AN ABSTRACT OF THE THESIS OF

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Title: WHEAT VERSUS CORN AND BARLEY IN BEEF FINISHING RATIONS.

Abstract Approved By: Redacted for Privacy

Two trials were conducted to test the performance of cattle on high concentrate finishing rations composed of either wheat, corn, or barley fed in the Northwest. In trial 1, forty-four head of British and exotic cross-bred steers were stratified by weight and allotted to nine groups. The nine groups were then randomly assigned a pen number followed by a random assignment to one of three finishing ration treatments: 1) 70% corn; 2) 70% barley; and 3) 70% wheat. In addition to the grain, the pelleted diets all contained 17% oats, 10% alfalfa hay and 3% dry additives. The nutrient content of the three diets were similar across treatments. Feed intake was recorded daily, as well as individual steer weights at 28 d intervals. The steers remained on feed until they were finished, determined by visual appraisal and an ultrasonic back fat measurement at a minimum of 0.3 inches. Feedlot parameters measured were finished weight, averaged daily gain, feed to gain ratio, and days on feed. Carcass parameters measured included dressing percent, loin eye area, percent kidney,

pelvic, and heart fat, backfat thickness, quality grade, and yield grade. Treatment diets had no significant effect on either feedlot or carcass parameters.

In trial 2, the statistical design used was a cross-over with repeated measures. Six head of three year old heifers, that were spayed and had rumen fistulas, were randomly assigned to one of three groups followed by random assignment to one of three treatments for the first treatment period. Treatments consisted of the same rations as in experiment one. The treatments were then rotated so that each group of two heifers would receive each treatment sometime during the three periods. Each treatment time period consisted of three distinct phases; 1) a seven day adjustment phase where cattle received grass hay only; 2) a 28-day ration adjustment phase during which cattle were gradually adjusted to the high concentrate ration over a period of 18 days. The last 10 days cattle received 15 lbs/head/day of the treatment ration only; 3) a rumen fluid sampling phase on day 29. Samples were taken on the hours of 0, 2, 4, 8, and 12. Hour zero represents the time just prior to the morning feeding and the subsequent hours represent times after feeding. The wheat treatment diet depressed rumen pH ($P<.05$) when compared to either barley or corn. There was also a significant hour effect within, but not between treatments ($P<.001$). No ration by hour effect was found. Gas Chromatography was used to determine volatile fatty acid and lactic acid concentrations of the rumen fluid. A significant hour effect was determined within, but not between treatments for the straight chain fatty acids ($P<.001$) and lactic acid ($P<.05$). The branched chain fatty acids remained constant over the time periods. Corn did exhibit a numerical difference in total acid concentration. It was somewhat lower than either barley or wheat.

Wheat did not demonstrate detrimental effects in either experiment. This trial demonstrated that under these conditions wheat can be an effective feed grain for beef cattle finishing rations. On the basis of the results of this trial, the constraints to feeding wheat would be price and availability.

WHEAT VERSUS CORN AND BARLEY IN BEEF FINISHING RATIONS

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INTRODUCTION

Cattle feeders have known for a long time that wheat can be used in a finishing ration. Most are also aware of the recommendation that wheat should not constitute more than 50% of the grain portion of the finishing ration. However, recent studies have demonstrated that wheat can be used as the only grain in the finishing ration with no detrimental effects (Pryor and Laws, 1972; Reddy et al, 1975; Aimone and Wagner, 1977; Martin et al, 1985; Combs and Males, 1986).

During times of low wheat prices, wheat may be substituted for part or all of the other grain in all-concentrate rations. Brethour (1972), Hale (1973), and Aimone and Wagner (1977), have suggested that wheat be mechanically processed before inclusion in the ration. Partial or all wheat rations have been shown to be as good as or slightly superior to other feed grain rations in terms of feed efficiency and carcass characteristics (Reddy et al, 1975; Backus et al, 1980; Martin et al, 1985; Combs and Males, 1986). In contrast Oltjen et al. (1966) found that wheat did not produce the gains that corn achieved.

Also Backus et al. (1980) demonstrated that a high level of wheat in the ration produced a slightly inferior carcass than produced by those fed on lower levels of wheat.

Studies have indicated that ruminal concentrations of VFA do increase with the feeding of wheat rations (Oltjen et al, 1966; Shaw and Pryor, 1972; Aimone and Wagner, 1977). These researchers also discovered that there was a precipitous drop in pH 2 to 4 hours after feeding due to the concentration of the VFA. It has been suggested by Oltjen et al. (1966) and Varner and Woods (1975) that there is also an increase in lactic acid production acidosis which can be lethal in severe cases.

The objectives of this research trial were to evaluate the differences and similarities of wheat, corn, and barley in a beef finishing ration. In experiment 1, yearling feeder cattle were used to measure feedlot and carcass parameters when fed either wheat, corn, or barley finishing rations. In experiment 2, six fistulated heifers were used to measure ruminal parameters when fed the same rations as the feedlot cattle.

REVIEW OF LITERATURE

Introduction

Wheat is a valuable livestock feed; however, in most cases not competitively priced in the feed grain market due to its value as human food. Because of an increase in production, export competition, and recent farm programs, wheat may at times be considered as an alternative feed grain for finishing cattle. In the United States approximately one-third of the annual wheat crop is used domestically for human food and seed purposes. The remaining two-thirds normally must be exported and/or used domestically as livestock feed. In recent years ending stocks have almost equaled total annual usage. This review of the literature will try to rationalize the use of wheat, as well as, cover the physiological aspects as it pertains to ruminant nutrition.

Feed Grain Production and Supply

Since the 1981/1982 production year, the U.S. had ending stocks of feed grain (corn, barley, oats, sorghum) and wheat approaching 50% of supply. Feed grain reached a low percentage used exclusively for feed in 1986/87 or 37%. This was coupled with a 41% of supply in ending stock. A high was reached in 1983/84 for strictly feeding purposes of 48%, with an ending stock of 16%. However, 15% more feed was used in 1986/87 than 1983/84. Wheat reached a low in 1981/82 for feed purposes of 3.5% of supply. The production year of 1985/86 showed an ending stock of 49% of supply with a feed use of 7%. A high feed use of 10% was reached in 1984/85. This was mainly due to the Midwest drought and the newly implemented Payment In Kind (PIK) program. Due to the decreased availability of corn and its increase in price, wheat replaced corn in least cost finishing rations in a number of cases (U.S.D.A.-Feed. 1987a).

In the crop year of 1986/87 a total of 140.7 million metric tons of feed was utilized domestically. The percentages of the grain sources were: corn 74.4%, sorghum 8.3%, barley 5.0%, oats 6.5%, wheat 5.7%, and other 0.2%. Their use was distributed as follows: dairy 15.3%, fed beef 21.8%, other beef 5.5%, hogs 25.2%, poultry 29.7%, and other 2.5% (U.S.D.A.-Feed, 1987a).

Supplies of 1986/87 feed grains were 14 percent above 1985/86 because of the large harvest and record carrying. Feed disappearance for the four feed grains in the 1986/87 marketing year was up 6 million tons from 1985/86. This seems to be a contradictory statement; however, a record harvest and decreased exports can account for the increased supplies. Possible increased use of feed grain due to lower prices allows for the disappearance. As the 1987 crops of small grains and early sorghum are harvested, feed use of corn could begin to decrease. Corn had experienced a large jump in use due to its relatively favorable price relationship in recent months. However, most small grains will likely be priced well above feeding value in relation to corn for a period of time. Wheat feeding is expected to be less than 5 million tons this summer as wheat prices remain high and above the price at which wheat will substitute for corn in most rations. Wheat will usually replace corn in least cost rations during the summer months due to an increase in supply immediately following harvest. This also coincides with a decreased supply of corn just prior to harvest in the fall (John Nalivka, personal communication).

The 1987 corn crop is projected at 7.2 billion bushels, down 13 percent from 1986. Despite the smaller crop, the total supply is expected to be up slightly because the 1986/87 carrying is projected to be a record high at 5.1 billion bushels. Corn use is expected to exceed production to decline 5 percent to 4.9 billion bushels. Sorghum production is projected to be 680 million bushels in 1987. Even with the large carrying, 1987/88 supplies may be down from 1986/87 because of the expected smaller crop. Although below this year's expected carryout, ending stocks in 1987/88 would still be large at 88 percent of use. Oat production could increase about 25 percent above last year, leading to a slight increase in supply. Imports are expected to remain a fairly important source of supply at 30 million bushels. Barley crops have been near record levels and use and almost kept pace with production. However, like oat prices, barley prices have been unusually high relative to corn at a 10-15 percent premium instead of the more traditional 15-20 percent discount. The expected larger wheat harvest will maintain U.S. wheat supplies at 3.97 billion bushels, just below the all time high 4.01 billion bushels. Domestic disappearance is likely to show a decline, because the expected wheat/feed grain price spread will favor larger use of coarse grains (oats, barley, sorghum, corn) in livestock feed rations (U.S.D.A.-Feed, 1987a).

Global 1986/87 wheat output hit a record 528 million metric tons. The 1987/88 season seems to point to another large harvest, although adverse weather and reduced planting in some areas may preclude a new record. Trade will likely expand, particularly with a major harvest shortfall in the Soviet Union, but may not top the 100 million tons of the 1983/84 and 1984/85 season. Aggressive competition among exporters will likely continue as each seeks a share of the moderately expanding market (U.S.D.A.-Wheat, 1987b).

This research was conducted in the Pacific Northwest where Soft White Wheat is a major crop. Annual supplies of Soft White Wheat (SWW) have averaged around 435 million bushels for the last seven seasons. Included in those years were the three largest SWW crops ever harvested. The period also included a 29 percent decline in harvested acres. White wheat disappearance during the last six marketing years averaged 290 million bushels. Since 1980/81, the United States has produced 1.5 times more than was needed to meet domestic and export requirements. The results has been a long period of record stocks and low prices. Increased soft wheat production in Western Europe and expanded marketing has intensified competition in world markets which has been effective in reducing total demand for U.S. soft wheat. The 1987 short supplies and increased prices of Soft Red wheat have influenced buyers to shift to SWW. Total exports could rise 12 percent over last season, but would still be the second smallest in 15 years. Thus, carryover stocks would be only slightly down from last year's record level (U.S.D.A.-Wheat, 1987b).

Ordinarily, wheat prices, even when they are low, are higher than feed grain prices. As a result, most of the feed wheat demand occurs when low readily available feed grain stocks lift those grain prices to near or above that of wheat. Some wheat stock may be discounted for low quality, particularly at harvest, and end up as animal feed (U.S.D.A.-Wheat, 1987b).

Concentrate Feeding

There is not a clear-cut division when classifying feedstuffs as concentrates or roughages. Concentrates are feeds which contain a high concentration of digestible energy. As the proportion of cell wall increases, feeds become more bulky and require a greater volume to hold an equal substance (Van Soest, 1983). Grains are usually considered as concentrates.

