EFFECTS OF BARLEY CULTIVAR AND GROWING ENVIRONMENT ON FEEDLOT PERFORMANCE AND CARCASS CHARACTERISTICS OF FINISHING BEEF CATTLE

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Michael F. McDonnell

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Michael F. M^{c}Donnell

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Dr. Janice G. P. Bowman

Approved for the Department of Animal and Range Sciences

Dr. Michael W. Tess

Approved for the College of Graduate Studies

Dr. Bruce R. McLeod

STATEMENT OF PERMISSION TO USE

Michael F. McDonnell

August 27, 2004

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ABSTRACT

Thirty-two crossbreed beef heifers (initial weight 349 kg ± 2.21 kg) were individually fed finishing diets for 84 d in a 2 X 2 factorial experiment examining the effects of barley cultivar (Harrington vs. Valier) and growing environment (irrigated vs. dryland) on animal performance, carcass characteristics, and nutrient digestibility. No differences in ADG ($P = 0.46$; average 1.78 kg/d) or final weight ($P = 0.23$; average 498 kg) were detected due to cultivar. Barley cultivar did not affect DMI ($P = 0.80$; average 9.8 kg/d), or feed efficiency ($P = 0.63$; average 18.3 kg gain/100 kg of feed). Growing environment did not influence ADG ($P = 0.17$; average 1.77 kg/d), or final weight ($P = 0.20$; average 498 kg). Heifers fed diets containing irrigated barley had lower ($P = 0.009$) DMI than heifers fed diets containing dryland barley (9.3 vs. 10.3 kg/d, respectively). Feed efficiency was higher ($P = 0.001$) for heifers fed diets containing irrigated barley than for those fed dryland barley (19.8 vs. 16.8 kg gain/100 kg of feed). Barley NE_m ($P = 0.38$; average 2.15 Mcal/kg) or NE_g ($P = 0.38$; average 1.46 Mcal/kg) were not affected by cultivar. Irrigated barley NE_m and NE_g (2.31 and 1.61 Mcal/kg, respectively) contents were higher ($P = 0.001$) than dryland barley NE_m and NE_g (1.98 and 1.32 Mcal/kg, respectively) content. No differences ($P > 0.06$) in carcass characteristics were detected due to barley cultivar, growing environment or their interaction. Dry matter digestibility was higher ($P = 0.02$) for diets containing Valier barley than for diets containing Harrington barley (77.6 vs. 74.9 %, respectively). Starch digestibility was not affected ($P = 0.13$) by cultivar. Growing environment did not affect ($P > 0.06$) nutrient digestibility. In summary, irrigated barley had higher starch content and lower ADF content than dryland barley. The higher starch content of the irrigated barley resulted in the irrigated barley having higher energy content than dryland barley, which resulted in the irrigated barley being a more efficient feed source.

CHAPTER 1

INTRODUCTION

Barley's (*Hordeum vulgare* L.) adaptability to diverse growing environments enables it to be grown throughout the world, making it the fourth most universally grown crop (Nilan and Ullrich, 1993). Barley, a short-season early maturing crop, is classified by the physical arrangement of kernels on the plant as two-rowed or six-rowed, and is grown in irrigated and dryland growing environments throughout the United States. In the U.S. between 2.1 and 2.8 million hectares of barley are planted annually, making barley the third most popularly grown feed grain (U.S. Grain Council, 2004). Thirty states representing a wide variety of growing environments from Oregon in the Pacific Northwest to Arizona in the desert southwest, reported barley production in 2003 (NASS, 2004). However, the majority of U.S. barley production occurs in the northern tier of states, where its' adaptability to temperate climates and short dry growing seasons gives it advantages over other cereal grains.

Montana produced nearly 40 million bushels of barley in 2002, roughly 18 percent of total U.S. barley production, making it the third largest barley producing state in the country (NASS, 2004). Sixty percent of Montana's barley is produced in a dryland growing environment, whereas 40 percent is produced in irrigated growing environments. Approximately 40 percent of Montana's barley acreage is seeded with feed cultivars, while the remaining acreage is seeded to malting cultivars (NASS, 2004). However, variation in barley nutrient content, caused by cultivar and growing environment, results in about 35% of malt barley failing to meet commercial malting criteria, subsequently entering the feed market (Davis, 2002), where it is commonly used as the principle energy source in feedlot diets. A positive correlation between malting and feed characteristics has been shown (Molina-Cano et al., 1997). Boss and Bowman (1996) reported that steers fed finishing diets containing Harrington, a two-rowed malting cultivar, had greater animal performance than steers fed diets containing Medallion, a six-rowed feed barley, supporting this concept. However, similar trials attribute no difference in animal performance to cultivar when feeding beef steers finishing diets containing two-rowed malting cultivars or six-rowed feed cultivars (Hinman, 1979; Bradshaw et al., 1996). Growing environment has been shown to be equally important in creating variability in barley nutrient content (Reynolds et al., 1992). Surber et al. (1999) found that barley grown in irrigated environments had higher ADF and starch content, but lower CP content when compared to barley grown in dryland environments. While numerous studies have evaluated environmental influences on barley composition (Åman and Newman, 1986; Tester, 1997; Berthodsson, 1999), few deal directly with how it relates to beef cattle performance. Hinman (1979) compared the effects of growing environment (irrigated vs. dryland) on the animal performance of steers consuming finishing diets containing malting or feed cultivars. Cultivar or growing environment did not influence animal performance. However, Hinman (1979) made the comparison using a two-rowed malting barley and a six-rowed feed barley. Two-rowed cultivars have been shown to be higher in nutritional content (Kong et al., 1995) and stimulate better animal performance (Boss and Bowman, 1996; Ovenell-Roy et al., 1998) when compared to six-rowed cultivars.

Therefore, the objectives of this trial were to compare the animal performance of finishing beef cattle fed Harrington, a two-rowed malting cultivar, or Valier, a two-rowed feed cultivar, grown under two growing environments (irrigated vs. dryland). Influences of barley cultivar, growing environment (irrigated vs. dryland) and cultivar x growing environment interactions were investigated.

CHAPTER 2

LITERATURE REVIEW

Effects of Cultivar

Our study examined the effects of finishing diets containing Harrington or Valier barley. Harrington, derived by crossing Klages x Gazelle/Betzes//Centennial, is a mid-season, spring habit, two-rowed malting barley developed by the University of Saskatchewan's Crop Science Department (Harvey and Rossnagel, 1984). Harrington was developed for improved malting characteristics and its adaptability to southern Alberta's growing environment (Harvey and Rossnagel, 1984), which is comparable to many growing environments in Montana. During 2003, Harrington accounted for 46 percent of Montana's barley acreage, making it the top variety planted in Montana for the tenth consecutive year (NASS, 2004). Valier, developed from the cross Lewis/Baronesse, was produced by the Montana Agricultural Experiment Station. Valier was designed explicitly to combine enhanced feed quality characteristics with superior agronomic performance (Blake et al., 2002). Valier was developed in an effort to increase starch content, while decreasing fiber content. Of the acreage seeded to feed barley cultivars in Montana in 2003, slightly less than three percent was seeded with Valier barley (NASS, 2004). While the development of Harrington and Valier was directed towards two different end uses, some research reports that dry matter (DM), crude fat, crude protein, and fiber level (all key components of barley feed quality) of the two cultivars are very similar (Yu et al., 2003).

Despite the similarities found by Yu et al. (2003), the nutrient content of barley can be inherently variable between cultivars. Åman and Newman (1986) compared the nutrient content of various barley cultivars, including two- and six-rowed barley cultivars, grown under commercial conditions at the Montana Agricultural Experiment Station in Bozeman, Montana to that of barley grown in Sweden. In order to minimize confounding issues, such as production practices, and more accurately report differences and similarities between the Montanan and Swedish barleys, findings from previously published studies conducted on normal Swedish barleys were compared to the findings of the study conducted in 1986 (Åman and Newman, 1986). In this study, regardless of location, two- and six-rowed barley cultivars were found to be similar in nutrient content. Starch content ranged from 53 to 61 percent of barley DM and was found to be the largest component in barley, followed by crude fiber content ranging from 18 to 23 percent, and crude protein making up 12 to 17 percent of barley DM. Similar to the trends found when looking at the proportions of the nutrient composition constituents of the barley, when comparing the standard deviations of these nutritional components starch had the largest standard deviation followed by crude fiber and crude protein. Admittedly, production practices, cultivars, and growing environments differ between the two locations. Åman and Newman (1986) reported that barley produced in Montana's relatively short dry growing environment had a higher protein content and lower starch content than barley grown in Sweden, suggesting that growing environment can manipulate key constituents of barley nutrient content.

