MONTANA STATE UNIVERSITY

Extruded barley fed to early weaned calves
by Walter Timothy Hudyma

A thesis submitted in partial fullfillment of the requirements for the degree of Master of Science in Animal Science
Montana State University
© Copyright by Walter Timothy Hudyma (1989)

Abstract:
The purposes of this study were to investigate the effects of an extruded diet versus a dry ground diet for starting early weaned calves; to investigate an extruded barley diet versus a dry ground barley diet for finishing early weaned steer calves and to investigate carcass characteristics of early weaned calves fed a barley ration compared to calves fed a corn ration.

The starter ration was 55.36% corn, 19.23% oats, 12.31% soybean meal, 6.82% full energy bean and 6.29% mineral premix. Ingredients were mixed and extruded with an InstaPro® extruder (Western States Feeds, Choteau,Mt.) for treatment one. Grains were dry ground and mixed with other ingredients for treatment two.

The finishing phase barley diets were 86.03% barley, 3.95% soybean meal, 3.42% full energy bean, and 6.6% mineral premix. Extrusion and grinding was as above for treatments one and two respectively. Treatment three received 78% corn, 5% dehydrated alfalfa pellets, 12% soybean meal and 5% mineral supplement. This was ground and mixed as above.

Steers were slaughtered the same day. The average weight was 487 kg. The average age was 460 days.

Extrusion decreased the extractable fat by 65% in the starter ration and by 58% in the finishing ration.

In the starter phase the extruded diet had significantly lower daily feed intakes ($p<.05$). Calves fed the extruded diet ate significantly less feed per unit of gain ($p<.10$) . There was no significant difference in average daily gain ($p=.12$).

The finishing phase showed no significant differences in overall daily gain ($p=.28$) , feed to gain ($p=.90$), gain to feed ($p=.86$) , or daily feed intake ($p=.53$) among treatments.

Carcass characteristics showed no significant treatment effect for hot carcass weight ($p=.25$), fat thickness ($p=.63$), yield grade ($p=.86$), ribeye area ($p=.99$) and kidney pelvic heart fat ($p=.84$).

It is concluded that extrusion reduced the extractability of the fat portion of the above diets.

Extrusion of a corn, oat and soybean starting ration improved the efficiency of early weaned steer calves in this trial.

Extrusion or diet had no effect on overall finishing performance or carcass characteristics of early weaned steer calves in this trial.

EXTRUDED BARLEY FED TO EARLY WEANED CALVES

by

Walter Timothy Hudyma

A thesis submitted in partial fullfillment
of the requirements for the degree

of

Master of Science

in

Animal Science

MONTANA STATE UNIVERSITY
Bozeman, Montana

April 1989

N378
H8698

APPROVAL

of a thesis submitted by

Walter Timothy Hudyma

This thesis has been read by each member of the thesis committee and has been found to be satisfactory regarding content, English usage, format, citations, bibliographic style and consistency and is ready for submission to the College of Graduate Studies.

4/21/1989 — Mark K Petersen

Date — Chairperson, Graduate Committee

Approved for the Major Department

4-21-89 — Arthur E. Winter

Date — Head, Major Department

Approved for the College of Graduate Studies

6/6/89 — Henry L Parsons

Date — Graduate Dean

STATEMENT OF PERMISSION TO USE

In presenting this thesis in partial fulfillment of the requirements for a master's degree at Montana State University, I agree that the Library shall make it available to borrowers under rules of the Library. Brief quotations from this thesis are allowable without special permission, provided that accurate acknowledgment of source is made.

Permission for extensive quotation from or reproduction of this thesis may be granted by my major professor, or in his absence, by the Dean of Libraries when, in the opinion of either, the proposed use of the material is for scholarly purposes. Any copying or use of the material in this thesis for financial gain shall not be allowed without my written permission.

Signature Walter T. Hudyma

Date 4/25/89

ACKNOWLEDGMENTS

I would like to give special thanks to my wife Marie and my children who were able to put up with this endeavor. I would also like to thank my parents Edward and Joanne Hudyma who also provided support for myself and my family in more ways than can be mentioned here. I would like to thank my major professor Dr. Mark Petersen for this opportunity to pursue my master's degree. I would like to thank all the staff at the Nutrition Center and the friends that helped me while at the University. This research was made possible by a grant from the Montana Wheat and Barley Commission and the Montana Science and Technology Alliance. Western States Feeds in Choteau, MT. provided the feed ingredients and performed the extrusion.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF TABLES (cont.)