The United States stockpile of feed grain is increasing due to three factors: 1) production. 2) export competition. 3) carryover stocks. Therefore, if cattle perform similarly on corn, barley, or wheat (the most common feed grains in the Northwest), a feeder can use the concentrate with the greatest potential for profit. The corn, barley and wheat do have slightly different levels of energy, protein, fiber, dry matter, and minerals (National Research Council, 1984). When price optimizing, all these factors should be taken into account. For example, when replacing corn with wheat, the feeder can decrease the protein supplement in the ration. Wheat is higher in protein than corn by 2 to 6 percent; and wheat is comparable to corn in energy (Oltjen et al., 1966; Pryor and Laws, 1972; Galyean et al., 1979a; Backus et al., 1980). Table 1 illustrates the nutrient content of the major feed grains and wheat. Although grains are usually said to be less variable in composition than roughages, many factors influence nutrient composition and, thus, feeding value for a given grain.

Crude protein content of feed grains, is relatively low, ranging from 8 to 12 percent for most grains, with wheat being the exception. The fat content may vary greatly, ranging from less than 1% to more than 6%. Oats usually has the most and wheat the least. Seed oils are high in linoleic and oleic acids which are unsaturated fatty acids that tend to become rancid quickly. This is particularly true after the grain is processed (Church and Pond, 1978; National Research Council, 1984). This is a reason to keep the feed bunk clean of old and refused feed.

The carbohydrates in grains, with the exception of the hulls, are primarily starch with small amounts of sugars. The starch makes up most of the endosperm and is highly digestible (Waldo, 1973; Slyter, 1976; Nagaraja et al., 1981; Huntington and Prior, 1983; Ewing et al., 1986).

Hulls of the grains have a substantial effect on feeding value. Most hulls must be broken to some extent before feeding for efficient utilization, particularly by ruminant animals. Grinding, Crushing, Rolling or Soaking appear to improve the palatability and (or) utilization of

Item	Corn, dent	Opaque-2 corn	Wheat hard winter	Wheat soft white	Rice, with hulls	Rye	Barley	Oats	Sorghum (Milo)
Crude protein, %	10.4	12.6	14.2	11.7	8.0	13.4	13.3	12.8	12.4
Ether extract, %	4.6	5.4	1.7	1.8	1.7	1.8	2.0	4.7	3.2
Crude fiber, %	2.5	3.2	2.3	2.1	8.8	2.6	6.3	12.2	2.7
Ash, %	1.4	1.8	2.0	1.8	5.4	2.1	2.7	3.7	2.1
NFE, %	81.3	76.9	79.8	82.6	75.6	80.1	75.7	66.6	79.6
Total sugars, %	1.9		2.9	4.1		4.5	2.5	1.5	1.5
Starch, %	72.2		63.4	67.2		63.8	64.6	41.2	70.8
Essential amino acids, % of DM									
Arginine	0.45	0.86	0.76	0.64	0.63	0.6	0.6	0.8	0.4
Histidine	0.18	0.44	0.39	0.30	0.10	0.3	0.3	0.2	0.3
Isoleucine	0.45	0.40	0.67	0.44	0.35	0.6	0.6	0.6	0.6
Leucine	0.99	1.06	1.20	0.86	0.60	0.8	0.9	1.0	1.6
Lysine	0.18	0.53	0.43	0.37	0.31	0.5	0.6	0.4	0.3
Phenylalanine	0.45	0.56	0.92	0.57	0.35	0.7	0.7	0.7	0.5
Threonine	0.36	0.41	0.48	0.37	0.25	0.4	0.4	0.4	0.3
Tryptophan	0.09	0.16	0.20		0.12	0.1	0.2	0.2	0.1
Valine	0.36	0.62	0.79	0.56	0.50	0.7	0.7	0.7	0.6
Methionine	0.09	0.17	0.21	0.19	0.20	0.2	0.2	0.2	0.1
Cystine	0.09	0.22	0.29	0.34	0.11	0.2	0.2	0.2	0.2
Minerals, % of DM									
Calcium	0.02		0.06	0.09	0.06	0.07	0.06	0.07	0.04
Phosphorus	0.33		0.45	0.34	0.45	0.38	0.35	0.30	0.33
Potassium	0.33		0.57	0.44	0.25	0.52	0.63	0.42	0.39
Magnesium	0.12		0.11	0.11	0.11	0.13	0.14	0.19	0.22

Table 1. Average composition of the major cereal grains on a dry matter basis. Taken from Church and Pond, 1978 pp. 233.

certain grains (Smith et al., 1949; Albin and Durham, 1966; Hale et al., 1966; McGinty et al, 1967; Buchanan-Smith et al., 1968; Cornett et al., 1971; Hale, 1973; Hinman and Johnson, 1974; Toland, 1976; Aimone and Wagner, 1977).

Numerous studies have indicated that cattle can be finished more quickly and efficiently on high concentrate rations than on rations containing a high percentage of roughages (Morris et al., 1969; Tietz, 1969; Ellis, 1970; Brokken et al., 1976; Harrison et al., 1978). The lower bulk of concentrate diets has allowed higher intakes and greater productivity. The higher feed intakes and subsequent increase in nutrients available for rumen and lower tract digestion have reduced feed/gain ratio, increased average daily gain and have also improved carcass characteristics (Davis et al., 1963; Oltjen et al., 1963; Deetz et al, 1985).

Pressures to increase the efficiencies of ruminant production have been met largely be feeding concentrates. The concentrates contain much starch, which is subjected first to microbial fermentation in the rumen with its consequent production of microbial cells and volatile fatty acids; and, secondly, enzymatic digestion in the small intestine which produces glucose (Karr et al., 1966; Tucker et al., 1967; Waldo, 1973; Huntington and Prior, 1983).

Because of high concentrate feeding, improved genetic ability, the use of hormone implants and feed additives, such as the ionophores, it is not uncommon to achieve feed/grain ratios approaching 6.5 to 7:1 on a dry matter basis. It is also not uncommon to achieve average daily gains of 3.0 to 3.5 lbs per day. (Reddy et al., 1975; Deetz et al., 1985; Combs and Males, 1986). As early as 1963, Davis et al., reported that steers consuming low fiber required about 20% less feed per day; and they required 20% less feed per pound of gain. Carcasses from concentrate finished cattle tend to have higher marbling scores with subsequent higher quality grades, whiter external fat, increased flavor, tenderness, and juiciness (Klosterman et al., 1965; Kroph et al., 1975; Bowling et al., 1976; Harrison et al., 1978). Moody (1976) stated that flavor is highly associated with intramuscular fat which is usually found in greater amounts in grain-fed cattle than in roughage-fed animals. He also found that higher marbling scores are associated with increased juiciness. Bayne et al., (1969) found no difference in tenderness between carcasses from cattle finished on concentrates vs. roughages, while Kropf et al., (1975) and Bowling et al., (1976) reported that steaks from grain-fed beef were more tender than steaks from grass-fed beef.

Problems Associated with Concentrate Feeding

Attempts to feed high-energy ration, particularly wheat based rations, have not always been successful. Wise et al., (1961) reviewed early but unsuccessful attempts to feed all-concentrate rations. The major problems were acidosis and bloat. Cattle experienced enlargement and stiffening of the joints, dizziness, impaired locomotion, anorexia, salivation, diarrhea, hyperventilation, and rumen atony.

Acidosis is probably the most severe and economically important disorder that can be caused by high concentrate feeding. Acidosis has been considered as a collective term for several digestive disturbances of the rumen (Dirkson, 1970) and the lower intestine (Allison et al., 1975). Acute acidosis is a disturbance in animals that are definitely sick (Dunlop and Hammond, 1965; Nagaraja et al., 1985) because they have consumed readily fermentable carbohydrates in amounts sufficient to cause a nonphysiological reduction in ingesta pH (Varner and Woods, 1975) and the production of a toxic factor(s). Compounds considered as possible toxic factors include lactic acid (Juhasz and Szegedi, 1968; Telle and Preston, 1971), histamine, tyramine, and tryptamine (Ahrens, 1967; Irwin et al., 1972), ethanol (Allison et al, 1964), bacterial endotoxins (Doughtery et al, 1975), as well as other unidentified toxic factors (Nagaraja et al., 1985). Acids, other than lactic, may also be involved. It has been demonstrated than an increase of volatile fatty acids decreases rumen pH such as is associated with high concentrate feeding (Kay et al., 1969; Slyter, 1976; Huntington and Reynolds, 1986); and this in turn contributes to acidosis.

Several general chemical properties of feeds and ruminal end products are likely to be major contributors to acidosis problems in cattle. First, readily fermentable feed such as wheat, barley, and corn provide less buffering capacity to the rumen than do natural forages (Terry et al., 1973). Because lactic acid has a pK of 3.7, its accumulation in the rumen causes a lower pH than would similar amounts of volatile short-chain fatty acids, which have a pK of 4.6 (Neil Forsberg, personal communication). There is a marked increase in Streptococcus bovis. S. bovis is an L-lactic acid producer (Slyter et al., 1974; Buchanan and Gibbons, 1975). The reason for the outgrowth of S. bovis according to Hungate (1968) is as follows: "As long as carbohydrates is limiting, the fermentation efficiency in ATP production from a given quantity of carbohydrate has competitive survival value and bacteria obtaining more than 2 ATP per sugar can compete successfully with S. bovis. In acute indigestion the great excess of starch and sugar make carbohydrate no longer limiting. Streptococcus bovis can metabolize the carbohydrate faster than competing types that use each molecule more efficiently. The ATP yield of S. bovis per molecule of sugar is low, but when carbohydrate is in excess, the yield of ATP per unit of time is considerably greater than in competing species. When the carbohydrate has been utilized the rumen acidity returns to normal and more efficient producers of ATP compete successfully".

Krogh (1961) further found that when pH in the rumen decreases to 5.0 or less, many of the rumen bacteria and protozoa are killed. The low pH allows the lactobacilli and yeast to have a selective advantage. At the lower pH's in a concentrate acclimated rumen, growth of some of the lactate-utilizing bacteria stop before lactobacilli outgrowth and lactate production are favored (Slyter et al., 1976). The precipitous drop in pH that kills the cellulolytic bacteria and protozoa will reduce the diversity of substrate available to other bacteria (Scheifinger and Wolin, 1973) and give the lactobacilli further selective advantage to use the large quantities of carbohydrates that are in the rumen. In addition, at pH's above 5.0, as the pH is reduced, the ruminal free amylase activity is increased but glucose fermentation rates are reduced (Huntington et al., 1981). In acute acidosis, death is caused by the absorption of large amount of lactic acid across the rumen wall to the systemic system, which causes failure of hemoglobin to carry oxygen (Van Soest, 1983).