Much of the literature that considers barley feed quality pertains to the feeding of monogastric animals. Honeyfield et al. (1987) examined the effects of cultivar and growing conditions on the feeding value of barley for swine. Similar to other studies, Honeyfield et al. (1987) reported variability in chemical composition among the five feed barley cultivars used in the study. Differences in feed intake and DM digestibility were found between cultivars. In general, the feeding value of the barleys used by Honeyfield et al. (1987) was dependent upon the cultivar x growing environment interactions. While, Honeyfield et al. (1987) investigated variation in feed quality between feed barleys no comparisons were made between feeding and malting cultivars. Furthermore, no comparisons were made between two-rowed and six-rowed cultivars.

Molina-Cano et al. (1997) examined the genetic and environmental variation in malting quality and feed quality of barley for poultry. Five barley cultivars, including two-rowed and six-rowed, having excellent or no malting characteristics were grown under normal agricultural practices in Spain. Significant effects of cultivar were reported for all feeding and malting characteristics. Cultivar had the greatest effect on fiber and metabolizable energy. Furthermore, there was a positive correlation between malting and feeding characteristics, suggesting that barley having superior malting characteristics would be superior in feeding characteristics, subsequently eliciting greater animal performance (Molina-Cano et al., 1997). As indicated above, the work of Molina-Cano et al. (1997) and Honeyfield et al. (1987) dealt with issues of barley feed quality as it pertains to monogastric species. Beta-glucans, a major constituent of the cell walls of barley (Engstom et al., 1992), have been shown to decrease the nutritional value of barley for poultry (White et al., 1983) and hinder the animal performance of growing swine (Taylor et al., 1983). The negative impacts reported in these studies may be attributed to the fact that, with the exception of the occasional β 1-3 linkage, the structure of β-glucans is very similar to the structure of cellulose, making β-glucans indigestible to mammalian enzymes (Van Soest, 1994). However, fermentation of β-glucans by fiber digesting bacteria inhabiting the rumen should alleviate negative affects seen in monogastric animals. Therefore, the impact of β-glucans and other aspects of how cultivar affects barley feed quality as it pertains to ruminant nutrition remains unanswered.

Hinman (1979) compared the effects of malting and feed barley on the performance of finishing beef cattle. The animal performance of steers consuming finishing diets containing Klages, a two-rowed malting barley, was compared to the animal performance of steers consuming diets containing Steptoe, a six-rowed feed barley. Both barley cultivars were grown under dryland and irrigated growing environments resulting in four separate dietary treatments. Average daily gain (ADG) was not affected by barley treatment. Hinman (1979) reported no differences in feed efficiency for steers consuming diets containing Klages, the two-rowed malting barley, when compared to that of steers consuming diets containing Steptoe, the six-rowed feed barley. However, there was a cultivar x growing environment interaction for dry matter intake (DMI), with the DMI by steers consuming diets containing dryland Klages being lower than the DMI by steers consuming the other dietary treatments (9.3 vs. average 9.9 kg/d, respectively). While cultivar did not affect feed efficiency, steers consuming diets containing Steptoe tended to require more feed per unit of gain than steers consuming diets containing Klages (9.0 vs. 8.5 kg feed/kg gain). Hinman (1979) proposed that the differences seen in feed efficiency were caused by the higher fiber content reported in the Steptoe barley (6.83 vs. 4.41% crude fiber, Steptoe vs. Klages, respectively) reducing the energy available to the beef steers. In a similar study, Bradshaw et al. (1996) examined the effects of barley variety and processing method on the feedlot performance and carcass characteristics of finishing beef steers. Again the comparison was made using the two-rowed malting cultivar Klages and the six-rowed feeding cultivar, Steptoe. No effect of cultivar was found for DM digestibility or for the energy content of the diet. Furthermore, no differences in ADG, DMI or feed efficiency were attributed to cultivar, which agrees with the work of Hinman (1979). With the exception of ADF digestibility, which was greater for diets containing Steptoe than for diets containing Klages (40.5 vs. 31.4%, respectively), nutrient digestibility was not influenced by cultivar (Bradshaw et al., 1996). Neither the work of Hinman (1979) or Bradshaw et al. (1996) revealed any effect of cultivar on carcass characteristics of steers.

Boss and Bowman (1996) compared the animal performance of beef steers fed finishing diets containing Harrington (a two-rowed malting barley), Gunhilde (a two-rowed feed barley), or Medallion (a six-rowed feed barley). The crude protein content of the three barleys was similar, however, higher starch content and lower fiber content was reported for Harrington than for Gunhilde or Medallion. Steers consuming diets containing Harrington, the malting cultivar, experienced greater ADG resulting in higher ending weights than steers consuming Gunhilde or Medallion. Additionally, steers consuming diets containing Harrington had heavier carcass weights, better marbling scores, and graded higher in yield and quality grades than steers consuming diets containing Gunhilde or Medallion (Boss and Bowman, 1996).

One confounding variable occurring in the work of Hinman (1979), Bradshaw et al. (1996), and Boss and Bowman (1996), is that the comparisons in animal performance were made between animals consuming diets containing a two-rowed cultivar and a six-rowed cultivar. Differences in the agronomic traits (Jedel and Helm, 1995), chemical composition (Froseth et al., 1983; Campbell et al., 1995), and feeding value (Bowman et al., 2001) of two-row and six-rowed cultivars have been shown. Campbell et al. (1995) compared the chemical composition of six barley cultivars that included two six-rowed malting cultivars (Argyle and Bonanza), two, two-rowed feed cultivars (Duece and Norbert), and two six-rowed feed cultivars (Bedford and Heartland). Starch content was found to be four percent higher in two-rowed cultivars than in six-rowed cultivars. Additionally, fiber content was highest for six-rowed feed cultivars, intermediate for six-rowed malting cultivars, and lowest for two-rowed feed cultivars (Campbell et al., 1995). Bowman et al. (2001) examined variation in the feed quality of fifteen hundred of the roughly twenty-five thousand barley accessions contained in the USDA barley core collection. The fifteen hundred selected samples were cracked in a Buehler mill and analyzed for in situ DM digestibility. The thirty-six samples with the lowest DM digestibility and thirty-seven with the highest DM digestibility were selected. These selected samples, together with eight standard spring cultivars, were analyzed for ADF, starch, and DM content as well as ruminal DM digestibility. Of the seventy-three selected accessions from the USDA core collection, six-rowed cultivars had lower starch content and contained more DM and ADF than two-rowed cultivars. Additionally, DM and starch digestibility were lower for six-rowed cultivars when compared to two-rowed cultivars. When comparing the feed quality of the eight commonly grown spring cultivars, ADF content was higher and starch content was lower in six-rowed cultivars than two-rowed cultivars. However, no other differences in feed quality parameters were reported for these eight samples. Genotype affected all feed quality parameters in the seventy-three samples selected for DM digestibility, however, only ADF content was affected by genotype when examining the eight commonly grown spring barley cultivars (Bowman et al., 2001).

Fairbairn et al. (1999), in a study examining energy content of barley fed to growing pigs, reported that ADF content, with a R^2 = -0.85, was the most significant constituent of barley feed quality influencing variation in energy content. The ADF content of barley has been shown to negatively influence the feedlot performance of finishing beef cattle (Surber et al., 2000). Surber et al. (2000) used results from eighteen feedlot trials performed throughout Montana and Idaho during a seven-year period from 1993 to 2000 to develop a prediction equation for barley feed quality as it relates to finishing beef cattle. While starch intake was shown to be the parameter with the strongest correlation to ADG (r = 0.53), barley ADF content significantly and negatively influenced starch intake. These data suggest, that when fed to finishing beef cattle, barley cultivars with lower ADF content would elicit better animal performance than cultivars containing higher levels of ADF. The influence of starch and ADF content on animal performance is shown in the work of Engstrom et al. (1992), who evaluated the animal performance of steers consuming finishing diets containing barley from one of six lots. Table 1 lists the six lots in descending order according to starch content, which ranged from 65.5 to 56.5%. With the exception of lots 6 and 5, this arrangement results in the barleys being ranked in ascending order according to their ADF content. The relationship between starch and ADF content shown in Table 1 is reflected in the feed to gain ratio, in that, with the exception of lots 6 and 5, the steers consuming diets containing barleys with higher starch content and lower ADF content had better feed efficiencies (Engstrom et al., 1992).

Ovenell-Roy et al. (1998) examined the influence of barley cultivar on the feedlot performance and carcass characteristics of finishing beef steers. Feed efficiency was influenced ($P < 0.05$) by cultivar, with steers consuming diets containing cultivars with higher starch content having the most desirable feed efficiencies (Ovenell-Roy et al., 1998). The findings of Engstrom et al. (1992) and Ovenell-Roy et al. (1998) are supported by the work of Surber et al. (2000). All show the importance of the fiber and starch content of barley in finishing beef cattle diets.