Table Page

LIST OF FIGURES

ABSTRACT

The purposes of this study were to investigate the effects of an extruded diet versus a dry ground diet for starting early weaned calves; to investigate an extruded barley diet versus a dry ground barley diet for finishing early weaned steer calves and to investigate carcass characteristics of early weaned calves fed a barley ration compared to calves fed a corn ration.

The starter ration was 55.36% corn, 19.23% oats, 12.31% soybean meal, 6.82% full energy bean and 6.29% mineral premix. Ingredients were mixed and extruded with an InstaPro® extruder (Western States Feeds, Choteau,Mt.) for treatment one. Grains were dry ground and mixed with other ingredients for treatment two.

The finishing phase barley diets were 86.03% barley, 3.95% soybean meal, 3.42% full energy bean, and 6.6% mineral premix. Extrusion and grinding was as above for treatments one and two respectively. Treatment three received 78% corn, 5% dehydrated alfalfa pellets, 12% soybean meal and 5% mineral supplement. This was ground and mixed as above.

Steers were slaughtered the same day. The average weight was 487 kg. The average age was 460 days.

Extrusion decreased the extractable fat by 65% in the starter ration and by 58% in the finishing ration.

In the starter phase the extruded diet had significantly lower daily feed intakes ($p<.05$). Calves fed the extruded diet ate significantly less feed per unit of gain ($p<.10$). There was no significant difference in average daily gain ($p=.12$).

The finishing phase showed no significant differences in overall daily gain ($p=.28$), feed to gain ($p=.90$), gain to feed ($p=.86$), or daily feed intake ($p=.53$) among treatments.

Carcass characteristics showed no significant treatment effect for hot carcass weight ($p=.25$), fat thickness ($p=.63$), yield grade ($p=.86$), ribeye area ($p=.99$) and kidney pelvic heart fat ($p=.84$).

It is concluded that extrusion reduced the extractability of the fat portion of the above diets.

Extrusion of a corn, oat and soybean starting ration improved the efficiency of early weaned steer calves in this trial.

Extrusion or diet had no effect on overall finishing performance or carcass characteristics of early weaned steer calves in this trial.

INTRODUCTION

In 1985 Montana was the sixth largest producer of barley in the nation contributing over sixty-two million dollars to the state's income (Montana Agricultural Statistics 1986). Further, Montana ranked seventh in the nation for beef cow numbers with cattle and calves contributing over 689 million dollars income to the state. Montana ranks only 21st in the nation for cattle on feed and 29th in the nation for cash receipts from cattle. How can a state that ranks seventh in the nation for the number of beef cows only rank 29th in the nation for income derived from cattle sales? This relationship is due in part to the lack of a strong cattle feeding industry in Montana. Potential income may be lost by not feeding livestock to heavier weights within the state. Since barley is the major feed grain produced, it would have the greatest potential for increased usage if a cattle feeding industry in Montana expanded. Nearly fifty percent of all barley grain in the state is stored on the farm (Mt. Agric. Statistics 1986) allowing convenient access to grain if a feeding industry expanded on farms.

A non-traditonal feeding program that may allow for an alternate use of barley and expand cattle feeding on the farm could be feeding young calves barley diets.

For barley to be efficiently digested by cattle it should be processed. Two popular forms of processing have been dry rolling and steam flaking. Recently the process of extrusion has become increasingly available. Little information is available concerning the use of extruded barley for feeding young calves. Therefore the objectives of this trial were:

1. To determine the effects of an extruded calf starter diet on average daily gain, feed conversion and feed intake.
2. To determine the effects of an extruded barley finishing diet on average daily gain, feed conversion, feed intake and carcass characteristics.
3. To evaluate average daily gain, feed conversion, feed intake and carcass characteristics of cattle fed a barley finishing diet and a corn finishing diet.

LITERATURE REVIEW

Introduction

Extrusion cooking is a process that was developed as an economic method of gelatinizing cereal starch. The principle of extrusion is based upon the conversion of a solid material to a fluid state by applying moisture and heat then forcing the material through a die (Chiang and Johnson, 1977). This process can form food products of various textures and shapes. The physical character of the extrudate can be varied by the use of different dies, different rates of speed and pressure during processing. The cooking is accomplished by application of heat, either by direct steam injection or indirectly through jackets and by the dissipation of mechanical energy via shearing (Harper, 1981).

Temperatures as high as 200C can be attained during the extrusion cooking process, yet the period the extrudate is subjected to these temperatures is approximately 5 to 10 seconds. For this reason the extrusion process is often referred to as "high temperature/short time" or HTST processing (Harper, 1981). This process may be preferable compared to other cooking methods because of improved nutrient retention, destruction of growth inhibitors (such as trypsin inhibitors in soybeans) and removal of contaminating microorganisms (Bjorck and Asp, 1983).