Chronic acidosis, while not as severe as the acute form, is detrimental economically. The reduced intake during chronic acidosis may be the result of the continuous high production of volatile fatty acids and the low pH that the acids cause (Varner and Woods, 1975). Nagaraja et al (1985) found that the continuous production of large quantities of volatile fatty acids in the rumen would reduce salivation and ruminal motility. Possibly, the fatty acid concentration continues to remain as high and pH in the rumen as low because ruminal turnover is reduced; and therefore a greater proportion of the feed is fermented in the rumen. Factors such as tissue damage or reduced tissue activity in the rumen wall and elsewhere seem to contribute to chronic acidosis (Hinders and Owens, 1965; Kay et al., 1969). Lack of protozoa may also be a contributing factor. Eadie and Mann (1970) found that the rumen is more stable, having a higher pH and a lower fatty acid content, when there are large ciliate populations than when bacteria are the only organisms using the diet. The protozoa may also contribute toward slowing down fermentation by storing starch and (or) by ingesting bacteria (Chalupa, 1977).

Wheat seems to cause more problems with acidosis than corn (Oltjen et al., 1967; Brethour, 1970) or sorghum (Morris, 1971). Woods and Varner (1970) suggest that soft winter wheats might have the advantage in causing less lactic acid to be produced in the rumen than hard winter wheats. Gibbons (1963) suggests that wheat followed by barley and rye are most likely to cause acidosis.

Bloat is another feeding disorder that can be a problem when feeding a high concentrate ration. Feedlot bloat occurs rather infrequently and death losses are minimal in well managed feedlots. Most cases are chronic rather than acute as with legume pasture bloat. Feedlot bloat is usually of a chronic nature, meaning that it occurs repeatedly in only a few of the cattle in the lot.

There are various alternative theories regarding bloat etiology. The microbes may produce gas to make foam; but gas production is insufficient, in itself, as a primary factor (Cheek and Shull, 1985). Foam stabilization through various mechanisms leads to interference with eructation by the presence of foam and ingesta in the area of the cardia. Bacteria are seen as a force, both promoting and destroying condition for bloat, since they can ferment soluble protein as well as salivary mucus and may produce slime themselves (Van Soest, 1983). However, the character of the bacteria is largely determined by the nature of the substrate they offered. A high rate of gas production is required which, in turn, requires a high rate of eating (an animal factor) and a high non-cell wall diet content. The adequacy of salivary secretion and its composition is another animal factor (Van Soest, 1983). Feeding high amounts of concentrates often causes bloat which is usually of the chronic variety. This type of bloat seems to be different from that of animals on legume pasture (Bartley et al., 1975). Rumen contents are characterized by high viscosity and consequent foam resulting from the production of extracellular slime by amyolytic bacteria. The mucin fraction of ruminant saliva, which may have protective action on bloat, might be inactivated by rumen organisms with mucinolytic activity. Such factors might be promoted by smaller amounts of saliva per unit feed and low rates of rumen turnover characteristic of high concentrate diets (Van Soest, 1983).

Due to wheat's greater digestibility within the rumen, it seems to be more prone to cause bloat. Barley and rye follow wheat with corn the most unlikely candidate (Gibbons, 1963). Barley when fed with long alfalfa hay has been known for years to be especially prone to cause bloat (Henry Nichols, Jr, personal communication).

Rumen Environment

The microbial population of the rumen is regulated by the peculiar ecological balance of condition that tend to prevail there. The rumen environment contains a number of unique features that cause it to differ from most other anaerobic systems. The system is isothermal and is regulated by the homeothermic metabolism of the host animal. There is a relatively constant influx of water and feed and the fermentation of the feed produces a considerable amount of acid. The pH (6 to 7), however, remains relatively constant, because fermentation acids are removed by absorption across the rumen wall and neutralized by salivary buffers. The pH of a concentrate ration differs markedly from a roughage ration, with the concentrate being predominantly lower. The buffering of the rumen not only comes from the saliva, but also from buffers crossing the rumen wall from the systemic system (Esdale and Satter, 1972). Ionic concentrations are regulated through dilution, absorption and passage. The undigested substrate is ultimately passed down the digestive tract after being subjected to microbial digestion. End products and wastes do not accumulate and are removed, such that all factors relative to the microbial environment are regulated within narrow limits. This makes the rumen a continuous culture system (Nakamura et al., 1971).

Rapid rates of fermentation are dependent upon sufficient nutrition for rumen microorganisms. Adequate external sources of nitrogen, sulfur and essential minerals are required for optimum carbohydrate utilization (Raun et al., 1962). If any essential nutrient is lacking or the rumen environment is not at optimum, the rate of digestion will slow down and either intake or digestibility will decrease. The most important factors influencing rate of digestion are the intrinsic properties of the feed carbohydrates and protein or, in other words, a balanced ration.

The rumen secretes no enzymes; and it is only through the vast number of microorganisms present, that nutrients in the rumen are transformed into compounds for use by the animal. The rumen, in effect, modifies the food of the ruminant before further digestion proceeds later in the alimentary tract. Microorganisms perform a wide variety of synthetic reactions to degrade cellulose, protein, and other polysaccharides into volatile fatty acids, peptides, amino acids, ammonia, gasses and a variety of vitamins (Neil Forsberg, personal communication).

Extent of Starch Digestion of Feed Grains

Total tract digestibility of all feed grains is very close to 99%, especially if there is some sort of mechanical processing (Waldo, 1973). Greater amounts of feed do escape digestion when fed whole or if the particle sizes are coarse (Hale, 1973; Hinman and Johnson, 1974;

Toland, 1976; Aimone and Wagner, 1977).

Lofgren (1970) listed Megacalories of Net-energy for gain per kilogram dry matter for feed grains as follows: corn, 1.52; wheat, 1.43; sorghum, 1.34; and barley, 1.32. Corresponding NEm values were 1.94, 1.90, 1.83, and 1.79. Tyrell et al., (1972) demonstrated that corn and barley rations did not differ in digestibility or metabolizability of energy; but the efficiency of use of metabolizable energy for tissue synthesis was 53% for a corn ration compared to 47% for a barley ration. Thivend and Vermorel (1971) found that growing lambs retained more energy on corn than on barley, wheat or sorghum, and upon slaughter, starch distribution indicated wheat starch to be most readily attacked in the rumen followed by barley, corn, and sorghum. They observed about 44% propionate in the rumen with corn diets vs. about 33% with other grains. In contrast, other workers observed that corn rations produced the lowest percentage propionate in the rumen when compared to other grains (Oltjen et al., 1966; Oltjen et al., 1967; Reddy et al., 1975).

As has been stated total tract digestibility of the grains approaches 99%, depending on processing. Waldo (1973) conducted an extensive study on digestibility of different grains and found that rolled wheat, barley, and oats, flaked corn, and steam flaked sorghum are about 94% fermented in the rumen. Ground corn is 74% fermented in the rumen and this value is 1) affected by corn source, 2) greater for sheep than cattle, and 3) similar at 20 and 80% rations but less on 40% and least on 60% corn rations.

Starch fermentation in the rumen has an energetic efficiency of 75 to 80%, i.e. a loss of 20 to 25% due to microbial wastage during digestion. Therefore, concentrate rations that introduce starch into the abomasum and small intestine for enzymatic digestion should be more efficient than those extensively fermented in the rumen. This assumes little starch fermentation occurs in the large intestine where there may be microbial digestion with lessened absorption of nutrients.

Protein Utilization

Dietary N is used, first, for nourishment of the rumen microorganisms. Ultimately, however, the function of dietary N is for tissue maintenance or for tissue and milk synthesis; amino acids may also provide a significant amount of the total energy in many situations (Allison, 1969).

Protein quality is generally defined as the ability of a specific protein to provide essential amino acids in the required amounts to a given animal performing a specific function such as growth and (or) milk production (Van Soest, 1983). In the case of ruminant animals, it has been assumed in the past that protein quality is of relatively little importance and that protein of equal digestibility are of equal value. This assumption has been based on the fact that ruminal microorganisms synthesize the essential amino acids. However, now there is little doubt that quality of protein in the gut has an effect on animal performance. Colebrook and Reis (1969) fed whole egg protein, egg albumen, corn gluten, casein, and gelatin to sheep via the abomasum. Casein increased wool growth rate 140 to 200%, and similar responses were obtained from the egg protein. Corn gluten produced about one half of this response, and gelatin had little effect. In cases where certain proteins have given a markedly better response, data show that more intense ruminal fermentation occurs; and there is a big correlation between biological value of the protein and numbers of ruminal bacteria (Tagara, 1969).

The animo acid composition of rumen bacterial protein seems to be rather constant. A comparison of the values between laboratories yielded a correlation of 0.98 (Purser, 1970). Ration does not appear to affect the composition, since correlation coefficients of 0.98 and 0.99 were found in comparing the bacterial protein from animals fed different rations (Pursor, 1970). Pursor also reported that the composition of bacterial and protozoal protein was highly correlated (r=0.97).

Cellular protein in ruminal microorganisms generally constitutes a large and important part of the alpha-amino nitrogen assimilated by the host. The concentration of extracellular amino acids in the rumen is usually relatively low since amino acids are rapidly catabolized within the rumen by the microbial population. Only a small proportion of these amino acids are incorporated intact into microbial proteins. The de novo synthesis of amino acids by ruminal microbes is an important activity even in animals fed natural rations (Allison, 1969). Differences were recorded in amino acid availability from rumen microbes of cattle fed different protein supplements (Burris et al., 1974). Although no differences in bulk amino acid patterns were evident, ruminal bacteria isolated from cattle fed a high concentrate ration had a higher biological value for the laboratory rat than the bacteria from a high roughage ration (Keyser et al., 1978).

Wheat is higher in protein and has a better amino acid distribution than most cereal grains (Church and Pond, 1978). Even though wheat is 94% digested within the rumen and the protein composition is changed by the microbial population, the portion that escapes rumen digestion is of very high quality. The enzymatic digestion of wheat would be expected to be of greater biological value compared to the other feed grains. Wheat would also give rise to a greater population of microbes due to its high digestibility and N content. This could be seen as an increase in amount of microbial protein synthesis.

However, a balanced ration that is isonitrogenous and isocaloric may negate this latter hypothesis.

Volatile Fatty Acid Production and Absorption

The production of Volatile fatty acids (VFA) as waste products of anaerobic microbial metabolism provides the ruminant with a major source of metabolizable energy (Raun et al, 1962; Shell et al., 1983). The amounts and proportions of the VFA produced are variable, depending on the nature of the diet, the time after feeding and the age of the animal. The principal fatty acids in descending order of abundance are acetic, propionic, butyric, valeric, isovaleric, and traces of other acids such as isobutyric and 2-methylbutric. The proportions of VFA are markedly influenced by diet (Huntington et al., 1981). Other organic acids may appear as products. Lactic acid is important when starch is a part of the diet and is, itself, fermented to acetate, propionate, and butyrate.

Rumen concentrations of VFA are regulated by a balance between production and absorption whereby increased production rate induces higher concentrations. Since production rates vary diurnally as a consequence of eating patterns, rumen concentration and pH also vary (Stewart et al., 1957; Ryan, 1964). The pattern following feeding shows a rise of VFA and a drop in pH, followed by a slow recovery to original conditions. When sheep were given a fourfold range in forage intake (Weston and Hogan, 1968) or steers given a twofold range in intake of a low-roughage diet (Yost et al., 1977), the rate of VFA production was directly proportional to apparent digestion of organic matter.