Table 1. Starch and ADF content of the six lots of barley used by Engstrom et al. (1992), together with the feed/gain ratio of steers consuming the six finishing diets

Lot #	Starch, %	ADF, %	Feed/Gain
6	65.6	6.3	5.92
5	64.9	5.7	5.85
3	62.0	6.7	5.97
2	61.8	7.1	6.12
1	61.2	8.5	6.35
4	56.5	9.7	6.34

Effects of Growing Environment

Variation in growing environment can lead to variation in the chemical composition of barley grain (Åman and Newman, 1986; Oscarsson et al., 1998). Water stress, which often occurs in dryland growing environments, is one of the most important variables in determining crop productivity and yield associated with growing environment (Zhongjin and Neumann, 1998). Low levels of irrigation increase grain protein content (Bertholdsson, 1999), decrease starch content, and increase fiber content (Bowman et al., 1996), and cause variability in bulk density (Voltas et al., 1999) of barley grain. Feed barley is marketed under the assumption that bulk density is an accurate measure of feed quality. Early research did show a positive correlation between bulk density and animal performance, as measured by finishing beef steers, supporting this assumption (Thomas, 1962; Hinman, 1978). However, more recent research attributes no differences in ADG, feed efficiency, DMI or carcass characteristics of finishing beef steers, to barley bulk density (Grimson et al., 1987; Mathison et al., 1991). Fed as part of a high concentrate diet, barley's primary purpose is to provide energy. Starch content, a key constituent of barley feed quality, is positively correlated to the energy content of barley. While a slight correlation between barley starch content and bulk density exists, barleys with heavier bulk densities are often higher in starch content, it is far from perfect (Hunt, 1996). McDonnell et al. (2003) reported no differences in the NE_m or NE_g values of heavy (63.1 kg/hL) or light (50.8 kg/hL) bulk density barley fed to finishing beef steers. However, DMI by steers consuming diets containing whole light barley was greater than steers consuming diets containing whole heavy barley (9.7 vs. 8.1 kg/d, respectively). Additionally, ADG of steers consuming diets containing whole light barley was greater than the ADG of steers consuming diets containing whole heavy barley (1.06 vs. 0.75 kg/d, respectively). Due to the lack of any measurable differences in the net energy values of the barleys, McDonnell et al. (2003) suggested that the differences seen in animal performance might be attributed to the higher fiber content of the lightweight barley relative to the heavyweight barely (5.66 vs. 4.56% ADF, respectively). An increase in rumination and chewing associated with more fibrous feeds (Balch, 1971) may have occurred with the diets containing the whole light barley, which may have slowed acid production in the rumen reducing incidences of subclinical acidosis, which in turn resulted in the higher ADG, feed efficiency, and DMI. Furthermore, the differences in animal performance, observed by McDonnell et al. (2003) when barleys differing in bulk density were fed whole, were eliminated by dry rolling the barleys prior to feeding. Additionally, Grimson et al. (1987) and Mathison et al. (1991), when examining the effects of bulk density and processing method (steam-rolled vs. dry-rolled), reported no differences in ADG, feed efficiency, DMI, or carcass characteristics of finishing beef steers, due to bulk density when barleys were processed. The findings of McDonnell et al. (2003) support the findings of Grimson et al. (1987), and Mathison et al. (1991) and suggest that barley bulk density is indeed a poor indicator of barley feed quality. However, Engstrom (2000) suggests that the economic value of lightweight barley, based on reported differences in feed to gain ratios, can be determined through its bulk density by discounting its price 1% for each pound of bushel weight below the industry standard of 48 lb/bu (59 kg/hL).

Oscarsson et al. (1998) examined the effects of cultivar and growing environment on the yield and grain quality of ten barley cultivars grown in separate locations throughout different years. Large variations in the chemical composition of the barleys were reported due to cultivar. Effects of growing environment were generally found to be less influential in creating variability in the chemical composition of the barley than the cultivars used (Oscarsson et al., 1998). Conversely, in a two-year study examining the agronomic response to seeding rate of two and six-rowed barley cultivars, Jedel and Helm (1995) reported that the variability associated with the agronomic traits of barley due to cultivar was strongly associated with head morphology (two-rowed vs. six rowed). However, significant differences in all parameters measured were attributed to a location x year interaction, indicating the importance of growing environment in determining the quality of barley grain (Jedel and Helm, 1995). Similarly, Åman and Newman (1986) attributed the differences in the chemical composition of various barley cultivars to barley head morphology. However, Montana barleys had higher crude protein and lower starch contents than the Swedish barley. The difference in starch and fiber content found when comparing the Montana barleys to the Swedish barleys, was attributed to the rapid maturation of barley crops brought on by the relatively short dry growing seasons present in Montana (Åman and Newman, 1986), suggesting the importance of growing environment in determining barley feed quality.

Campbell et al. (1995) compared the chemical composition of barley grown throughout Manitoba. The comparison was made using six cultivars, two six-rowed malting cultivars, two two-rowed feed cultivars, and two six-rowed feed cultivars. All six cultivars were grown in twelve locations in 1986, 1987 and 1988. As noted above, Campbell et al. (1995) reported the major differences in chemical composition associated with cultivar were found when comparing two-rowed cultivars to six-rowed cultivars. Growing environment was responsible for creating 84.4, 58.9, and 42.1% of the variance reported for protein, starch, and ADF, respectively (Campbell et al., 1995).

In a study examining variation in malting and feed quality of two-rowed and six-rowed cultivars, Molina-Cano et al. (1997) reported effects of growing environment on all barley feed quality parameters pertaining to poultry. Growing environment was more influential in determining the protein content and bulk density of the barleys than the cultivars used. Environments characterized by a relatively hot dry growing season produced barley higher in protein content than barleys grown in relatively cool wet growing environments. Conversely, Honeyfield et al. (1987) reported higher crude protein content in irrigated barley than in dryland barley (15.4 vs. 13.4%, respectively). Molina-Cano et al. (1997) reported the tendency of barley starch content to be higher in barley produced in growing environments with heavy precipitation than in barley grown in drier environments (56.6 vs. 52.1%, respectively). The differences in barley starch content resulted in similar trends in the apparent metabolizable energy of the barleys (Molina-Cano et al., 1995). Similarly, Honeyfield et al. (1987) found higher digestible energy values in diets containing irrigated barley than in diets containing dryland barley (3.32 Mcal/kg vs. 3.24 Mcal/kg) when fed to swine.

Hinman (1978) fed finishing diets containing Steptoe barley of different bushel weights grown in irrigated or dryland growing environments to finishing beef cattle. With the exception of the heaviest weight barley, ADG, DMI, and feed efficiencies of the steers consuming diets containing dryland barley were equal to those reported for the steers consuming diets containing irrigated barley. The ADG of steers consuming diets containing the heaviest irrigated barley was greater than the ADG of steers consuming diets containing the dryland barley (1.25 vs. 1.14 kg/d, respectively). However, because DMI was less for steers consuming diets containing dryland barley than for steers consuming diets containing the heavyweight irrigated barley, the disparity in ADG was not reflected in feed efficiency. The ADF content of the dryland barley was 13% higher than the ADF content of the heavyweight irrigated barley (9.60 vs. 8.52% ADF, respectively). Other studies have shown adverse effects of ADF content on animal performance (Engstrom et al., 1992; Surber et al., 2000) with some suggesting a negative correlation between fiber content and energy availability in finishing diets fed to beef steers (Hinman, 1979).

Grove et al. (2003), in a study examining the effects of level of irrigation and barley cultivar, found level of irrigation had limited effects on barley chemical composition. Starch (56.2 vs. 56.5%; high vs. low irrigation, respectively), ISDMD (81.8 vs. 81.6%; high vs. low irrigation, respectively), NDF (20.0 vs. 20.2%; high vs. low irrigation, respectively), or ADF (5.5 vs. 5.6%; high vs. low irrigation, respectively) content of the barley grain was not affected by level of irrigation. Conversely, crude protein content of the barley receiving lower amounts of irrigation was greater than the crude protein content of barley receiving higher levels of irrigation (10.6 vs. 9.8%, respectively; Grove et al., 2003). Similarly, Bowman et al. (1996) found that crude protein content of dryland barley was greater than that of irrigated barley (14.2 vs. 12.1%, respectively). However, starch content of the irrigated barley was reported to be greater than the starch content of the dryland barley (55.2 vs. 49.8%, respectively; Bowman et al., 1996). Hinman (1979) investigated the effects of growing environment (irrigated vs. dryland) on the animal performance of finishing beef cattle. Growing environment did not affect ADG, with steers consuming diets containing irrigated barley gaining 1.14 kg/d and steers consuming diets containing dryland barley gaining 1.11 kg/d. An increase in DMI was reported for steers consuming diets containing irrigated barley when compared to the steers consuming diets containing dryland barley (10.0 vs. 9.6 kg/d). However, the increase in DMI was not accompanied by an increase in ADG, subsequently steers consuming diets containing dryland barley had a more desirable feed efficiency than those consuming diets containing irrigated barley (8.69 vs. 8.73 kg feed/kg gain; Hinman, 1979).