An extruder is composed of five principal components: a feeding mechanism, a screw and its driving mechanism, a screw sleeve or barrel, a flow restrictor or die and a cutting mechanism (El-Dash, 1981).

A typical chronology for the production of extruded animal feeds includes the mixing of all ingredients, followed by milling into the proper size before being fed into the extruder. The extrudate is then cut to the proper size, dried and cooled (El-Dash, 1981).

The extrusion process is versatile with large production capacities. It can produce a great variety of products and requires less labor per ton of production than any other cooking process. The extruder requires limited amounts of floor space and the products (feed) would be free of salmonella organisms. There is no ecologically hazardous residual material created from the extrusion process.

Extrusion Effects

Attempting to summarize the effects of extrusion becomes difficult due to the use of different extruders and processing conditions that are not well defined. Processing conditions that vary are: mass temperature or barrel temperature, moisture content, feed rate, screw speed, screw compression ratio, die diameter, residence time, pressure and torque (Bjorck and Asp, 1983).

Protein

Mild heat treatment of vegetable or plant proteins usually results in an improvement of protein utilization (Church, 1977; Bjorck and Asp 1983). This response is partly due to the inactivation of protease inhibitors. An example is the destruction of trypsin inhibitors in soybeans. However if too much heat is applied Maillard reactions may take place. This reaction occurs between reducing sugars and free amino groups in proteins. Pentoses are the most reactive, followed by hexoses and disaccharides (Bjorck and Asp, 1983). Lysine is the most reactive protein-bound amino acid; however, arginine, tryptophan, cysteine and histidine may also react with a sugar. The Maillard reaction involves the condensation of sugar residues with amino acids followed by polymerization to form a brown substance of approximately 11% nitrogen. This substance possesses many of the physical properties of lignin (Van Soest, 1982) and reduces protein digestibility.

Starch

There are two major effects of extrusion on starch. First is starch gelatinization which occurs when native starch is suspended in water and gradually heated. The granules swell and imbibe 50% or more of their weight in water (French, 1973). If heating is continued starch will undergo an irreversible gelatinization and the granules lose their crystallinity. Gelatinization during the extrusion of wheat flour was reported by Chiang and Johnson (1977). They indicated that temperature, moisture content, screw speed and interaction between temperature and moisture significantly affected starch gelatinization during extrusion. Starch gelatinization increased with increasing temperature when moisture contents were 24% or 27%. Starch gelatinization also decreased as screw speed increased. Gelatinized starch absorbs water better than dextrinized starch. Water absorption depends on the availability of hydrophilic groups which bind water and also the gel-forming capacity of various macromolecules. In the rumen this may allow enzymes in the liquid fraction to initiate starch digestion with less lag time.

Dextrinization is the reduction in chain length of amylopectin in the starch molecule (enzymatic or mechanical in the case of extrusion) to yield D-glucose, a small amount of maltose and a resistant "core" called a limit dextrin (Lehninger, 1982). Dextrinized starch shows higher enzymatic susceptibility and is more water soluble than gelatinized starch due to decreased size of polymeric chains. Gomez and Aquileral (1983,1984) reported investigations on the extrusion of corn starch in which a model for the degradation of starch was proposed. Depending on the moisture level, heat and shear rate or screw speed there can be varying proportions of gelatinized or dextrinized starches in the extrudate. According to Gomez and Aquileral (1984) the term "gelatinization" should not be used to describe starch that has been extruded at a moisture content below 20%. This starch has been dextrinized. Physicochemical properties of extruded starch similar to those of gelatinized starch are only achieved when the extrusion moisture content is 28% - 29%. This moisture content is slightly higher than what Chiang and Johnson (1977) reported.

Lipids

There are three proposed mechanisms to describe the influence of extrusion on the nutritive value of lipids. Changes in lipids are thought to occur due to oxidation, cis-trans isomerization or hydrogenation. A common reaction to extrusion is a decrease in the extractable fat content of products (Bjorck and Asp, 1983). This response has been documented for wheat and maize, with the average fat recovery in extruded wheat being 40% and in maize only 20%

of the original lipid content. This yield was not increased by using different organic solvents. Mercier (1980) reported that monoglycerides and free fatty acids form complexes with amylose during extrusion cooking. This may explain some of the difficulty in extraction with organic solvents. Another possible explanation for decreased fat content of extruded products may be due to thermal degradation or steam distillation. Nielson (1976) reported that the HTST process should not cause thermal destruction of lipids. More recently Shin and Gray (1983) measured deterioration of extruded and raw barley flour quality during storage due to lipid oxidation. They found that extruded barley flour exhibited a higher oxidation status initially, probably due to temperature related oxidation during the extrusion process. However, during storage extruded barley flour had a decreased rate of oxidation compared to raw barley flour. There was also a lower unsaturated to saturated lipid ratio in the extruded barley flour samples. Since almost all lipid oxidation occurs with unsaturated fatty acids this ratio suggests a slower rate of lipid oxidation in the rate of lipid oxidation.