Acids are absorbed across the rumen wall in the free form apparently without active transport. There may be considerable metabolism of the acids (particularly butyrate) in the rumen wall leading to a differential decline in concentration and more rapid absorption. The intracellular pH of the rumen wall and blood is ordinarily more alkaline than that of the rumen which favors movement of acid toward the blood through the free energy of neutralization. This gradient similarly discourages flow of fatty acid anions. Bicarbonate, sodium ions and some urea flow in a reverse direction toward the rumen. Along with the inherent properties of saliva and the absorption of the VFA, the pH of the rumen is maintained (Neil Forsberg, personal communication).

The molar proportions of VFA in the rumen are little affected by change in intake of forage-based diets, but when diets contain large amounts of concentrates, the proportion of acetate falls and that of propionate increases with increasing intake (Bath and Rook, 1963; Sutton et al., 1977). In certain circumstances, large changes in the proportion of butyric acid also occurs (Eadie and Mann, 1970). It has been suggested that increased propionate production is energetically more efficient (Wolin, 1960; Hungate, 1968; Raun et al., 1976). Richardson et al., (1976) calculated that a monensin-induced increase in propionate concentration would increase gross energy available as VFA by 5.6%.

It is well recognized that reduction in the forage: concentrate ratio, by decreasing forage and increasing concentrate, causes the molar proportions of the concentrations of individual VFA to change over a wide range (Shaw et al., 1960; Rogers and David, 1982; Shell et al., 1983); but the effects on the production rates of individual acids are less clear.

As has been stated, volatile fatty acid production is sensitive to pH. The total quantity of acid as well as the relative amount of each is affected by pH. Generally as pH is lowered from 7 to 5.5, the relative amount of acetate produced decreases while propionate and butyrate production may be sustained or decreased only slightly. This has been demonstrated in vitro (Daughters et al., 1963; Slyter et al., 1976) and indicated in vivo (Emery et al., 1965; Rumsey et al., 1970). Since the relative amounts of ruminal acetate and propionate may influence the caloric efficiency of fattening, then pH control of the rumen is important to animal productivity (Blaxter, 1962; Aimone and

Wagner, 1977). Esdale and Satter (1972) demonstrated that as ruminal pH increased from 5.5 to 6.23 the acetate:propionate ratio raised from 1.1:1 to 2.8:1 and that VFA production was largely unaffected between pH 6.2 and 6.8. They also showed that between pH 5.6 and 6.2 acetate production was inhibited and propionate and butyrate production were increased at pH 5.6

The volatile fatty acids produced in the rumen are known to be absorbed through the ruminal epithelium. The rate of VFA absorption has been shown to be dependent upon the ruminal VFA concentration (Brown et al., 1960; Lemenager et al., 1978) and development of the ruminal epithelium (Sutton et al., 1963; Hinders and Owens, 1965; Kay et al., 1969). Parakeratosis or the keratination of ruminal epithelium inhibits this absorption of the VFA. Excess production of lactic acid or a high concentration of acid in the diet, in combination with less saliva and buffering capacity per unit of feed, result in lower rumen pH. These conditions are unfavorable to the rumen lining and lead to a darkening, abnormal appearance and atrophy of the papillae. In severe cases of rumenitis, the lining may actually be sloughed away. Hinders and Owens (1965) found that the amount of ruminal VFA absorption decreased with increasing severity of ruminal parakeratosis. The addition of roughage is very important to the development of the rumen. Sutton et al (1963) observed that the maximal absorption rate in calves fed milk, hay, and grain increased 16 times from 1 to 13 weeks of age. Calves fed only milk absorbed VFA at about the same rate at 13 weeks as at 1 week of age. Volatile fatty acids introduced into the rumen have been shown to stimulate rumen development (Flatt et al., 1958; Sander et al., 1959). However, excessive accumulation of keratinized epithelium (parakeratosis) has been reported in the rumina of calves fed propionate and butyrate (Gilliland et al., 1962), high concentrate rations (Kay et al., 1969), and pelleted rations (Hinders and Owens, 1965). For this reason it is recommended that roughage levels of finishing rations be maintained between the 10 to 15% level. This aids in inducing rumen motility and better mixing, rumination, and the neutralization of rumen contents. The addition of buffers has also been suggested (Nicholson and Cummingham, 1961; Rogers and Davis, 1982). Kay et al., (1969) and Hinders and Owens (1965) speculated that the depressed VFA absorption during severe cases of parakeratosis is due to one or all of the following: 1) restriction in the absorption surface area caused by sloughing and degenerating of papillae; 2) the physical barrier to absorption resulting from keratinization of the papillae; 3) reduced blood flow to the rumen epithelial tissue resulting from reduced motility and papillae degeneration;

and 4) disruption of the transport mechanism of the stratum granulosum.

Wheat has been shown to be highly digestible within the rumen (Waldo, 1973) and has demonstrated the pretension to producing lower rumen pH, with a greater production and concentration of VFA (Oltjen et al., 1966; Shaw and Pryor, 1972; Backus et al., 1980) when compared to the other feed grains.

Use of Wheat In Finishing Rations

Although grown primarily as a cash crop, wheat at times is priced competitively with other grains as a feed grain for livestock. During times of low wheat prices, wheat may be substituted for part or all of the other grain in high concentrate rations (Oltjen et al., 1966; Backus et al., 1980; Combs and Males, 1986).

Nichols (1970) has stated that wheat should not be used to replace more than 50% of the grain portion of the ration. Backus et al (1980) reported that the best results were obtained by replacing the grain portion with only 40% wheat. In contrast, several investigations have observed that feeding high levels of wheat did not exhibit any detrimental effects (Cornett et al., 1971; Pryor and Laws, 1972; Shaw and Pryor, 1972; Gartner and O'Rourke, 1975; Toland, 1976; Aimone and Wagner, 1977; Combs and Males, 1986). The problems that have been associated with feeding levels of wheat range from acidosis and digestive disturbances to decreased consumption which may cause a decrease in average daily gains.

Reddy et al. (1975) reported that average daily gains of steers fed triticale, corn, and wheat were 1.13, 1.33 and 1.22 kg, respectively. Daily feed intake was higher for corn-fed steers than for steers fed wheat and triticale. Furthermore the feed to gain ratios tended to be best on wheat and poorest on triticale. Combs and Males (1986) demonstrated that steers fed a ration consisting of 100% steam rolled wheat as the sole concentrate source had a feed efficiency which was 120% better than a 100% steam rolled barley diet. Feed efficiency decreased linearly as barley replace wheat in the mixed diets. They also discovered that the 100% corn ration resulted in steers converting their feed 5.5% less efficiently than steers fed 100% wheat. There was no differences in average daily gain and no digestive disturbances were reported. However, Oltjen et al. (1966) showed results that steers fed 60 and 90% corn rations made greater gains than steers fed 60 to 90% wheat rations. He also indicated that feed required per unit of gain increased as the amount of wheat in the ration increased. Animal performance was very similar for all the groups during the first 70 days; but during the last 28 days, the steers consumed less of the high-wheat rations; and as a results overall performance was lowered. They also observed a significant increase in liver abscesses on the higher wheat diets, but no digestive disturbances. Dyer and Weaver (1955) reported that ground wheat fed as the only grain in rations containing from 30 to 35% roughage caused frequent digestive disturbances and slow gains, and resulted in carcasses of relatively low grade.

Carcass characteristics generally show no differences with the use of different grains in finishing rations. Combs and Males (1986) reported no difference in carcasses finished on corn, wheat, or barley. These findings agree with the findings of Bull and Dahman (1970), Garrett (1968), and Oltjen et al. (1966) who fed milo, corn or barley in comparison to wheat. However, Gartner and O'Rourke (1975) observed that steers finished on wheat had higher dressing percentages than those fed oats or a combination of the two grains.

Most feeding studies have reported little improvement in performance of finishing cattle fed processed wheat compared with dry rolled or coarsely ground wheat. Some kind of mechanical process is required mainly due to the small size of the kernel and the hard exterior shell. Evens and Coleburn (1967) demonstrated that the physical form of grains, including wheat, markedly influenced its dry matter digestion in the rumen. They reported that digestible dry matter was 65.9% and 91.8% for corn and wheat, respectively, ground through a 2mm screen vs. 7.01% and 17.2% for the whole grain corn and wheat, respectively. Similarly, Toland (1976) showed that dry rolling significantly increased the digestibility of organic matter and starch of barley and wheat when compared to feeding whole grain. Aimone and Wagner (1977) and Lofgren (1970) reported no differences in gain or feed efficiency due to steam flaking, micronizing, coarse grinding, or dry rolling wheat. In contrast Brethour and Duitsman (1966) and Martin (1973) produced improved intake, gain and efficiency when comparing dry rolling to steam flaking and roasting. Fines in the ration may be a potential problem when dry rolling or grinding wheat. Hale et al. (1970) found some improvement in performance with poorly flaked wheat compared to flat flaked wheat due primarily to the reduced percentage of fines in the poorly flaked wheat. Bris et al. (1966) reported somewhat higher performance with steam flaked and pelleted than with dry rolled soft wheat grown in the Pacific Northwest. They attributed the reduced performance to excessive fines in the dry rolled wheat. However, DelCurto and Weber (unpublished data) reported no adverse affects to feeding finely ground wheat to finishing steers in a loose textured ration. Both feedlot and metabolism studies suggest that wheat is very digestible and is not improved by processing to the extent noted in other grains, particularly sorghum.

Wheat has demonstrated a tendency to be highly digestible within the rumen, and this increases the concentrations of volatile fatty acids and tends to decrease rumen pH (Chou and Walker, 1964; Oltjen et al., 1966; Aimone and Wagner, 1977). As is expected a decreased acetic to propionate ration also is exhibited. Shaw and Pryor (1972) observed a lowered acetic to propionate ratio when cattle were fed high wheat rations as compared to lower levels of wheat. Oltjen et al. (1966) observed steers fed 60 and 90% wheat rations had significantly greater ruminal concentrations of VFA and ammonia but significantly lower ruminal pH values, when compared to steers fed 60 and 90% corn rations.

Feeding of high levels of wheat has been associated with production of high levels of lactic acid (Ahrens, 1967) and a reduction in feed intake (Baker and Baker, 1960; Tremere et al., 1968). Varner and Woods (1975) reported much higher rumen lactate levels in cattle fed hard vs. soft wheats. In contrast, Shaw and Pryor (1972) observed very low lactic acid levels in the rumen of wheat fed cattle. In approximately 30% of these samples lactic acid could not be detected at all. It is however generally accepted that wheat, regardless of variety, seems to be digested more rapidly and to a greater extent than corn, as indicated by lactate and VFA production, and in vitro dry matter digestibility. The increased digestibility of wheat starch and subsequent high levels of rumen lactate and VFA levels could partially explain the reduced feed intake by cattle fed wheat as compared to corn. Brethour (1970) observed a decrease in feed intake coupled with comparable average daily gains to give a better feed efficiency. He stated that "the depressed intake of wheat-containing rations, even though associated with increased efficiency, can be very disconcerting to the cattle feeder".

