which was 6 mm ground field peas, or CORN that was dry rolled corn. Supplements were coated in molasses to increase palatability (95% grain, 5% molasses; DM basis) and fed at 0.43% BW, DM basis. There was a time × treatment interaction \( (P < 0.01) \). Treatment differences \( (P < 0.05) \) within time points are marked with a letter (a or b) to show statistical differences \( (P < 0.05) \) within time point. Those times marked with an “a” indicates that all treatments differed from each other. Time points marked with a “b” indicates that CON differed from CORN and PEAS, which were similar.
Table 6. RUP and RUP digestibility of protein supplements in Experiment 2

<table>
<thead>
<tr>
<th>Feedstuff</th>
<th>Field Peas, Year 1</th>
<th>Field Peas, Year 2</th>
<th>Soybean Meal</th>
<th>SoyPass</th>
<th>SEM</th>
<th>Sample</th>
<th>Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crude Protein, %</td>
<td>26.5</td>
<td>22.0</td>
<td>49.4</td>
<td>44.4</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>RUP, % of CP</td>
<td>35.3&lt;sup&gt;b&lt;/sup&gt;</td>
<td>30.1&lt;sup&gt;bc&lt;/sup&gt;</td>
<td>23.6&lt;sup&gt;c&lt;/sup&gt;</td>
<td>74.1&lt;sup&gt;a&lt;/sup&gt;</td>
<td>4.06</td>
<td>&lt;0.01</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>8 Hour RUP&lt;sup&gt;x&lt;/sup&gt;</td>
<td>56.9</td>
<td>50.9</td>
<td>52.6</td>
<td>98.4</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>16 Hour RUP&lt;sup&gt;y&lt;/sup&gt;</td>
<td>39.9</td>
<td>28.5</td>
<td>18.1</td>
<td>71.1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>24 Hour RUP&lt;sup&gt;z&lt;/sup&gt;</td>
<td>9.2</td>
<td>13.2</td>
<td>0.2</td>
<td>52.8</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>RUP Digestibility, %</td>
<td>97.4</td>
<td>98.9</td>
<td>98.7</td>
<td>97.2</td>
<td>0.64</td>
<td>0.18</td>
<td>0.97</td>
</tr>
<tr>
<td>TTIP, % of CP&lt;sup&gt;2&lt;/sup&gt;</td>
<td>5.96&lt;sup&gt;b&lt;/sup&gt;</td>
<td>0.00&lt;sup&gt;c&lt;/sup&gt;</td>
<td>9.78&lt;sup&gt;b&lt;/sup&gt;</td>
<td>25.07&lt;sup&gt;a&lt;/sup&gt;</td>
<td>3.7</td>
<td>&lt;0.01</td>
<td>0.88</td>
</tr>
</tbody>
</table>

<sup>a</sup>b<sup>c</sup> Indicates values with similar subscripts do not differ as a result of main effect of sample type.

<sup>xyz</sup> The main effect of time consist of 8 hour incubation having significantly greater RUP content than 16 hour incubation and both 8 and 16 hour incubations had significantly greater RUP content than 24 hour incubation (P < 0.01).

<sup>1</sup>Feeds listed were weighed into in situ bags and were ruminally incubated for 8, 16, and 24 hours in two different ruminally fistulated steers. Immediately after they were soaked in a pepsin/HCl wash. Two duodenal fistulated steers were then used to pass the bags through the lower portion of the digestive tract.

<sup>2</sup>CP weight of residue after duodenal incubation (g) / CP weighed into the bags (g) = TTIP (% CP).

<sup>3</sup>The Sample × Time interaction was not significant for RUP, RDP, or TTIP (P ≥ 0.56).
Figure 3. Variation in RUP content across different rumen incubation times for 4 different feedstuffs in Experiment 2

Feeds listed were weighed into in situ bags and were ruminally incubated for 8, 16, and 24 hours in two different ruminally fistulated steers. Immediately after they were soaked in a pepsin/HCl wash. Two duodenally fistulated steers were then used to pass the bags through the lower portion of the digestive tract. There was not a time × sample interaction for RUP as a percent of CP ($P = 0.82$). The main effect of time consist of 8 hour incubation having significantly greater RUP content than 16 hour incubation and both 8 and 16 hour incubations had significantly greater RUP content than 24 hour incubation ($P < 0.01$). For rumen incubation durations labeled with an “a”, Soypass differed from all other samples which were all similar. For rumen incubation durations labeled with a “b”, field peas were similar in year 1 and year 2, year 1 differed from all other samples, but year 2 was similar to SBM, Soypass differed from all other samples.