Barley

One of the most common uses of barley is for animal feeds. Barley is most important as an energy source, since it is rich in starch (Newman and McGuire, 1985). The kernal is covered by an outer husk consisting of the palea and lemma, but in some lines the husk separates from the kernel resulting in a naked kernel (Briggs, 1978). Below the husk is first the pericarp, then the aleurone layer, the starchy endosperm and the embryo (Briggs, 1978).

Starch

French (1973) states there are various pathways for the elongation of polysaccharide chains into starch. Starch granules fall into two major types due to their X-ray diffraction patterns. Cereal starches such as corn, wheat and rice produce an "A-type" diffraction pattern while root and tuber starches produce a "B-type" pattern. The diffraction pattern may also depend on chain length since ordinary corn starch gives an "A" pattern whereas high amylose corn (amylomaize) starch, which has long-chain amylopectin gives a "B" pattern (French, 1973).

Karlsson et. al., (1983), state that variations in the synthesis of starch from glucose could affect the final structure of the starch grain as well as the total yield of carbohydrates from the grain. During the process of grain filling and maturation starch granules vary in size distribution and starch composition. Barley has a bimodal distribution of starch granule size. It is generally accepted that starch granules which increase in size and remain as large granules at maturity are the first granules developed. Small starch granules are developed at a later stage of growth and remain small at maturity. According to Kang et. al. (1985) small granules represent about 90% of the total number of granules but only 10% by weight of granules isolated from mature barley endosperm.

Investigations previous to MacGregor and Morgan (1984) indicated the small and large granules contain similar proportions of amylose and amylopectin but they differed significantly in enzyme susceptibility and gelatinization temperature. MacGregor and Morgan (1984) found that large starch granules from both waxy and non-waxy cultivars of barley had slightly higher contents of amylose than the small granules. They also found no differences in amylopectin structure between the large and small granules.

The findings of Kang et. al. (1985) agree with MacGregor and Morgan (1984). In their investigation of six cultivars of barley (1 waxy and 5 non-waxy) it was found that the large granules of starch of a non-waxy barley cultivar contained more amylose than the small granules of the cultivar. Small granules of a given cultivar had a lower heat of gelatinization than the large granules of the same cultivar. They also reported that the small granules of non-waxy cultivars were digested by Rhizopus amagasakiens glucoamylase about four times more rapidly than large granules of the cultivars.

Beta-glucans

Barley contains a carbohydrate fraction called beta-glucans. These compounds are linear polymers of B-D-glucopyranose (Preece and Mackenzie, 1952) that are linked together with B-1,4 and B-1,3 linkages. About 25 to 30% of the glucosidic linkages are in the 1,3 position with the remainder being in the 1,4 position (Fleming and Kawakami, 1977). These compounds form part of the endosperm and account for 75% of the endosperm cell wall (Forrest and Wainwright, 1977). (Bourne and Pierce, 1970) reported the beta-glucan content in barley ranges from about 1.5 to 8.0% and is influenced by both genetic and environmental factors. Recently two hull-less waxy type barleys were found to contain over 10% beta-glucans (C.W. Newman, personal communication).

Beta-glucans are thought to be responsible for reduced performance of poultry fed barley based diets (Newman and Mcquire, 1985). They may also contribute to reduced performance in swine fed high levels of barley. Beta-linkages are readily attacked by rumen microorganisms (Engstrom and Mathison, 1988). However beta-glucans may exist long enough in the rumen to cause increased viscosity and contribute to bloat.

In a feeding trial using six types of barley selected on the basis of beta-glucan content (3.5 to 4.8%) Engstrom and Mathison (1988), found average daily gain and feed to gain were not influenced by beta-glucan content. They concluded that normal levels of beta-glucans in barley do not affect performance of feedlot steers.