The excellent cattle performance in a predominance of feedlot trials indicates that if proper management practices are used, lactic acidosis, bloat, and parakeratosis need not be a problem when cattle are fed high wheat rations. These maladies are virtually eliminated with the use of ionophores, buffers, and a judious amount of time for ration adaptation. When ionophores and buffers are utilized, an increase in feed efficiency is often observed with no decrease in average daily gain. Likewise carcasses are not adversely affected.

STATEMENT OF THE PRESENT PROBLEM

Prices of grains and other major feedstuffs continue to take wide swings, offering livestock feeders opportunities to make profitable substitutions in rations and feed current least-cost formulations. More aptly stated; They can feed rations that are more efficient in relation to cost and production efficiency.

Wheat has not been used extensively as a feed for finishing beef cattle. Most of the feed wheat demand occurs when supplies of low readily available feed grain stocks lift those grain prices to near or above that of wheat. A greater source of wheat as feed comes from that which is discounted for low quality, particularly at harvest time (U.S.D.A.-Wheat, 1987b).

When an oversupply of wheat causes it to be priced competitively with other feed grains, uncertainty as to proper management in cattle rations limits usage. In the past, the general recommendation of limiting wheat to 50% of the concentrate portion of the ration was related to palatability problems (Gartner and O'Rourke, 1975) as well as digestive disturbances, such as ,acidosis and bloat (Shaw and Pryor, 1972; Varner and Woods, 1975) and difficulty of keeping cattle on feed. Wheat has shown a propensity to increase ruminal VFA concentrations which reduces ruminal pH (Oltjen et al., 1966; Reddy et al, 1975; Aimone and Wagner, 1977). The above aspects are due to the high digestibility of wheat in the rumen (Waldo, 1973) and is one of the contributing factors in the digestive disturbances observed with wheat rations.

With the advent of ionophore, problems with acidosis and bloat have been greatly decreased (Bartley, 1983). Problems with palatability and keeping cattle on feed have been largely overcome by adjusting cattle slowly to the wheat ration (Gay and Wolf, 1977; DelCurto and Weber, 1985), by the use of buffers and ionophores (Nicholson and Cunningham, 1961; Shaw and Pryor, 1972; Nagaraja et al., 1981), and by the addition of highly palatable feed additives, i.e., molasses.

Level of roughage in wheat diets may be important (Morris et al., 1969; Pryor and Laws, 1972). Gill (1981) used corn-based diets and indicated that rate and efficiency of gain are improved as roughage levels are reduced to 12% or below. However, the type of grain, method of processing and type of roughage may make other levels more desirable. In a wheat based diet, the 12% level of roughage should provide some margin of safety while providing sufficient energy for rapid and efficient gains.

Wheat does have some inherent problems in the feeding or finishing of cattle. However, research and the actual use of wheat by feedlots have demonstrated that these problems can be largely overcome. There are advantages that should be taken into consideration when wheat is attractively priced in relation to other feed grains. Wheat is actually a premium feed grain due to several qualities: 1) Wheat has more protein than either corn or milo. Typical values indicate wheat has 12% protein while corn and milo generally have only 9% protein. The added protein in wheat dramatically reduces the need for expensive protein supplements and often makes wheat-based rations economical. 2) Wheat is usually drier than corn or milo. Moisture levels in wheat are typically from 11 to 13%. Corn and milo are usually about 15.5% moisture with much higher levels common during harvest in the fall. The added moisture in feed grains does not contribute to livestock gains and therefore makes wheat from 2.5 to 4.5% more valuable per 100 lbs. 3) A bushel of wheat weighs 60 lbs. while a bushel of corn or milo only weighs 56 lbs. This fact should be taken into account when pricing grain on a per bushel basis by converting prices to a 100 lb. basis. 4) Many wheat producers are also livestock producers. These producers can realize an economic advantage from feeding their own wheat rather than buying feed at retail prices. Using ones' own wheat avoids the cost of transportation, handling, and dealer margins (Oklahoma Wheat Commission, 1986).

Early research indicated that the feeding of wheat is risky and did not compare favorably to that of other feed grains (Dyer and Weaver, 1955; Dunlop and Hammond, 1965; Oltjen et al., 1966). Later research with the use of new management procedures and feed additives has shown that wheat can be used as a feed grain very effectively (Lofgren 1970; Dinnusson, 1971; Reddy et al., 1975; Combs and Males, 1986). The later research has demonstrated that average daily gains are comparable to other feed grains, while feed efficiency is improved when feeding wheat. Furthermore, carcass characteristics are not adversely affected by the feeding of wheat. It has also been demonstrated by these researchers that there is an increase in VFA concentration and a precipitous drop in rumen pH.

The report that follows is a similar study in that wheat was compared to corn and barley in finishing rations. This study compares feedlot, carcass, and ruminal parameters of the three grains in relation to animal performance and the economics of gain.

EXPERIMENT 1 AND 2: WHEAT VERSUS CORN AND BARLEY IN BEEF FINISHING RATIONS

Introduction

The objectives of this research trial were to evaluate the differences and/or similarities of wheat, corn and barley in a Northwest beef finishing ration. In experiment 1, yearling feeder cattle were used to measure feedlot and carcass parameters when fed either wheat, corn, or barley finishing rations. In experiment 2, six fistulated heifers were used to measure ruminal parameters when fed the same rations as the feedlot cattle.

Materials and Methods

Experiment 1. Forty-four head of exotic-British crossbred yearling steers were stratified by weight across three replications of three treatments. The average weight of steers within pens was 881 +/- 12 lbs. All of the animals were from the same management background having been raised at the Oregon State University ranch at Soap Creek. All animals received the usual vaccinations, worming and implants before arriving at the O.S.U. beef barns.

The three replications consisted of 8 pens with 5 steers/pen and one pen with 4 steers. Each pen was randomly assigned to one of three treatments. The nine groups of steers were also randomly assigned to a pen (figure 1). Each pen had it's own water source, feed bunks, and salt-mineral feeder. Pens were not rotated during the trial since they were all in close proximity. All pens of cattle were adjusted to their respective treatment diets by slowly decreasing the amount of roughage and increasing the concentrate in the ration. This process was completed in 21 days proceeding the start of the trial.

The three ration treatments consisted of: 1) 70% corn; 2) 70% barley; and 3) 70% wheat. In addition to the grain, the pelleted treatment diets contained 17% oats, 10% mid-bloom alfalfa hay, and 3% dry additives (table 2). The treatment diets were very nearly isonitrogenous and isocaloric (table 3). The treatment diets were hand-fed every morning and evening. As a result, consumption of the treatment diets were measured on a pen basis. The refused feed was weighed back and recorded in order to establish daily feed intake/pen.

Steer weights were taken every 28 days to establish average daily gains (ADG) and feed/gain (F/G) ratios. Following three weigh periods (May 22-August 15) ADG and F/G ratios were tabulated. The steers then remained on their respective treatments until finished. Finish was determined by visual appraisal and an ultrasonic back fat measurement with 0.3 inches as a minimum. Final weights were recorded prior to slaughter and ADG and F/G ratios

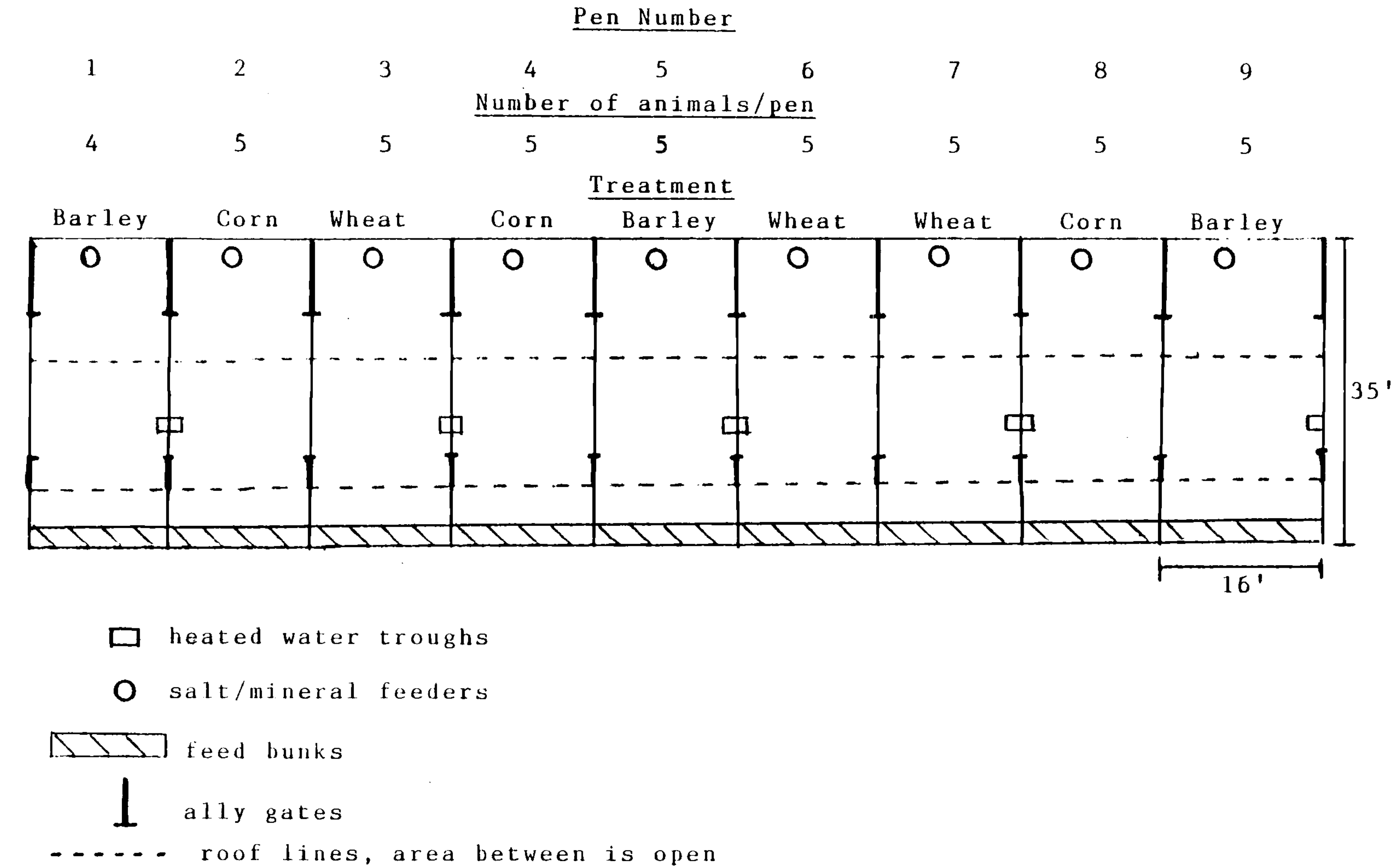


Figure 1. Experiment 1 design and pens. Treatments and groups of animals were randomly assigned to pens.