Cultivar x Growing Environment Interactions

May and Kozub (1993) reported that grain yield was positively correlated (r = 0.61) with total growing season precipitation. Molina-Cano et al. (1997) attributed variation in barley feed quality to cultivar and growing environment. However, with the exception of protein content, no cultivar x growing environment interactions were detected for feeding or malting characteristics (Molina-Cano et al., 1997). Campbell et al. (1995) examined variation in the chemical composition and test weight of six barley cultivars grown in 12 locations throughout Manitoba over 3 consecutive years. Differences in the chemical composition of two six-rowed malting cultivars (Argyle and Bonanza), two two-rowed feed cultivars (Deuce and Norbert), and two six-rowed feed cultivars (Bedford and Heartland) were investigated through laboratory analyses of the barley grain. Campbell et al. (1995) reported only small amounts of variation (7.5%) in barley protein content could be attributed to cultivar x growing environment interactions. However, cultivar x growing environment interactions accounted for 23 to 35 percent of the variability associated with bulk density, NDF and ADF concentrations in barley (Campbell et al., 1995).

One hundred sixty crossbred pigs were fed diets containing one of five barley cultivars (Andre, Lud, Minuet, Piston, or Steptoe) grown in either a dryland or irrigated growing environment in a feed trial conducted by Honeyfield et al. (1987). A cultivar x growing environment interaction was detected for ADG and feed efficiency. Pigs consuming diets containing dryland Piston gained more than pigs consuming diets containing irrigated Piston (0.62 vs. 0.58 kg/d, respectively). While the reported interaction was limited to diets containing Piston barley, if the animal performance related to the other eight dietary treatments is examined, a tendency for ADG to be greater for the pigs consuming diets containing irrigated barley than for pigs consuming diets containing dryland barley (0.56 vs. 0.58 kg/d, respectively) becomes apparent. There was no cultivar x growing environment interaction reported for DMI, which resulted in differences in feed efficiency. Feed efficiency was better for pigs consuming diets containing dryland Piston than for pigs consuming irrigated Piston (2.20 vs. 2.47 kg of feed/kg of gain, respectively). However, with the exception of pigs consuming diets containing Piston, feed efficiency of pigs consuming diets containing irrigated barley was more desirable than the feed efficiency of pigs consuming diets containing dryland barley (2.34 vs. 2.56 kg of feed/kg of gain; Honeyfield et al., 1987). When examining the nutrient composition of the treatment barleys for a possible explanation for the differences seen in ADG, the ADF content of the barley is the only component that shows similar trends. Honeyfield et al. (1987) reported, with the exception of Piston, that the irrigated barleys tended to have higher ADF content than their dryland counterparts (4.7 vs. 6.2% ADF, respectively). The ADF content of the dryland Piston was 9.4% higher than the 3.6% reported for the irrigated Piston (Honeyfield et al., 1987). Hinman (1978) suggested that barley fiber content was negatively related to energy availability, ultimately reducing the feed efficiency of finishing beef cattle. The energy content of the diets fed by Honeyfield et al. (1987) appear to be negatively correlated to the fiber content of the barley. When comparing digestible energy, with the exception of the diets containing Piston, the energy content of the diets containing the irrigated barley was higher than the diets containing the dryland barley (3.3 vs. 3.1 Mcal/kg, respectively; Honeyfield et al. 1987).

Hinman (1978) evaluated the influence of barley bulk density on beef cattle performance. No cultivar x bulk density interaction was reported for any of the animal performance parameters measured. Feed efficiency tended to be negatively correlated to barley ADF content (Hinman, 1978). In a similar study, Hinman (1979) reported a cultivar x growing environment interaction for DMI of steers consuming diets containing irrigated or dryland barley. Steers consuming diets containing dryland Steptoe (9.3 kg/d) consumed less DM than steers consuming irrigated Steptoe (9.9 kg/d), and irrigated or dryland Klages (10.0 and 9.9 kg/d, respectively). Corresponding differences were seen in feed efficiency due to the lack of a cultivar x growing environment interaction in ADG. Hinman (1979) theorized that the differences in DMI, as well as the differences in feed efficiency, might have resulted from differences in fiber content of the barleys. Dryland Steptoe had a lower crude fiber content than either of the remaining three treatment barleys. The higher fiber content of the other barleys, relative to that of the dryland Steptoe, may have reduced the energy availability of the barleys (Hinman, 1979).

Objectives

While numerous studies have been conducted examining the effects of cultivar on the nutrient composition of barley, few deal directly with how it relates to beef cattle performance. Those that do often have confounding variables, such as head morphology (Hinman, 1978; Bradshaw et al., 1996). Much of the literature examining the effects of growing environment on barley feed quality pertains to monogastric animals (Honeyfield 1987; Molina-Cano et al., 1997). Few studies adequately deal with the effects of barley cultivar, and growing environment on the feedlot performance of finishing beef cattle. Therefore, the objectives of this trial were to compare the animal performance of finishing beef cattle fed Harrington, a two-rowed malting cultivar, or Valier, a two-rowed feed cultivar, grown under two growing environments (irrigated vs. dryland). Influences of barley cultivar, growing environment (irrigated vs. dryland) and cultivar x growing environment interactions were investigated.

CHAPTER 3

MATERIAL AND METHODS

Design and Treatments

Thirty-two Angus x Hereford heifers (average initial wt 348.6 ± 2.21 kg) were assigned to one of eight pens, based on equal pen weight, to test the effects of barley cultivar (Harrington vs. Valier) and growing environment on feedlot performance. A randomized complete block design with a 2 X 2 factorial arrangement of treatments was used in a Calan Gate feeding system (American Calan, Inc; Northwood, NH) located in Bozeman, Montana for feedlot trial lasting 84 d. The four dietary treatments used were: 1) Harrington irrigated, 2) Harrington dryland, 3) Valier irrigated, and 4) Valier dryland. Dry matter diet and nutrient composition of the four dietary treatments are shown in Table 2**.** Supplements were formulated specifically for individual treatment barleys ensuring that diets were isonitrogenous (2.24% N) and isocaloric (2.01 Mcal/kg NE_m and 1.35 Mcal/kg NE_g).

Barley and Growing Environment

The two barley cultivars used were Harrington and Valier. Harrington, a mid-season, spring habit, two-rowed malting barley, derived by crossing Klages x Gazelle/Betzes//Centennial, was developed for improved malting characteristics and its adaptability to southern Alberta's growing environment (Harvey and Rossnagel, 1984). Valier, a two-rowed spring feed cultivar, was developed from the cross Lewis/Baronesse. Valier was designed explicitly to combine enhanced feed quality characteristics with superior agronomic performance (Blake et al., 2002). These barley cultivars were grown in irrigated and dryland growing environments. Irrigated barley treatments were grown in Southwestern MT near the town of Bozeman. Based on a 112-year average spanning from 1892 to 2004 reported by the Western Regional Climate Center (2004), Bozeman, Montana, on average, annually receives 18.26 inches of precipitation and has an average annual temperature of 55.0^0 F. Dryland barley treatments were grown near the Northern Agricultural Research Center in Havre, MT. The average precipitation for the 2003 growing season was 11.54 inches, roughly four percent lower than the eighty-four year average of 11.99 inches for the years spanning 1916 to 2000 (Western Regional Climate Center, 2004). The mean temperature for the 2003 growing season was 45.3^o F, five percent higher than the eighty-four year average of 43.1^o F. All barleys were cracked prior to feeding and evaluated for DM, OM, N, starch (AOAC, 2000) and ADF (Van Soest et al., 1991) content (Table 3). Barley bulk density ranged from 79.7 to 56.8 kg/hL (55 to 44 lb/bu) with the irrigated barleys having the highest bulk density (Table 3). Dry matter and starch content was slightly higher in the irrigated barley than in the dryland barley, while the ADF and nitrogen content of the dryland barley was slightly higher than that of the irrigated barley (Table 3).