Protein

Barley usually contains more total crude protein than corn. It also normally contains higher levels of lysine, tryptophan, methionine and cystine than corn (Church, 1977). The protein content will vary inversely with the starch component of the grain (Briggs, 1978). Composition and amount of protein are two major factors which influence the nutritional quality of the barley kernel. Salt soluble proteins which are classified as albumins (soluble in water) and globulins (soluble in dilute neutral solutions of salts of acids and bases) account for 15 to 30% of the total grain nitrogen (Shewry et al., 1984). Salt-soluble proteins are considered highly nutritious since they are rich in lysine and threonine. Non-protein components, which include peptides, free amino acids and nitrates are found within the albumins and these compounds make up 10 to 12% of the total seed nitrogen (Newman and McGuire, 1985). These proteins are found in the kernel embryo and aleurone layer. Proteins derived from the endosperm are classified as prolamins (soluble in 70-80% ethanol) and glutelins (soluble in dilute acids or bases). Prolamins, commonly referred to as hordein, are the major storage proteins (Kirkman et al., 1982) and account for 35 to 50% of the total nitrogen in the seed. Usually as the hordein content of the barley kernel is increased there is a resulting decrease in lysine content of the protein of the kernel. Glutelins are mainly bound structural proteins which are associated with the matrix of the cell wall.

Processing Grain

The appearance of whole grain kernels in the feces of animals consuming unprocessed grain diets has indicated the necessity of processing some types of grain. Cereals are processed assuming that gelatinization and reduction of particle size would improve digestion. Barnes and Orskov (1982) state that before 1960 cereal grains fed to ruminants were either rolled, ground or pelleted. During the 1960's new methods were devised such as exploding, roasting, extruding and micronizing. All systems of grain processing involve some degree of starch gelatinization or damage to the starch granules, making them more readily available for enzymatic breakdown and degradation in the rumen. As extrusion has been discussed some of the other methods will be discussed here.

Exploding

The grain is subjected to steam at pressures of about 225 pounds per square inch (392^{o}F to 401^{o}F) inside a closed chamber. The grain is held in the pressure chamber for 15 to 20 seconds, then the pressure is released through an orifice. This results in a rapid expansion of the grain. Only sorghum grain has been treated by this method (Hale and Theurer, 1972). In a feedlot trial conducted by Lofgreen and Dunbar (1970) there was no significant difference in gain or feed required per unit gain in steers receiving exploded or flat flaked steam processed sorghum grain. The rations contained 60% grain.

Roasting

Roasting is a dry heat method of treating grains. The grain goes through a revolving cylinder which lifts the grain through jets of flame. The exit temperature of the grain is about 300°F. There is some expansion of the grain during this process and the moisture of the grain will be decreased about 5% (Hale and Theurer, 1972). Perry et al (1970) showed a 14% improvement in gain and a 9% improvement in feed required per unit of gain when comparing ground roasted corn to ground corn.

Micronizing

This is another method using dry heat. The grain is heated with gas-fired infrared generators. Microwaves with $3x10^8$ to $3x10^{11}$ cycles per second are emitted from the infra red burners. The grain can be popped or simply roasted using this method. This method has generally been used with sorghum grain and work by Schake et al (1970) estimated that the process of micronizing cost less than steam processing and flaking.

Processing Barley

A study conducted by Rust (1984) demonstrated that cattle fed a 90% whole barley diet gained significantly less weight and were less efficient than counterparts fed an 80% dry rolled barley diet. Carcasses from the whole barley diet contained less fat which was evidenced by lower dressing percentages, less kidney, pelvic, heart fat, less fat thickness and lower numerical yield grade values than the rolled barley diet.

Rumen microorganisms are unable to digest whole barley suspended in nylon bags in the rumen (Nordin & Campling, 1976). Morgan and Campling (1978) demonstrated once the husk of barley grain was broken by rolling, steers and cows were able to completely digest the available starch. These findings supported the conclusions of Morrison (1956) that, barley should be processed for all classes of cattle and it was concluded that rolling barley was likely to improve intake of digestible energy by 10 to 30% by cattle of all ages given mixed diets.

The extent to which barley must be processed to achieve maximum utilization by cattle has been suggested in several studies. In two in vitro trials Osman et al. (1970) and Frederick et al. (1973) investigated starch degradation in steam flaked barley. They found that in vitro digestibility of barley starch was improved by applying a combination of moisture, temperature and pressure. Optimum cooking pressure (with flat flaking) appeared to be 4.2 kg/cm^2, (Frederick et al. 1973), while the critical pressure (with a hydraulic press) occurred at 140 kg/cm^2.