DIET COMPOSITION

	Treatment Diet					
	Barley		Corn		Wheat	
Ingredient	lb	%	lb	%	lb	%
Alfalfa Hay	200	10.00	200	10.00	200	10.00
Barley	1400	70.00	-	-	-	-
Corn	-	-	1400	70.00	-	-
Wheat	-	-	-	-	1400	70.00
Oats	340	17.00	340	17.00	340	17.00
Sodium Bicarb.	30	1.50	28	1.40	30	1.50
Limestone	19	0.95	18	0.90	21	1.05
Urea	5	0.25	8	0.40	3	0.15
Supplement	6	0.30	6	0.30	6	0.30

Table 2. Composition of the experimental treatment diets. The supplement contained lasalocid*, an antibiotic, and a vitamin/mineral package. The variable amounts of urea reflect the attempt to equalize the protein quantities in the three grains.

* active ingredient of Bovatec, the commercial product produced and marketed by Hoffman-La Roche, Inc.

PROXIMATE ANALYSIS OF TREATMENT DIETS

Ration	D.M.	TDN	C.P.	NDF	ADF	Ash	Fat	Ca.	P.
				%					
Barley	87.0	69.6	12.9	29.9	9.2	4.1	2.3	0.44	0.25
Corn	86.4	71.8	13.0	25.8	7.8	4.6	3.6	0.45	0.25
Wheat	86.8	70.3	12.5	32.8	8.7	4.3	1.9	0.51	0.24

Table 3. Chemical analysis of treatment diets. All are similar in nutrient value.

were again tabulated for the entire feeding period. Days on feed were determined for the entire period from May 22 to the day each steer was slaughtered. Following slaughter, carcass parameters were determined. These included dressing percent (hot carcass wt./live wt.), rib eye area (REA, determined by dot matrix grids), backfat thickness (measured at the 12th rib, 2/3 down the longissimus dorsi muscle), kidney, pelvic and heart fat (KPH, determined by visual appraisal), quality grade (a function of maturity and marbling), and yield grade (2.5 + [2.5 (adjusted backfat thickness)] + [(.0038) (hot carcass wt.) + (.2) (KPH%)] - (.32) (REA).

Statistical Analysis. Average daily gains and feed efficiency (F/G ratios) were analyzed by analysis of variance. Specifically, analysis of variance was used testing ration by variation among pens of the same ration and testing pens by the variation among animals within pens (Bob Delongchamp, personal communication).

Experiment 2. Six head of 3-year-old heifers that were rumen-cannulated and spayed, were randomly assigned to 3 different groups. The heifers were of mixed exotic-British crosses and weighed approximately 1000 lbs. All heifers had similar management prior to the initiation of the experiment.

Each pair of heifers in a group was housed in an individual pen, with an adequate supply of water and minerals. Since the pens were nearly identical, rotating the animals between pens was not conducted.

Treatments consisted of the same diets as used in experiment one. Each pen of heifers was randomly assigned a treatment diet. The diets were rotated so that all groups received each treatment (figure 2).

The experimental protocol for each crossover of animals to treatments involved three distinct phases (figure 3). First, the animals were placed in an equilibration period for 7 days. During this phase, the animals were allowed to readjust to a diet of grass hay. In effect, the time was used for rumen metabolism and/or fermentation to re-equilibrate prior to initiation of next treatment. The second phase lasted 28 days and involved the initiation of the treatment diets. During this phase, the heifers were allowed to adjust to the high concentrate treatment ration for 18 days. This was accomplished by gradually increasing the amount of treatment diet and decreasing the amount of grass hay in the diet. During the last ten days, the heifers were receiving 15 lbs/hd/day of the treatment diet alone. The final phase was the rumen sampling. It was conducted on day 28 at five different times during the day. Each set of phases was repeated three times to complete the crossover design.

Rumen sampling was conducted on the hours of 0, 2, 4, 8 & 12 of the final phase. Hour zero represents the time

	Pen		
Period	1	2	3
1	B	C	W
2	W	B	C
3	C	W	B

Figure 2. Cross-over design on Experiment 2. Each pen contained two head of rumen-cannulated heifers. Heifers were allotted at random to a pen. Initial treatment diets were allotted at random to the first period. Each period was 28 days in length and an equilibration period of 7 days between treatment. Letters B, C and W denote barley, corn, and wheat treatment rations respectively.

Equilibration Period

d-1 d-2 ....d- 7

Treatment Ration Adjustment Period

d-1 d-2 d-3................d-28

Sampling P.

hr-0 hr-2 hr-4 hr-8 hr-12

Figure 3. Sampling and experiment protocol of Experiment 2. Samples were taken on hours 0, 2, 4, 8 and 12 of the sampling period. Hour 0 represents the time prior to the morning feeding and the subsequent hours represent the times post feeding. During the adjustment period the percent of the treatment ration was gradually increased. By day 18, all animals were receiving 15 lbs/hd/day of their respective treatments. During the equilibration period the diet contained only grass hay. Schedule was repeated for periods 2 and 3 of the three-treatment crossover design.

just prior to the A.M. feeding. The heifers were then fed their respective treatment diets and the subsequent hours represent the time after feeding. Hour twelve represents the time just prior to the evening feeding. Rumen samples were taken by utilizing a swirling action within the rumen. This was to insure that a representative sample of rumen fluid would be obtained. The rumen fluid was then strained through a small-meshed fish net into thermoses for transport back to the laboratory.

Upon arrival at the laboratory the pH of the rumen fluid was taken and recorded. The pH was determined by utilizing a Corning pH/ion Meter 150 in conjunction with a Corning Stirrer PC-153. The rumen fluid was then strained through four layers of cheese cloth. Five ml of the strained fluid was then pipetted into a centrifuge tube. In order to stop microbial activity 50 ul of concentrated phosphoric acid were added to the five ml of stained rumen fluid. Four, five ml samples were saved for each hour of the sampling period. The samples were then frozen at 15° F. for storage until later analysis. These sample preparation procedures are outlined by Supelco, Inc. (1975).

<u>Gas Chromatography Analysis</u>. The five ml of strained rumen fluid were thawed at room temperature and then centrifuged at 2000 rpm for 20 minutes (Beckman Model TJ-6). The resulting supernatant fluid was then pipetted into

1 ml vials and again centrifuged at 2500 rpm for 10 minutes (Eppendorf AMC 311). One ml of the final supernatant fluid was then added with 1 ml of the internal standard, which consisted of double distilled water containing 0.2% 2-ethylbutyric acid and 0.03M oxalic acid. The two ml sample was then thoroughly mixed and pipetted into a chromatography vial for analysis. Analysis was performed by a Perkin-Elmer Sigma 2000 Capillary Chromatograph. The column packing utilized was 80/120 Carbopack B-DA/4% Carbowax 20M in a glass column.

Two chromatography vials were made for each treatment hour sampled to reduce variation caused by faulty pipetting of internal standard. One injection was taken from each vial giving two analyses for each treatment hour. The mean of the two analyses was used as an individual ruminal observation for that treatment hour. A chromatography vial containing 0.03M oxalic acid in double distilled water occupied alternating positions with the rumen fluid. This was injected to cleanse the column between each injection of rumen fluid. This procedure was used to insure that there was not a build up of residual acids in the column.

Peaks were integrated according to retention time and relative area. Integrated peaks include acetate, propionate, isobutyrate, N-butyrate, 2-methylybutyrate, isovalerate, lactate, and valerate.

Statistical Analysis. This was a cross-over design to test treatment rations with repeated measures at five different sampling hours. The cross-over design ("whole plots"= animals) was used to test differences in period, diet, animal and used error 2. The repeated measures design ("sub-plots" = hours within an animal) was used to test differences in hour, hour x animal, hour x diet and used error 1. (Bob Delongchamp, personal communication).

Results

Experiment 1. The average daily gains and feed efficiencies in the first 85 days were 3.45, 3.43, 3.44 and 5.96, 5.78, 5.61 for the barley, corn and wheat diets respectively (Table 4). This is consistent with previous studies using high concentrate finishing rations (Davis et al., 1963; Reddy et al., 1975; Harrison et al., 1978; Gill, 1981; Martin et al., 1985). The three treatment diets were found to have no effect on either ADG or F/G during this period.

Final feedlot parameters were calculated after each steer was determined to be finished. When each steer was removed from the pen individual data was calculated. These figures were averaged among treatment. The treatment means for the final feedlot parameters are presented in table 5. As with the first 85 days, these figures are consistent with high concentrate feeding. Similarly, treatment diets

Feedlot Performance Following 85 days on Feed

Treatment	ADG	F/G
	lb	lb
Barley	3.45	5.96
Corn	3.43	5.78
Wheat	3.44	5.61

Table 4. Average daily gain (ADG) and feed efficiency (F/G) following 85 days on the treatment diets.

Final Feedlot Parameters

Treatment	Ending Wt.	Days Fed	ADG	F/G
	lb	d	lb	lb
Barley	1205	109	3.01	6.85
Corn	1214	108	3.09	6.60
Wheat	1200	105	3.00	6.60

Table 5. Feedlot parameters at end of trial. Feedlot parameters measured were (1) Pre-slaughter weight (2) average days on feed (3) average daily gain, (4) feed efficiency measured as pounds of feed/pound of gain, on a dry matter basis.

were found to have no effect on ending weight, days on feed, average daily gain, or feed efficiency.

The third part of experiment 1 was the comparison of carcass data. This trial did not have a specified ending date where all animal would be slaughtered. As with the final feedlot parameters, the carcass data were collected individually as each steer was slaughtered. Over time this data was averaged among treatments. The treatment means for carcass parameters are shown in table 6. Again a treatment effect was not found for any of the following parameters; dressing percent, loin eye area; kidney, pelvic and heart fat, back fat, quality grade, or yield grade. These findings are in agreement with previous research that compared different grains in a finishing ration (Reddy et al., 1975; Martin et al., 1985; Combs and Males, 1986).