Animals and Management

Heifers were implanted with Synovex-H (Fort Dodge Animal Health, Overland KS) prior to the beginning of the trial. Pens were bedded with wheat straw and cleaned once weekly at a regular time and day. Within a pen, heifers were randomly assigned to one of four gates. Gates were then randomly assigned to one of four dietary treatments. A three-wk adaptation and training period was allowed to ensure that heifers adapted to the environment and diet. A week and a half into the adaptation period heifers were fitted with collars equipped with an electronic key that operated their assigned gate. Initial and final weights were determined by taking the average of weights measured on two consecutive days. Interim weights were taken every 28-d. Heifers were fed daily at 0930 and allowed ad libitum access to feed and water. In order to ensure a minimum of a 10% feed refusal, feed offered was adjusted daily according to the previous day's ort weight.

Sampling and Analysis

Diets were mixed a minimum of once weekly. Diet samples were obtained when mixed. Orts were collected and weighed daily. Ort sub-samples were taken daily and composited by animal and period. Fecal grab samples were obtained from individual heifers when they were weighed every 28 d. Diet and fecal samples were composited by animal and period. Fecal samples were dried in a forced-air oven at 60^{o} C for 48 h. Diet and fecal samples were ground to pass a 1- mm screen in a Wiley mill and analyzed for DM, OM, N, starch (AOAC, 2000), ADF (Van Soest et al. 1991) and acid insoluble ash (Van Keulen and Young, 1977). Acid-insoluble ash was used as an internal marker to estimate fecal output for the calculation of DM, starch and CP apparent total tract digestibility for every 28-d period. Ort samples were air-dried and ground to pass a 2-mm screen in a Willey mill. Ort samples were analyzed for DM, which was later used to determine DMI of individual heifers.

NE_m and NE_g Calculations

Using NRC (1996) equations, NE_m and NE_g for each of the four barleys were calculated from average weight, DMI and ADG of the individual heifers. Requirements for NE_m and NE_g were estimated using the following equations:

NE_m (Mcal) = [(average BW x 0.96 x 0.891)$^{0.75}$] x 0.077

NE_g (Mcal) = [{(average BW x 0.96 x 0.891)$^{0.75}$} x 0.0635] x (ADG x 0.96 x 0.956)$^{1.097}$

Diet NE_m and NE_g were estimated using an iterative process to fit the relationship NE_g = (0.877 NE_m) – 0.41. Barley NE_m and NE_g were estimated using the following equations:

Total diet NE_m (Mcal/kg) = (proportion barley x NE_m) + (proportion straw x 0.64 NE_m Mcal/kg) + (proportion oil x 5.881 NE_m Mcal/kg) + (proportion supplement x 1.015 NE_m Mcal/kg)

Total diet NE_g (Mcal/kg) = (proportion barley x NE_g) + (proportion straw x 0.11 NE_g Mcal/kg) + (proportion oil x 4.317 NE_g Mcal/kg) + (proportion supplement x 0.685 NE_g Mcal/kg)

The DM proportions of barley, straw, oil, and supplement in the diets were as reported in Table 2.

Carcass Data

Heifers were visually assessed and slaughtered when 70% were estimated to grade choice. Hot carcass weights were taken the day of slaughter. Carcass data was obtained following a 24-h chill period and included: 1) longissimus muscle area, measured by tracing the longissimus muscle at the 12th rib, and the area determined by a planimeter; 2) subcutaneous fat thickness over the longissimus muscle at the 12th rib, measured at ¾ the lateral length from the chine bone; 3) kidney, pelvic and heart fat as a percentage of carcass weight; 4) marbling score; and 5) quality and yield grades, as assigned by a USDA grader. All procedures were conducted following a protocol approved by the Montana State University Institutional Animal Care and Use Committee.

Cost of Gain Calculations

As fed composition and input cost of the four finishing diets are shown in Table 4. Barley cost per ton was calculated using $4.56/cwt, the average price received by producers for feed barley during 2003, as the base price (NASS, 2004). Additionally, no premiums were assigned to any of the barleys based on malting characteristics, in other words, all barleys were assumed to be unsatisfactory for malting purposes. Barleys with a bulk density greater than or equal to 48 lb/bu were assigned the price of $91.20/ton shown in Table 4. Lightweight barleys were discounted 1% for every pound under 48 lb/bu. Calculations used to discount the dryland Harrington and Valier barleys are shown below:

Harrington dryland/cwt = [$4.56/cwt – {$4.56/cwt x (48 lb/bu – 47 lb/bu)/100}]

= $4.51/cwt

$/ton = ($4.51/cwt) x 20

= $90.29/ton

Valier dryland/cwt = [$4.56/cwt – {$4.56/cwt x (48 lb/bu – 44 lb/bu)/100}]

= $4.38/cwt

$$\$/ton = (\$4.38/cwt) \times 20$$

$$= \$87.55/ton$$

Barley processing, straw, and oil, in all four dietary treatments were equal type, quality and cost. Supplements were formulated specifically for individual treatment barleys ensuring that diets were isonitrogenous (2.24% N), and as such varied in protein content and cost (Table 4). Diet cost per ton was calculated for the individual diets using the diet compositions shown in Table 4 and are shown on an as fed basis. Cost of feed per unit of gain was determined using diet cost per lb (Table 4) and the feed efficiencies shown in Table 5.

Statistical Analyses

A randomized complete block design (block = pen) with a 2 X 2 factorial arrangement of treatments was employed, testing the effects of cultivar (Harrington vs. Valier), growing environment (irrigated vs. dryland) and cultivar x growing environment interactions. The GLM procedure of SAS (SAS Inst. Inc., Cary, NC) was used to analyze the data. Means with F-values found to be significant ($P < 0.10$) were separated using the LSD method. Correlations between animal performance parameters, and diet and barley nutrient content were made using the PROC CORR of SAS, while regression analysis was performed using the PROC STEPWISE procedure of SAS (SAS Inst. Inc., Cary, NC).

CHAPTER 4

RESULTS AND DISCUSSION

Barley Nutrient Content

Barley nutrient content is shown in Table 3. Bulk density ranged from 70.3 to 56.8 kg/hL, with the dryland barley having a lower bulk density than the irrigated barley (average 58.7 vs. 70.2 kg/hL, respectively). Barleys ranked in the same order in terms of starch content as they did when examining bulk density, with the heavier bulk density barleys having a higher starch content. The similarities between the ranking of barley starch content and bulk density would be expected because, starch is denser than fiber and an inverse relationship between barley starch content and fiber content exists. In other words, as barley grain develops and the endosperm fills, the starch to fiber ratio grows and the bulk density of the grain increases (Hunt, 1996). In general, irrigated barley has lower nitrogen content than dryland barley (Table 3). As much as 84 and 59% of the variation in barley protein and starch content has been attributed to growing environment (Campbell et al., 1995), with barley produced in drier growing environments having lower starch content than barley grown in irrigated growing environments (Åman and Newman, 1986; Bowman, 2001), similar to the findings of this trial. Acid detergent fiber content of the barleys ranged from 3.69 to 6.94%. Average ADF content was lower for Harrington than for Valier (average 3.98 vs. 5.34%, respectively). Higher ADF content was found in the dryland barleys than in the irrigated barleys (average 5.53 vs. 3.76%, respectively). Other studies have reported higher ADF content in irrigated barley than in dryland barley (Honeyfield et al. 1987; Bowman, 2001) contradicting the findings of this study. While on average the ADF content of the irrigated barleys used by Honeyfield et al. (1987) was higher than the ADF content of the dryland barleys (average 6.2 vs. 4.7 %, respectively), the ADF content of two of the five cultivars used was lower in the irrigated than the dryland barley. Bowman (2001) reported the mean value for the ADF content of ten cultivars, with irrigated barleys having a higher ADF content than the dryland barleys (4.81 vs. 4.46%, respectively). Molina-Cano et al. (1997) reported that cultivar had greater influence than growing environment in determining the ADF content in five barley cultivars. While cultivar was the most influential factor in determining barley ADF content, Molina-Cano et al. (1997) did reported differences in ADF content associated with growing environment. In our study only two cultivars were used, and the lack of agreement between finding of our study and the findings of Honeyfield et al. (1987) and Bowman (2001), may be differences associated with cultivar rather than growing environment. Additionally, barleys used in our trial were grown only in two separate locations. Data presented by Bowman (2001) were from ten cultivars grown in seven separate locations. The lack agreement between our trial and Bowman (2001) may be due to differences in the number of locations as well as cultivar.