In a feeding trial Hale et al. (1966) compared steam processed flaked barley and dry rolled barley in an 85% concentrate ration. They reported increased gains in fattening steers fed the steam processed and flaked but feed required per unit of gain was not affected. This suggests that feed intake was increased without an improvement in grain utilization. Parrot III et al. (1969) reported two digestion trials comparing dry rolled barley, steam processed regular flaked barley and steam processed flat flaked barley. They indicated that steam flake processing may improve the TDN of a lower quality barley over that of a dry rolled processing, however it may not improve the digestibility of a higher quality dry rolled barley. An in vitro study done by Kempton and Hiscox (1983) showed that when barley was subjected to starch degradation by an alpha-amylase after being cracked, pelleted or extruded, accessibility of polysaccharides to enzymatic hydrolysis was increased with the increased severity of the processing method. The cracked barley resulted in the lowest yield of glucose, with the extruded barley yielding the greatest with the pelleted barley being intermediate. Dry matter disappearance from nylon bags suspended in the rumens of sheep were also compared between cracked, pelleted and extruded barley. In this study there was no difference in dry matter disappearance after 24 hours of incubation among the processing treatments of the barley.

In two comparative slaughter feeding trials reported by Garrett (1965), a steam-rolled barley was compared with barley ground through a hammermill. In one trial there was no significant difference in feedlot performance as measured by average daily gain, feed consumption, corrected carcass weight, yield, percent of carcass fat or carcass grade of steers. In a second trial there were no differences in gain, yield and feed consumption. However the animals fed steam rolled grain had significantly heavier fat corrected carcasses and a significantly greater daily energy gain than steers fed grain ground through a hammermill.

MATERIALS AND METHODS

Treatments

The trial was divided into two periods, each period representing different dietary regimes (Figure 1). The first or starting period utilized two processing treatments of the same diet (extruded and dry rolled) . When the starting period was initiated the calves were an average of fifty-one days of age weighing an average of 50kg. Seven calves were allotted to the extruded diet while 13 were allotted to the dry rolled diet. The diets were composed of 74% corn grain and oats, 20% soybean meal and full energy soybean with 6% mineral premix (Table 1).

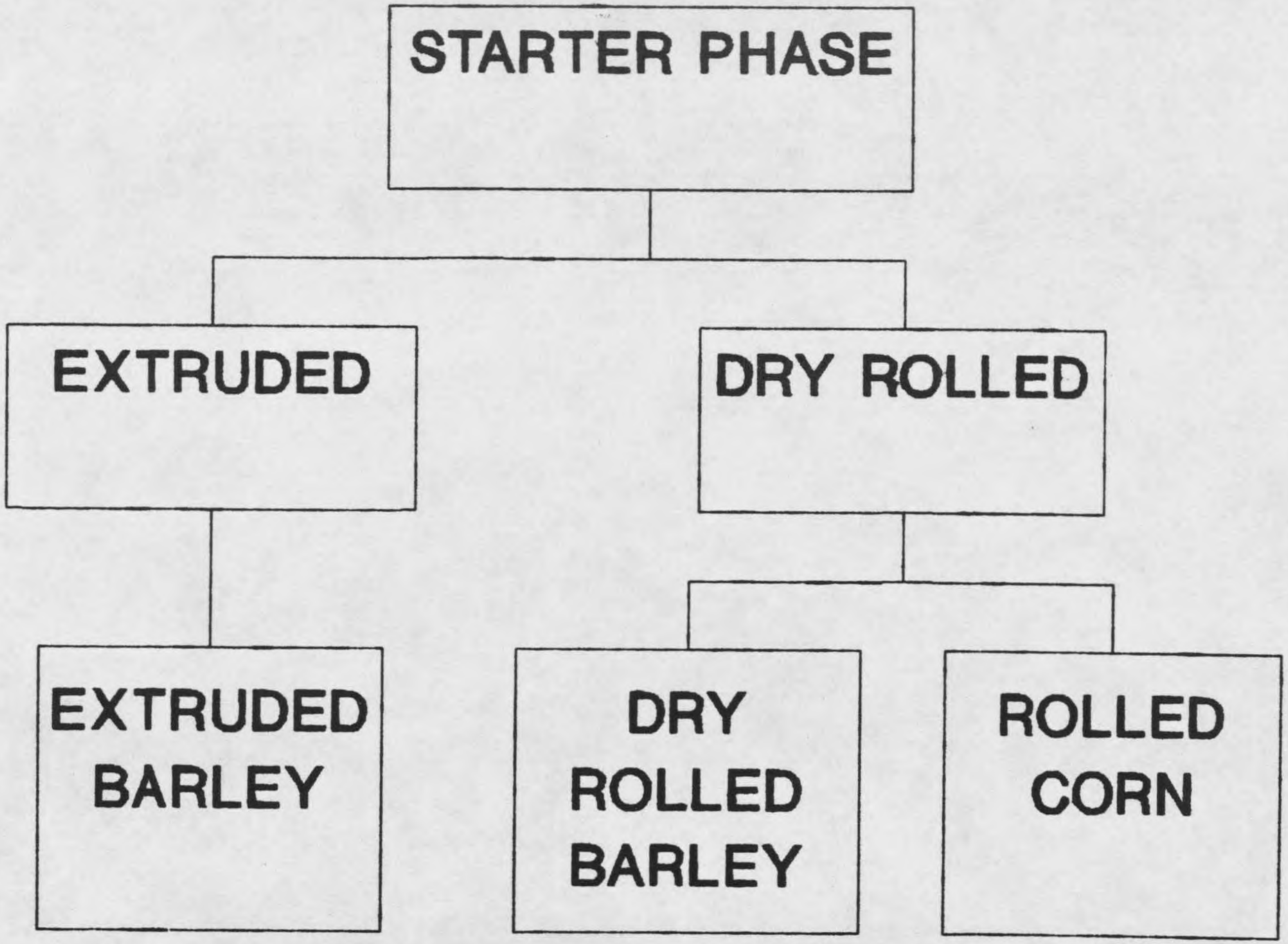
The full energy bean in the dry rolled treatment had also been extruded before being mixed into the diet.