<u>Experiment 2</u>. Treatment effects on pH by hour, diet, and period are listed in table 7. The difference in pH recorded at the five sampling hours within treatments was found to be highly significant ($P<.001$). As time progressed, pH declined to a low at the 4 hour sampling for barley and wheat. This was followed by subsequent increases in pH at hours 8 and 12. Corn had a low pH at the 2 hour sampling followed by a subsequent increase in pH for the remaining hours. While there was a significant hour effect within treatment, a difference due to ration x

Treatment Ration	Dress% %	LEA sq.in	KPH %	Back Fat inches	Q.G. (a)	Y.G (b)
Barley	62.3	12.9	3.0	0.45	11.9	3.0
Corn	62.2	13.4	3.0	0.43	11.9	2.8
Wheat	62.6	13.7	2.9	0.40	12.2	2.7

(a) 11 = high good; 12 = low choice
(b) scale from 1-5; 1 = high carcass yield; 5 = low carcass yield

Table 6. Carcass parameters measured following slaughter were: (1) Dressing percent, (2) loin eye area, (3) kidney, pelvic, and heart fat, (4) back fat, (5) Quality Grade, and (6) Yield Grade

hour was not observed. Figure 4 graphically displays the decline and subsequent increase in pH of the three treatments. This pattern of pH decline and rise over time is due to the ruminal fermentation of feedstuffs and is well known. The mean pH of the corn and barley treatments were similar, while wheat was found to have a lower mean pH ($P<.05$) (table 7). Oltjen et al., (1966) along with Shaw and Pryor (1972) also noted this trend when using wheat in a finishing ration. An unexplained difference in the mean pH of all animals by periods was also found. Period three exhibited a lower mean pH ($P<.05$) by all animals than the two previous periods. Ruminal volatile fatty acid and lactic acid concentration of the treatment diets at the different sampling hours are presented in table 8. As is reflected by the pH findings, the acid concentrations were found to have an hour effect within treatment. The difference in the hour effect was limited to the straight chain fatty acids (acetate, propionate, n-buytyrate, n-valerate) ($P<.001$) and lactic acid ($P<.05$). The hour effect demonstrated the well known fact that as rumen fermentation proceeds, the VFA concentration increases rapidly on high concentrate rations (Davis et al., 1963; Galyean et al., 1979b; Shell et al., 1983). Similarly, lactate also increases rapidly after ingestion of feedstuffs. A difference was not found for the ration x hour effect between the treatments.

pH Treatment Means by Hours

Ration	Hour 0***	2***	4***	8***	12***
Barley	6.774	6.234	6.185	6.537	6.979
Corn	6.743	6.084	6.194	6.611	6.937
Wheat	6.660	5.925	5.744	6.173	6.713

***Hour difference are significant by (P<.001)

pH Means by Diet

Diet	Mean pH
Barley	6.54
Corn	5.51
Wheat	6.24*

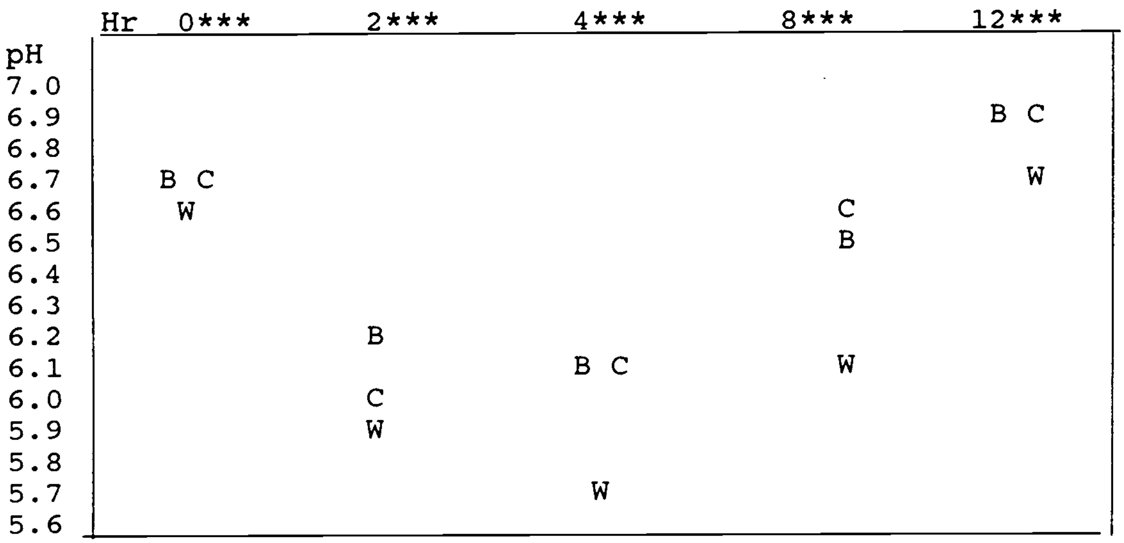
*Wheat Different from Barley and Corn by (P<.05)

pH Means by Period

Diet	Mean pH
Period 1	6.68
Period 2	6.56
Period 3	6.07*

*Period 3 different from Period 2 and Period 1 by (P<.05)

Table 7. Means of rumen pH by hour, ration, and period.



***Hours (P<.001)

Figure 4. Means of rumen pH for the treatment diets at the different sampling hours.

Barley

Hr	Ace***	Pro***	Isop	N-but***	2-meth	Isov	Lac*	Nval***
0	28.890	10.891	0.611	10.227	0.759	0.639	0.002	1.812
2	39.327	18.179	0.599	14.024	0.774	0.702	0.007	2.555
4	34.553	16.709	0.558	12.411	0.697	0.742	0.001	2.151
8	26.392	11.872	0.599	10.295	0.662	0.655	0.001	1.630
12	21.209	7.443	0.567	7.172	0.556	0.439	0.001	1.164

Corn

Hr	Ace***	Pro***	Isop	N-but***	2-meth	Isov	Lac*	Nval***
0	22.462	11.095	0.568	7.532	1.535	0.666	0.006	0.913
2	31.609	17.656	0.572	10.547	1.645	0.552	0.105	1.195
4	26.717	15.162	0.439	8.474	1.439	0.440	0.088	1.030
8	23.460	13.134	0.451	8.342	1.481	0.463	0.007	0.932
12	18.775	9.491	0.537	6.977	1.375	0.509	0.002	0.844

Wheat

Hr	Ace***	Pro***	Isop	N-but***	2-meth	Isov	Lac*	Nval***
0	23.601	9.017	0.501	9.361	2.038	0.475	0.181	1.252
2	38.235	17.410	0.598	13.548	2.726	10.612	0.058	2.244
4	37.471	16.182	0.603	14.610	2.994	0.676	0.039	2.273
8	27.231	13.099	0.513	10.735	2.398	0.568	0.006	1.832
12	21.176	10.299	0.635	8.378	2.224	0.592	0.011	1.274

***Hour effect (P<.001); *(P<.05)

Table 8. VFA concentrations of the rumen as affected by diet treatments at sampling hours. Concentrations expressed in mg/ml fluid analyzed. Acids analyzed were acetic, propionic, isopropionic, n-butyric, 2-methylbutyric, isovaleric, lactic, and n-valeric.

The least square means and standard errors for the straight chain fatty acids plus lactate, the branched chain fatty acids (isopropionate, isovalerate, 2-methylbutyrate), and the total concentrations of all acids are presented in table 9. Other than the hour effect, no difference was discovered. The total concentration did show a numerical trend towards being different, in that corn was lower in total concentration than either wheat or barley. However, the difference was not significant (P>.10).

The individual acid means for hour and treatment along with the least square means for treatment are shown in the appendix (tables 12-19). It is interesting to note how well the concentration differences in straight chain fatty acids fluctuate over time, versus, how relatively constant remain the branched chain fatty acid concentrations.

Ratios of the major volatile fatty acids (acetic, propionic, n-butyrate) for hour and treatment are listed in table 10. It follows that since there was no difference among these acid concentrations due to treatment that there would be no difference in the ratios. This theory was indeed substantiated. Corn does have some lower acetic to propionic ratios. However, this can be explained by the lower concentrations of acetic acid that were found and not by an increase in propionic acid.

Straight Chain Fatty Acids

Treatment	Least Square Means	SE
Barley	55.784	3.754
Corn	47.312	3.754
Wheat	55.873	3.754

Branched Chain Fatty Acids

Treatment	Least Square Means	SE
Barley	1.914	0.472
Corn	2.534	0.472
Wheat	3.631	0.472

Total Concentration of Acids

Treatment	Least Square Means	SE
Barley	57.698	3.400
Corn	49.846	3.400
Wheat	59.503	3.400

Table 9. Least square means and standard errors of straight, branched, and total concentrations of fatty acids.

Corn

VFA Ratio	Hours 0	2	4	8	12
ace/prop	2.025	1.790	1.762	1.786	1.978
ace/n-but	2.982	2.997	3.153	2.812	2.691
prop/n-but	1.473	1.674	1.789	1.574	1.360

Barley

VFA Ratio	Hours 0	2	4	8	12
ace/prop	2.652	2.163	2.068	2.222	2.849
ace/n-but	2.825	2.804	2.784	2.563	2.957
prop/n-but	1.065	1.296	1.346	1.153	1.038

Wheat

VFA Ratio	Hours 0	2	4	8	12
ace/prop	2.618	2.196	2.316	2.079	2.056
ace/n-but	2.521	2.822	2.565	2.537	2.528
prop/n-but	0.963	1.285	1.108	1.220	1.229

Table 10. Ratios of the major volatile fatty acids. Ratios utilized were acetate to propionate, acetate to n-butyrate, and propionate to n-butyrate and were not found to be significantly different.

DISCUSSION

Experiment 1. The feedlot trial demonstrated that any one of the three grains can be well utilized by feeder cattle under these conditions. The finishing diets were found to be of equal value in terms of the parameters measured. A significant difference was not found for any of these parameters. The average daily gain and feed efficiency were very acceptable for the type of cattle fed in this trial. The ration also contained an ionophore and an antibiotic, both of which tend to improve ADG and F/G. Reddy et al., (1975) also demonstrated that there was no difference in corn or wheat based rations when measuring ADG and F/G, and Combs and Males (1986) reported no difference in ADG when using barley, corn, or wheat in a finishing diet. They did however discover a significant difference in F/G favoring wheat compared to barley ($P<.01$). Corn was found to be less efficiently utilized compared to wheat ($P<.05$). Brethour (1972) also noted this trend of depressed intake by cattle on wheat rations. In an earlier study Oltjen et al. (1966) showed that wheat based rations had a lower ADG than corn based rations, while the F/G was not different.

The current trial used the treatment grains at 70% of the grain portion of the ration. Several studies have indicated that wheat is best utilized when replacing approximately 50% of the grain in the ration (Baker and Baker, 1960; Nichols, 1970; Backus et al., 1980; Martin et al., 1985). This is contradictory and confusing since other researchers have demonstrated that wheat can be used effectively at 100%. The difference in findings may be due most notably to the use of ionophores (Bartley, 1983), and secondarily to buffers (Shaw and Pryor, 1972), and low level antibiotics (Brown et al., 1973). The use of these additives has improved all finishing rations but most particularly wheat based rations. Wheat mixed at 50% with another grain such as corn may have an additive effect. Because of the high ruminal digestibility of wheat and the somewhat lower digestibility of corn, (Waldo, 1973) these grains may work well together in finishing rations. The wheat would tend to produce an abundance of VFAs allowing a greater percentage of corn to bypass ruminal digestion.

The days on feed were not found to be significant in this trial. Previous studies had specified ending dates to compare their data. In this trial a specified ending date was not possible due to economic reasons. Therefore this parameter is difficult to compare to other findings. The smaller end of the cattle in this trial finished as early as 87 days compared to the larger exotic breeds which finished as late as 135 days. This is not unusual and is a trend typically observed in the industry.