Animal Performance and Carcass Characteristics

No cultivar x growing environment interactions ($P > 0.10$) were detected for animal performance or carcass characteristics, so the main effect means are presented in Tables 5 and 6. Due to varying weight gains during the adaptation and training period, previous weight of the heifers influenced ($P < 0.001$) the heifer weights throughout the study and was used as a covariate when analyzing performance data. If previous weight was not significant (P > 0.05) in the model, then previous weight was removed as a covariate. Table 5 shows the effect of cultivar and growing environment on the animal performance. No differences (P > 0.23) in 28-d (average 409.2 kg), 56-d (average 457 kg), or final 84-d weights (average 497.9) were detected due to cultivar. Twenty-eight d (average 2.15 kg/d), 56-d (average 1.94 kg/d), or 84-d (average 9.8 kg/d) ADG was not influenced (P > 0.46) by cultivar. Hinman (1979) reported no differences (P > 0.10) in ADG between steers consuming finishing diets containing the feed cultivar Steptoe and steers consuming diets containing the malting cultivar Klages (1.11 vs. 1.14 kg/d, respectively). These findings were later supported by Bradshaw et al. (1996) who reported no differences (P > 0.05) in ADG between steers consuming diets containing Steptoe when compared to those consuming diets containing Klages (1.44 vs. 1.48 kg/d, respectively). Furthermore, neither Hinman (1979) nor Bradshaw et al. (1996) reported any differences in final weights of steers consuming finishing diets containing either cultivar. Boss and Bowman (1996) reported no differences in ADG of steers consuming diets containing Gunhilde (a two-rowed feed cultivar) when compared to the ADG of steers consuming diets containing Medallion (a six-rowed feed barley). However, the ADG of steers consuming diets containing Harrington (1.30 kg/d), a two-rowed malting cultivar, was greater (P = 0.002) than the ADG of the steers consuming diets containing either Gunhilde or Medallion (1.18 an 1.22 kg/d, respectively). Additionally, final weight of steers consuming diets containing Harrington (527 kg) was greater than the final weight of steers consuming diets containing Gunhilde or Medallion (499 and 512 kg, respectively).

Cultivar did not influence (*P* > 0.55) DMI at any point in this trial. As shown in Table 5, during the first 28-d, DMI of heifers consuming diets containing irrigated barley was lower (*P* = 0.05) than the DMI of heifers consuming diets containing dryland barley (9.0 vs. 9.7 kg/d, respectively). Similar trends were seen in after 56 and 84 d, with heifers consuming diets containing irrigated barley having a lower (*P* < 0.06) DMI than heifers consuming diets containing dryland barley. Cultivar did not influence (*P* > 0.41) feed efficiency after 26, 56, or 84 d. Heifers consuming diets containing irrigated barley had more desirable (*P* < 0.06) feed efficiencies than heifers consuming diets containing dryland barley after 28, 56, and 84 d.

Carcass characteristics are presented in Table 6. Ribeye area (average 73.5 cm^2, *P* = 0.84), fat thickness (average 1.4 cm, *P* = 0.14), kidney, pelvic and heart fat (average 2.2%, *P* = 0.78), marbling score (average 484, *P* = 0.72), quality grade (average 2.2, *P* = 0.51), carcass weight (311.4 kg, *P* = 0.90), and yield grade (average 3.3, *P* = 0.22) of heifers consuming diets containing Harrington were not different from heifers consuming diets containing Valier (Table 6). Likewise, ribeye area (*P* = 0.21), fat thickness (*P* = 0.19), kidney pelvic heart fat (*P* = 0.06), marbling score (*P* = 0.59), quality grade (*P* = 1.0), carcass weight (*P* = 0.93), and yield grade (*P* = 0.76) of heifers consuming diets containing irrigated barley did not differ from heifers consuming diets containing dryland barley (Table 6).

These findings agree with the work of Bradshaw et al. (1996), who reported no differences in carcass characteristics between steers consuming diets containing malting cultivars when compared to the steers consuming diets containing feeding cultivars.

Similarly, Hinman (1979) reported no differences in carcass characteristics due to barley cultivar. Additionally, no differences in carcass characteristics were found between steers consuming diets containing irrigated or dryland barley (Hinman, 1979). Conversely, Boss and Bowman (1996) found that steers consuming diets containing Harrington (a two-rowed malting cultivar) had heavier carcass weights, better marbling scores, and tended to have higher yield and quality grades than steers consuming Gunhilde (a two-rowed fed cultivar), or Medallion (six-rowed feed cultivar).

In Vivo Digestibility

A cultivar x growing environment interaction was detected for ADF digestibility in Period 1 (P = 0.001) and for the 84-d average (P = 0.004) and for nitrogen digestibility in Period 2 (P = 0.001) and overall (P = 0.009), however, only main effect means are presented in Table 7. In Period 1, in vivo ADF digestibility was lowest (P = 0.001) for diets containing dryland Valier (11.5%), intermediate for diets containing irrigated Harrington (13.4%), and greatest for diets containing dryland Harrington and irrigated Valier (average 42.5%). The 84-d average in vivo ADF digestibility was lowest (P = 0.004) for diets containing irrigated Harrington (14.1%), intermediate for diets containing dryland Valier (22.9%), and greatest for diets containing dryland Harrington and irrigated Valier (average 30.5%). In period 3, nitrogen digestibility was greatest (P = 0.01) for diets containing dryland Valier (79.8%), intermediate for diets containing irrigated Harrington and dryland Harrington (average 74.9%), and lowest for diets containing irrigated Valier (73.1%).

Cultivar did not affect (P > 0.30) the digestibility of DM, OM, ADF or starch during Period 1 (Table 7). Growing environment did not influence the digestibility of N (average 75.2%, P = 0.96), ADF (average 27.5%, P =0.90), or starch (average 92.5%, P = 0.96) in Period 1. Dry matter and OM digestibility of diets containing irrigated barley was higher (P < 0.01) than that of diets containing dryland barley during Period 1 (78.4 vs.72.7%, and 80.3 vs. 75.2%, respectively). Cultivar did not affect (P > 0.23) DM, OM, N or starch digestibility in Period 2. However, ADF digestibility was higher (P = 0.07) for Harrington diets compared with Valier diets (29.7 vs. 21.6%, respectively). In Period 3, DM, OM, ADF and starch digestibilities were higher (P < 0.07) for Valier than Harrington. The dryland growing environment resulted in higher (P < 0.07) DM, OM, N and ADF digestibilities that the irrigated growing environment during this period. Table 7 shows that the 84-d average in vivo DM or OM digestibility was higher (P = 0.02) for diets containing Valier barley than for diets containing Harrington barley (79.9 vs. 74.9%, and 79.9 vs. 77.3, respectively), contradicting findings by Boss and Bowman (1996) who reported no difference in the DMD of diets containing either malting or feeding cultivars. Starch, ADF, and N digestibility over 84 d were not affected (P > 0.11) by cultivar.

NE_m and NE_g Content

No cultivar x growing environment interactions were detected for barley or diet energy content, so main effect means are presented in Table 8. Barley NE_m (P = 0.38; average 2.15 Mcal/kg) and NE_g (P = 0.38; average 1.46 Mcal/kg) were not affected by cultivar (Table 8). Likewise, diet NE_m (P = 0.36; average 2.04 Mcal/kg) and NE_g (P =

0.36; average 1.38 Mcal/kg) were not affected by cultivar (Table 8). Growing environment did affect (*P* = 0.001) barley and diet energy content. Irrigated barley NE_m and NE_g (2.31 and 1.61 Mcal/kg, respectively) content was higher (*P* = 0.001) than dryland barley NE_m and NE_g (1.98 and 1.32 Mcal/kg, respectively) content. Similarly, diets containing irrigated barley had higher (*P* = 0.001) NE_m and NE_g (2.16 and 1.49 Mcal/kg, respectively) content than diets containing dryland barley (1.90 and 1.26 Mcal/kg, respectively). Molina-Cano et al. (1997) reported differences in the apparent metabolizable energy content of barley fed to poultry due to environment, with the barleys grown in areas receiving greater amounts of moisture having a higher apparent metabolizable energy value than those grown in drier growing environments. Honeyfield et al. (1987) reported a cultivar x growing environment interaction when looking at the digestible energy content of barleys fed to swine. Diets containing dryland Piston had a lower digestible energy content than diets containing irrigated Piston. However, the digestible energy content of the four remaining diets was higher in the diets containing irrigated barley than in the diets containing dryland barley (Honeyfield et al., 1987). Boss and Bowman (1996) reported, when fed to finishing beef steers, the net energy content of diets containing Medallion (a six-rowed feed cultivar) was higher than the net energy content of diets containing Harrington (a two-rowed malt cultivar). However, when comparing the net energy content of diets containing Harrington or Gunhilde, both two-rowed cultivars, no differences were reported (Boss and Bowman, 1996).