TABLE 1. COMPOSITION OF EXTRUDED AND DRY ROLLED CALF STARTER DIETS, DRY MATTER

Ingredients	%
Corn	55.36
Oats	19.23
Soybean Meal	12.31
Full Energy Bean	6.82
Mineral Premix[a]	6.29

[a] Lean and Free Starter Premix@ , Triple "F" Feeds, Des Moines, Iowa.

Figure 1 STATISTICAL DESIGN



The termination of the starting phase was determined by average daily feed intake of the steers. When the calves consumed an average of three kilograms per day (as fed) of the calf starter diet the finishing phase was initiated. There was a five day adjustment period between the starter phase and finishing phase.

For the second period or the finishing phase, calves from the dry rolled treatment in the starter period were divided into two groups with seven calves being fed dry rolled barley and six calves being fed dry rolled corn. Calves from the extruded treatment in the starter phase were fed an extruded barley based diet in the finishing phase (Tables 2 and 3). The calves were individually fed ad libitum, daily and were weighed every two weeks.

TABLE 2. COMPOSITION OF THE EXTRUDED AND DRY ROLLED BARLEY DIETS OF THE FINISHING PHASE, DRY MATTER.

Ingredient	%
Barley	86.03
Soybean Meal	3.95
Full Energy Bean	3.42
Mineral Premix[a]	6.60

[a] Lean and Free Finisher Premix®, Triple "F" Feeds, Des Moines, Iowa.

TABLE 3. COMPOSITION OF THE CORN DIET OF THE FINISHING PHASE, DRY MATTER.

Ingredient	%
Corn	78
Dehydrated Alfalfa Pellets	5
Soybean Meal	12
Mineral Supplement[a]	5

[a] Calcium Carbonate -40.65%
Dicalcium Phosphate -30.89%
Salt -19.51%
Potassium Chloride - 6.5%
Trace Mineral - 1.63%
Vitamin A&D - .81%

The extruded diet in the finishing phase was mixed before being extruded and contained approximately 20 to 22% moisture. The extruder was a single screw extruder and the die diameter was 5/8" or 1.59cm. Residence time in the barrel was approximately 25 sec. with the barrel temperature reaching 128 to 133°C. The extrudate had a moisture level of about 5 to 6%. The full energy bean was also extruded previous to mixing into the dry rolled diet for treatment two.

Diet samples were taken throughout the trial and were composited for analysis (Table 4). The samples were analyzed for nitrogen, ether extract, dry matter , ash and acid detergent fiber content (AOAC 1980). Analysis for neutral detergent fiber content was performed according to the method of Robertson and Van Soest (1977) as modified by Roth et al. (1982). Calcium content was determined using a modified Kramer-Tisdall method (Clark-Collip, 1925). Phosphorous content was determined using the method described by Fiske and Subbarow (1925). Starch content was determined according to Aman and Hesselman (1984).

TABLE 4. CHEMICAL COMPOSITION OF DIETS FED IN THE STARTER PHASE AND THE FINISHING PHASE.