Carcass parameters measured displayed no significant differences between treatments. This is also attributed to having a specified ending date. Since all cattle were judged to be finished and the treatment rations were nearly the same in nutrient content, it follows that the carcasses should not display any differences. The only differences should be accounted for by the genetic variations among cattle. Since all pens were stratified by weight, the genetic differences should have been negated. However, previous researchers have shown that the type of grain fed does not seem to affect the carcass parameters measured (Oltjen et al., 1966; Martin et al., 1985; Combs and Males, 1986). Reddy et al (1975) found that corn and wheat produced comparable carcasses while triticale produced a smaller, lower quality carcass ($P<.05$). Backus et al., (1980) using varying levels of corn and wheat discovered that the highest percentage of wheat in the diet produced a carcass lower in yield grade ($P<.05$).

Cattle were visually appraised at feeding time for signs of sickness. The two most likely maladies in this trial, would be acidosis and bloat. Neither problem was encountered during the course of this trial. However, a greater rumen distension was noted for these cattle on the wheat diets as compared to the corn and barley treatments. This was also observed in experiment 2 as the rumen of the wheat fed cattle seemed to contain a greater amount of froth and gas. The reason(s) for this is probably explained by the high rumen fermentability of the wheat in the ration. Rumen distension in experiment 1 would decrease markedly following four hours post feeding. Similarly, in experiment 2 the frothiness and gaseous state of the rumen would markedly decrease four hours post feeding. This coincides with the increase in VFA levels at the sampling periods.

Experiment 2. Many researchers have reported a negative correlation between VFA and pH (Rumsey et al., 1970; Esdale and Satter, 1972; Shaw and Pryor, 1972). Briggs et al (1957) made a comprehensive study of the relationship between pH and VFA in sheep, including partial regression analysis of rumen pH and VFA levels. They concluded that under a wide variety of dietary conditions rumen pH is largely a function of rumen VFA levels. Concentrations of VFA increase and pH decreases after consumption of feedstuffs by ruminants. This pattern depends on the type of diet the animal is consuming, with concentrate rations peaking sooner than roughage rations.

This trial exhibited the same pattern reported by other workers (Oltjen et al., 1966; Shaw and Pryor, 1972; Aimone and Wagner, 1977; Shell et al., 1983), in that, it demonstrated a rise in VFA concentrations and a decrease in pH when sampled over a period of hours. The hour effect was found to be significantly different within treatments

(P<.001), but not between treatments. Therefore the decline in pH and increase in VFA followed by the rise in pH and decline of VFA was the same for all treatments. Rumen pH of the animals on the corn diets reached a low at the 2 hour sample period, compared to barley and wheat which reached a low at the 4 hour sample period. This is somewhat unusual since both barley and wheat are more susceptible to ruminal fermentation than corn (Waldo, 1973). Another puzzling finding is that while corn followed the accepted pattern of increased VFA production causing a decrease in pH, barley and wheat did not. All three treatments exhibited their highest concentrations of acids at the 2 hour period. Therefore, the lowest pH reading should have been at the 2 hour period for all three treatments. The differences in the VFA concentrations are small between these two sampling periods for all treatments. It may be that the higher concentrations in the barley and wheat treatments cause the pH to continue to decline until buffering or absorption can effect an increase.

As shown in table 7 the mean pH of wheat was determined to be different (P<.05) than that of barley or corn. This is consistent with previous research (Oltjen et al., 1966; Gartner and O'Rourke, 1975; Reddy et al., 1975; Toland, 1976). The most implicated reasons for the lower pH is the high digestibility of wheat causing high levels of VFA and lactic acid production. Ahrens (1967) noted that feeding high levels of wheat produced high levels of rumen lactate. In this study lactate was not found in a number of samples and the probability that the concentration found equal zero was significant ($P<.05$). Both barley and wheat had similar concentrations of VFA while corn was numerically lower although not significant ($P>.10$). This could explain the difference between corn and wheat but not between wheat and barley.

Period displayed an unexplained difference in mean pH of all animals. Period three was found to be different from the previous period ($P<.05$). Protocol was not changed nor were treatment rations.

The optimum rumen pH for cattle has been established at approximately 6.6-7.0 (Neil Forsberg, personal communication). Generally as pH is lowered from 7 to 5.5, the relative amount of acetate produced may be sustained or decreased slightly. However, much depends on the type of diet consumed. Since the pH ranged between 5.7 and 6.9 with an average pH of approximately 6.5 there is no reason to expect any detrimental effect due to pH. The feedlot parameters and the carcass parameters measured would substantiate this since they were all very acceptable in terms of industry standards.

The most abundant acid found was acetic followed by propionic, n-butyric, n-valeric, 2-methylbutyric, isolvaleric, isopropionic, and lactic. This is the accepted order of production. A difference was not found between the treatment rations although corn was numerically lower in total concentrat- ions than the other two treatments. If there had been more data, this difference might possible have been significant. Waldo (1973) indicted that approximately 78% of corn is fermented within the rumen but is 99% digestible within the total digestive tract. Steers on the corn diets had equal feedlot and carcass data compared to those on barley and wheat, but there was less VFA production. Therefore it follows that a greater percentage of corn must be digested in the lower intestinal tract to achieve equal production.

The ratios of the main fatty acids were not found to be different. Corn did have numerically lower acetate to propionate ratios but this can be accounted for by the lower acetate concentration. The ratios are misleading for this reason. If they were different, then corn would be the most energetic of the three rations. This was not substantiated by the data. Acetate is mainly used for energy or for lipogenesis while propionate is reserved for gluconeogenesis. Propionate has been judged to have the most energy potential of the VFA (Richardson et al., 1976).

The branched chain fatty acids remained relatively constant which supported the fact that no differences were found in any production parameters. These acids have been reported to enhance microbial growth, N retention, and cellulose digestion (Oltjen et al., 1970; Deetz et al., 1985).

The breakeven analysis for this trial favored barley followed closely by corn with wheat a distant third. The poor showing by wheat was due to a greater total ration cost rather than poor utilization, as is evidenced by the similarities of the production parameters. The analysis was figured on a treatment comparison basis. Therefore, while the differences in incoming weight, finishing weight, days on feed, average daily gain, and feed efficiency, were not found to be statistically different, these average differences did play a major role in the dollar outcome of this analysis (table 11).

Summary

These studies demonstrated that there was no detrimental effects due to feeding wheat under the conditions specified. All the parameters measured indicated that there is no difference in barley, corn, or wheat when used at 70% of the diet, in a Northwest beef finishing ration. This would seem to indicate that a producer can price optimize when making grain purchases for finishing cattle. The most efficient ration can be formulated by taking into account the nutrient composition and cost of the grains that are available.

	Barley (14 hd)	Corn (15 hd)	Wheat (15hd)
Purchase Costs[a]	7989.16	8580.00	8626.80
Feed Costs[b]	2571.17	3014.14	3231.29
NON-FEED COSTS			
Interest on op. exp.[c]	48.92	56.71	59.14
Interest on Purchase[d]	286.18	305.52	301.31
Vet., health, labor[e]	84.00	90.00	90.00
Other expenses[f]	76.25	81.15	79.45
Total costs to fatten	3066.52	3547.52	3761.19
Feed costs/lb gain	0.5605	0.6011	0.6848
Total costs/lb gain	0.6685	0.7075	0.7972
Breakeven selling price[g]	0.6550	0.6658	0.6886

a) [(No. of head) (avg. wt.)/100] $65/cwt
b) B=(18.13) ($141.81/T); C = (19.02) ($158.45/T); W=(17.96) ($179.91/T)
c) feed cost + vet, health, labor + other exp./avg. time over which exp. were incurred (half feeding period)
d) [(65) (avg. cwt) (no. of hd.) (12%)/part of year over which expenses were incurred
e) (6 dollars/hd) (number of head)
f) ($0.05/hd/day)
g) total costs/total wt. sold

Table 11. Breakeven Analysis.

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APPENDIX

APPENDIX I

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Acetic Acid

Treatment

Hours***	Barley	Corn	Wheat	SE
0	28.890	22.462	23.601	
2	39.327	31.069	38.235	
4	34.553	26.717	37.471	
8	26.392	23.460	27.231	
12	21.209	18.775	21.176	
L. S means	30.074	24.605	29.543	1.876

***Hours (P<.001)

Table 12. Acetic acid concentrations at different sampling hours with least square means.

Propionic Acid

Treatment

Hours***	Barley	Corn	Wheat	SE
0	10.891	11.095	9.017	
2	18.179	17.656	17.410	
4	16.709	15.162	16.182	
8	11.872	13.134	13.099	
12	7.443	9.491	10.299	
L. S. Means	13.020	13.307	13.201	2.721

***Hours (P<.001)

Table 13. Propionic acid concentrations at different sampling hours with least square means.

Isopropionic Acid

	Treatment			
Hours	Barley	Corn	Wheat	SE
0	0.611	0.568	0.501	
2	0.599	0.572	0.598	
4	0.558	0.439	0.603	
8	0.599	0.451	0.513	
12	0.576	0.537	0.635	
L.S. Means	0.589	0.513	0.570	0.047

Table 14. Isopropionic acid concentrations at different sampling hours with least square means.

N-butyrtic Acid

	Treatment			
Hours***	Barley	Corn	Wheat	SE
0	10.227	7.532	9.361	
2	14.024	10.547	13.548	
4	12.411	8.474	14.610	
8	10.295	8.342	10.735	
12	7.172	6.977	8.378	
L.S. Means	10.826	8.377	11.326	1.550

***Hours (P<.001)

Table 15. N-Butyric acid concentrations at different sampling hours with least square means.

2-methylbutyric Acid

Hours	Barley	Treatment Corn	Wheat	SE
0	0.759	1.535	2.038	
2	0.774	1.645	2.726	
4	0.697	1.439	2.994	
8	0.662	1.481	2.398	
12	0.556	1.375	2.224	
L.S. Means	0.690	1.495	2.476	0.509

Table 16. 2-methylbutyric acid concentrations at different sampling hours with least square means.

Isovaleric Acid

	Treatment			
Hours	Barley	Corn	Wheat	SE
0	0.639	0.666	0.475	
2	0.702	0.552	0.612	
4	0.742	0.440	0.676	
8	0.655	0.463	0.568	
12	0.439	0.509	0.592	
L.S. Means	0.635	0.526	0.585	0.071

Table 17. Isovaleric acid concentrations at different sampling hours with least square means.

Lactic Acid

	Treatment			
Hours*	Barley	Corn	Wheat	SE
0	0.002	0.006	0.018	
2	0.007	0.105	0.058	
4	0.001	0.088	0.039	
8	0.001	0.007	0.006	
12	0.001	0.002	0.011	
L.S. Means	0.002	0.041	0.026	0.019

*Hours (P<.05)

Table 18. Lactic acid concentrations at different sampling hours with least square means.

N-valeric Acid

	Treatment			
Hours***	Barley	Corn	Wheat	SE
0	1.812	0.913	1.252	
2	2.555	1.195	2.244	
4	2.151	1.030	2.273	
8	1.630	0.932	1.832	
12	1.164	0.844	1.274	
L.S. Means	1.862	0.983	1.775	0.380

*** Hours (P<.001)

Table 19. N-valeric acid concentrations at different sampling times with least square means.