Cost of Gain

While the lack of any correlation between bulk density and barley feed quality has been shown (Grimson et al., 1987; Mathison et al., 1991; McDonnell et al., 2003), barley with a bulk density below 62 kg/hL (48 lb/bu) is commonly discounted in today's feed barley market. Using reported differences in feed efficiency of steers consuming barley based finishing diets Engstrom (2000) suggested that feed barley can be discounted at a rate of approximately 1% for every pound of bushel weight below the industry standard of 62 kg/hL. Differences in bulk density were apparent between growing environments (Table 3). The average bulk density of the dryland barley (58.7 kg/hL) was lower than the irrigated barley (75.0 kg/hl). Furthermore, the bulk density of the dryland Harrington (60.6 kg/hL) and the dryland Valier (56.8 kg/hL) fell below the industry standard (62 kg/hL) and would be discounted according to Engstrom (2000). All ration input costs are shown in Table 4. Irrigated Harrington and Valier were assigned a price of $91.20/ton. The price for the irrigated barleys was based on the assumption that the average price received by producers for feed barley in 2003 was the maximum price, and that no premiums were assigned based on the malting or feeding characteristics of the barley. Dryland Harrington was assigned a price of $90.29/ton, discounted roughly 1% below the maximum price of $91.20/ton (Table 4). Dryland Valier was assigned a price of $87.55/ton, roughly 4% below the maximum price (Table 4). Using the input prices shown in Table 4 and feed efficiencies of the individual heifers, cost of gain was determined (Table 9).

Table 9 shows the mean values for feed efficiencies and cost of gain. When considering barley bulk density in terms of cultivar, neither the Harrington (average 65.5

kg/hL) or Valier (average 63.4 kg/hL) barleys average bulk density was low enough to be discounted in today's feed barley market. Cultivar did not influence (P = 0.64) feed efficiency or cost of gain (P = 0.55). However, as shown in Table 9, heifers consuming diets containing Valier barley had numerically greater feed efficiencies than heifers consuming diets containing Harrington barley (18.4 vs. 18.1 kg of gain/100 kg of feed, respectively), subsequently diets containing Valier barley tended to be a more cost efficient feed source that diets containing Harrington barley ($0.97 vs. $0.99/ kg of gain, respectively). In a large scale feeding operation this slight difference in cost of gain translates into substantial savings. For example, when compared to diets containing Harrington, feeding diets containing Valier to 100,000 head gaining on average 1.5 kg/d results in a savings of $3,000/d.

Growing environment influenced (P < 0.06) feed efficiency throughout our trial (Table 5). The mean values for the 84-d feed efficiencies associated with growing environment are shown in Table 5. Heifers consuming diets containing irrigated barley had greater (P = 0.001) feed efficiency than heifers consuming diets containing dryland barley (19.8 vs. 16.5 kg of gain/100 kg of feed). The disparities in feed efficiencies resulted in diets containing irrigated barley being a more efficient (P = 0.001) feed source than diets containing dryland barley ($0.90 vs. $1.06/ kg of gain, respectively).

In our trial assigning discounts based on bulk density, as prescribed by Engstrom (2000), resulted in an inaccurate prediction of the dryland barley's economic value. In fact the cost of gain for heifers consuming diets containing lightweight dryland barley was 15% greater than the cost of gain for heifers consuming heavyweight irrigated barley.

Correlations Between Animal Performance and Barley Characteristics

The correlations between the diet nutrient composition values shown in Table 3 and key animal performance parameters are shown in Table 10. Barley starch is the main constituent influencing the energy content of barley (Ramsey, 2000). A positive relationship, though imprecise, is apparent between barley starch content and bulk density, with barleys having a higher starch content generally having a heaver bulk density (Hunt, 1996). This relationship is reflected in the nutrient content of the irrigated and dryland barleys (Table 3) with the bulk density of the irrigated barley generally being greater than the dryland barley (75.0 vs. 58.7 kg/hL, respectively), and the irrigated barley having higher starch content than dryland barley (60.46 vs. 53.46%, respectively). A positive correlation between feed efficiency and diet starch content ($r = 0.63$, $P = 0.03$) was found (Table 10). However, the inaccuracy of bulk density in predicting animal performance has often been shown (Grimson et al., 1987; Mathison et al., 1991; McDonnell et al., 2003) and is supported by the findings of our study, in that with the exception of feed efficiency, and DMI the two of which are inherently connected, no differences in animal performance ($P > 0.17$) found due to growing environment. Additionally, with the exception of kidney-pelvic-heart fat ($P > 0.06$), no differences in carcass characteristics were attributed to growing environment.

The higher starch content of the irrigated barley subsequently resulted in the diets containing the irrigated barley having higher starch content than the diets containing the dryland barley (Table 2). A correlation ($P < 0.04$) between starch content of the diet and the animal performance parameters was found (Table 10). The starch content of the diet was negatively related to the DMI ($r = -0.60$, $P = 0.04$) and positively related to ADG (r

= 0.76, P = 0.004). A positive correlation was found between the starch content of the diet and diet NE_m (r = 0.72, P = 0.008) and NE_g (r =0.71, P = 0.01) content, showing the importance of starch in determining the energy content of barley-based finishing diets. A very strong positive correlation between diet nitrogen (N) content and DMI (r = 0.95, P < 0.001) was seen. While protein levels of the diet can effect microbial digestion and ultimately intake by ruminant animals (Van Soest, 1994), the strong correlation between DMI and the nitrogen content of the diet found here is probably confounded by differences associated with the energy content of the barley and the diet. When consuming high concentrate diets, intake is regulated by the animals' metabolic requirements for energy (Van Soest, 1994). The negative correlations between diet NE_m (r = -0.77, P = 0.004) and NE_g (r = -0.76, P = 0.004) content and DMI (Table 10), in combination with the increase in DMI associated with diets containing dryland barley, suggest that the heifers were eating to meet the metabolic energy requirements. Further support for this theory is gained by Surber et al. (2000) who, in a study using data from over 18 individual feedlot trials, reported a negative correlation between DMI of finishing beef cattle and barley NE_m (r = -0.71, P = 0.001) and NE_g (r = -0.71, P = 0.001) content.

CHAPTER 5

CONCLUSIONS AND IMPLICATIONS

Animal performance by finishing beef heifers was not affected by barley cultivar. With the exception of DMI and feed efficiency, the two of which are inherently connected, no differences in animal performance were attributed to barley growing environment. The energy content of dryland barleys was lower than the energy content of their irrigated counterparts. The disparities in energy content caused heifers consuming dryland barley to increase their DMI, relative to the heifers consuming diets containing irrigated barley, in order to fulfill their metabolic requirements for energy. The increases in DMI associated with diets containing dryland barley did not result in an increase in ADG. Subsequently, feed efficiency of heifers consuming diets containing dryland barley suffered. No cultivar x growing environment interactions were detected for animal performance or carcass characteristics.

The results of this study imply that no differences in animal performance can be attributed to cultivar when feeding diets containing Harrington or Valier barley to finishing beef heifers. Increases in DMI can be attributed to dryland growing environments. However, the higher NE_m and NE_g content of irrigated barley negated any benefits that may have been attributed to increases in DMI. The results of this study suggest that the feed value of Valier is equivalent to Harrington, and that an irrigated growing environment results in barley with a higher energy value than a dryland growing environment.

Table 2. Diet and nutrient composition (DM basis) of feedlot diets containing Harrington or Valier barley grown under irrigated or dryland conditions

	Harrington		Valier	
	Irrigated	Dryland	Irrigated	Dryland
Diet composition				
Barley, %	79.10	79.08	79.22	79.39
Straw, %	6.00	5.99	5.99	5.99
Oil, %	3.00	3.00	3.00	3.01
Supplement, %	11.90	11.92	11.78	11.61
Nutrient composition				
Period 1				
OM, %	95.61	96.02	96.52	95.61
N, %	2.02	2.27	1.98	2.39
ADF, %	6.78	13.33	11.02	8.55
Starch, %	52.61	50.02	51.26	45.42
Period 2				
OM, %	95.03	94.78	94.66	95.03
N, %	2.02	2.23	1.95	2.56
ADF, %	6.78	8.86	8.07	7.09
Starch, %	44.99	41.12	44.70	42.64
Period 3				
OM, %	95.37	96.07	96.78	96.02
N, %	2.16	2.26	1.91	2.47
ADF, %	7.10	7.47	7.96	7.80
Starch, %	46.56	45.39	50.02	45.86
Average				
OM, %	95.34	95.62	95.99	95.55
N, %	2.12	2.25	2.39	2.49
ADF, %	6.97	9.88	8.55	7.81
Starch, %	48.05	45.51	45.42	44.64

Table 3. Nutrient content of Harrington and Valier grown under irrigated or dryland environments

	Harrington		Valier	
	Irrigated	Dryland	Irrigated	Dryland
Bulk density, kg/hL	70.3	60.6	70.0	56.8
DM, %	89.67	88.41	90.52	89.95
ADF, %	3.83	4.12	3.69	6.94
N, %	1.87	2.50	1.92	2.10
Starch, %	60.56	55.91	60.35	51.01

Table 4. As fed composition and input costs of finishing diets containing Harrington or Valier barley grown in an irrigated or dryland growing environment

	Harrington		Valier	
	Irrigated	Dryland	Irrigated	Dryland
Composition				
Barley, %	79.89	80.10	79.86	80.11
Straw, %	5.84	5.77	5.88	5.85
Oil, %	2.72	2.69	2.74	2.73
Supplement, %	11.55	11.44	11.52	11.31
Input cost				
Barley[a], $/ton	$91.20	$90.29	$91.20	$87.55
Processing, $/ton	$25.00	$25.00	$25.00	$25.00
Straw, $/ton	$30.00	$30.00	$30.00	$30.00
Oil, $/ton	$1,112.00	$1,112.00	$1,112.00	$1,112.00
Supplement, $/ton	$322.00	$335.00	$324.00	$326.00
Crude protein, %	32.3	8.5	30.4	23.4
Diet, $/ton	$162.02	$162.31	$162.12	$160.17
Diet, $/lb	$.08	$.08	$.08	$.08

[a]Barley discounted 1% for every pound under 48 lb/bu.

Table 5. Effects of barley cultivar (Harrington vs. Valier) and growing environment (dryland vs. irrigated) on animal performance and carcass characteristics of beef heifers consuming a finishing diet

	Cultivar		Growing environment			*P*-value		
	Harrington	Valier	Irrigated	Dryland	SE	Cultivar	Growing environment	C x GE
Weights								
Initial wt., kg	347.0	351.0	349.0	349.2	2.21	0.21	0.88	0.77
28-d wt, kg	408.3	410.1	410.4	408.0	3.68	0.73	0.66	0.77
56-d wt, kg	456.9	457.9	459.4	455.4	4.21	0.88	0.51	0.59
Final 84-d wt., kg	494.1	501.6	501.9	493.8	4.27	0.23	0.20	0.31
Average daily gain								
28-d ADG, Kg	2.17	2.13	2.18	2.11	0.100	0.80	0.61	0.87
56-d ADG, kg	1.95	1.92	1.97	1.90	0.063	0.68	0.45	0.28
84-d ADG, kg	1.75	1.80	1.82	1.72	0.047	0.46	0.17	0.18
Dry matter intake								
28-d DMI, kg/d	9.3	9.5	9.0	9.7	0.24	0.70	0.05	0.88
56-d DMI, kg/d	9.7	10.0	9.3	10.4	0.34	0.55	0.06	0.18
84-d DMI, kg/d	10.0	10.1	9.3	10.9	0.37	0.86	0.008	0.10
Average DMI	9.7	9.8	9.3	10.3	0.25	0.80	0.009	0.51
Feed efficiency[x]								
28-d FE	22.6	21.5	23.4	20.7	0.42	0.41	0.06	0.27
56-d FE	19.6	19.5	21.7	17.8	0.34	0.90	0.003	0.34
84-d FE	18.1	18.4	19.8	16.8	0.44	0.63	0.001	0.90

[x]FE: kg of Gain per 100 kg of feed

Table 6. Effects of barley cultivar (Harrington vs. Valier) and growing environment (dryland vs. irrigated) on carcass characteristics of beef heifers consuming a finishing diet

	Cultivar		Growing environment			*P*-value		
	Harrington	Valier	Irrigated	Dryland	SE	Cultivar	Growing environment	C x GE
REA, cm^2	73.2	73.7	75.2	71.7	1.86	0.84	0.21	0.26
Fat thickness, cm	1.5	1.3	1.5	1.3	0.10	0.14	0.19	0.47
KPH, %	2.2	2.2	2.3	2.1	0.08	0.78	0.06	0.78
Marbling score[y]	476	491	472	494	29.3	0.72	0.59	0.66
Quality grade[z]	2.1	2.3	2.2	2.2	0.13	0.51	0.99	0.99
Carcass weight, kg	312.4	310.4	311.9	310.9	7.89	0.90	0.93	0.23
Yield grade	3.4	3.2	3.3	3.3	0.13	0.22	0.76	0.29

[y]Marbling score: Slight = 300, Small = 400, Modest = 500, etc.

[z]Quality grade- 1= Prime; 2 = Choice; 3 = Select; 4 = Standard.

Table 7. In vivo digestibility of finishing diets containing Harrington or Valier barley grown under irrigated or dryland conditions

	Cultivar		Growing environment			*P* – value		
	Harrington	Valier	Irrigated	Dryland	SE	Cultivar	Growing environment	C x I
Period 1								
DM, %	75.1	75.9	78.4	72.7	1.38	0.85	0.007	0.96
OM, %	77.3	75.6	80.3	75.2	1.31	0.75	0.01	0.98
N, %	74.8	75.6	75.3	75.1	2.09	0.79	0.96	0.83
ADF, %	28.9	26.1	27.0	28.0	5.56	0.72	0.90	0.001
Starch, %	91.4	93.5	92.4	92.6	1.44	0.30	0.96	0.54
Period 2								
DM, %	79.7	78.1	77.9	76.9	1.17	0.39	0.54	0.52
OM, %	78.2	80.1	79.8	79.8	1.16	0.50	0.68	0.67
N, %	76.9[a]	79.3	76.2	80.1	1.35	0.23	0.05	0.01
ADF, %	29.7	21.6	27.2	24.1	2.97	0.07	0.47	0.45
Starch, %	89.1	91.0	89.5	90.6	2.14	0.54	0.70	0.24
Period 3								
DM, %	72.79	78.8	74.0	77.6	1.17	0.001	0.04	0.87
OM, %	75.65	81.6	77.0	80.3	1.12	0.001	0.04	0.71
N, %	72.49	75.4	71.1	76.9	2.15	0.35	0.07	0.14
ADF, %	16.33	33.4	16.8	32.9	3.67	0.001	0.002	0.22
Starch, %	91.51	94.6	91.7	94.4	1.16	0.07	0.11	0.24
84 d Average								
DM, %	74.9	79.9	76.7	75.7	0.80	0.02	0.39	0.80
OM, %	77.3	79.9	79.0	78.2	0.77	0.02	0.47	0.95
N, %	74.7	76.5	73.9	77.3	1.33	0.37	0.08	0.09
ADF, %	22.5	26.6	22.13	26.9	2.68	0.30	0.22	0.004
Starch, %	90.7	93.1	91.2	92.6	1.03	0.11	0.37	0.31

Table 8. Effects of barley cultivar (Harrington vs. Valier) and growing environment (dryland vs. irrigated) on grain and diet energy content

	Cultivar		Growing environment			*P*-value		
	Harrington	Valier	Irrigated	Dryland	SE	Cultivar	Growing environment	C x GE
Grain energy content								
NE_m, Mcal/kg	2.12	2.18	2.31	1.98	0.047	0.38	0.001	0.64
NE_g, Mcal/kg	1.43	1.49	1.61	1.32	0.041	0.38	0.001	0.64
Diet energy content								
NE_m, Mcal/kg	2.01	2.06	2.16	1.90	0.037	0.36	0.001	0.63
NE_g, Mcal/kg	1.35	1.40	1.49	1.26	0.033	0.36	0.001	0.63

Table 9. Cost of gain for heifers consuming diets containing Harrington or Valier barley cultivars (C) grown in an irrigated or dryland growing environment (GE)

	Cultivar		Growing environment			*P* - value		
	Harrington	Valier	Irrigated	Dryland	SE	C	GE	C x GE
Feed efficiency[a]	18.1	18.4	19.8	16.8	0.45	0.64	0.001	0.90
Cost of feed/ kg gain	$0.99	$0.97	$0.90	$1.06	0.027	0.55	0.001	0.83

[a]Feed efficiency: kg gain per 100 kg of feed.

Table 10. Correlation between the animal performance of finishing beef heifers and laboratory analysis of finishing diets containing Harrington or Valier barley grown under irrigated of dryland conditions

	Diet N	Diet ADF	Diet Starch	Diet NE_m	Diet NE_g	Barley NE_m	Barley NE_g
Gain:Feed							
r =	-0.42	0.40	0.63	0.78	0.78	0.06	0.25
P =	0.17	0.20	0.03	0.003	0.003	0.86	0.43
DMI							
r =	0.95	-0.11	-0.60	-0.77	-0.76	-0.51	-0.62
P =	< 0.001	0.73	0.04	0.004	0.004	0.09	0.03
ADG							
r =	-0.13	0.41	0.76	0.70	0.70	0.26	0.40
P =	0.68	0.18	0.004	0.01	0.01	0.40	0.20
Diet NE_m							
r =	-0.64	-0.043	0.72	-	-	-	-
P =	0.03	0.89	0.008	-	-	-	-
Diet NE_g							
r =	-0.62	-0.06	0.71	-	-	-	-
P =	0.03	0.86	0.01	-	-	-	-

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