	Starting phase		Finishing phase		
Analysis	EXT[a]	DR[b]	EXTB[c]	DRB[d]	CORN[e]
Dry matter	92.60	92.03	93.40	92.57	91.66
Crude protein	17.04	17.01	15.02	16.29	14.50
Ether extract	1.12	3.20	.74	1.76	4.30
Ash	7.27	7.80	9.87	9.57	5.34
ADF	1.73	4.97	5.13	4.76	4.88
NDF	9.79	13.52	13.85	12.96	17.81
Calcium	1.01	.95	1.42	.91	1.01
Phosphorous	.55	.60	.69	.58	.40
Starch	53.35	50.41	47.71	51.22	55.20

[a] Extruded
[b] Dry rolled
[c] Extruded barley
[d] Dry rolled barley
[e] Dry rolled corn

Animals

Twenty young holstein bull calves were assigned to dietary treatments according to age (34 days to 68 days), weight (39kg. to 73kg.), and location of rearing (calves were acquired from three locations). The calves were then randomly assigned with the above limitation to one of six pens. Four of the six pens held four calves while two of the pens contained two head each. The calves were fed via Calan@ individual feeding gates.

Upon arrival at the M.S.U. Nutrition Center calves were given an oral dose of a paste containing Streptococcus faecium and an intramuscular injection of vitamin A and D was given. They also received a 10ml intramuscular injection of Liquamiacin@.

Each calf received eight pints of milk replacer a day. Four pints were fed in the A.M. and four pints were fed in the P.M. The commercial milk replacer used was "20-20 INSTANT MILK REPLACER NO.3220@"[1]. The ingredients of the milk replacer were dried whey, dried milk protein, dried milk albumin, dried skimmed milk and animal fat. When analyzed it was found to have a protein content of 20.41%, fat content was 17.82%, calcium was .60% and phosphorous was .56%. A probiotic ("SF PLUS"[2]) was fed at the rate of

---

[1] Triple "F" Feeds, Des Moines, Iowa

[2] Triple "F" Feeds, Des Moines, Iowa

one gram per head per day. This was mixed in with the milk replacer. During this period the calves were allowed free access to a dry starting diet and were trained to use the individual feeding gates. The diet was composed of 50% extruded calf starter and 50% dry rolled calf starter diet which contained the same ingredients. During the training period the gates were adjusted to remain permanently open so the calves could become accustomed to eating from the individual feed bunks. When the calves were consuming approximately 1 kg (as fed) per day of feed through the individual gates, the gates were adjusted to close but not lock shut. This encouraged the calves to open any gate themselves. After they learned to open the gates, the gates were adjusted to lock shut. At this time the calves were fitted with tags to open a specific individual gate, were weaned and provided with the appropriate experimental diet.

During the trial the calves received vaccinations for blackleg, enterotoxemia, infectious bovine rhinotracheitis, bovine viral diarrhea, Hemophilus somnus and parainfluenza-3. The calves also received an injection of Ivermectin on day 34 of the trial when lice were detected on all the calves. The calves were castrated on the same day (day 46) using the elastrater method.

During the starting phase of the trial the pens were supplied with fresh straw bedding every one and a half weeks. During the finishing phase the pens received fresh straw every week. All the pens were cleaned on the same day. The straw used as bedding also served as the only source of roughage available to the calves during the starter ration. The finishing phase treatment three did supply 5% of the diet as dehydrated alfalfa pellets.

Fresh dry feed was presented to the calves daily and feed refusals were also weighed daily. The quantity of feed refusals allowed was based upon observations of the accumulation of fines. The level of fines allowed to accumulate was assumed not to be a factor affecting daily intake.

Daily fecal samples were taken for one week during period three of the finishing phase in order to estimate straw consumption. Estimation of straw consumption was done by estimating total digestibility of the concentrate ration using TDN values according to NRC (1984). Total fecal output was estimated by multiplying concentrate intake by the indigestible portion of the ration (fecal output due to concentrate) divided by one minus the acid detergent fiber (ADF) content of the manure.

Straw intake was estimated by dividing total fecal output by the percent indigestible ADF content of the straw and then dividing again by the ADF content of the straw.

Ex. Intake x (1-%digestibility)=fecal output due to concentrate. Concentrate fecal output/(1-ADF content of manure)=total fecal output.

Total fecal output/indigestible ADF= ADF consumed. ADF consumed/ADF content of straw= straw consumed.

Analysis for ADF was done according to (AOAC, 1980). Analysis for indigestible ADF was done in vitro using the modified Tilley and Terrey procedure according to Harris (1970).

All the calves were weighed every fourteen days. The average daily gain, feed to gain and daily feed intake was calculated for each calf, for each two week period.

The calves were slaughtered after a total of 411 days on feed. The average weight of all the calves was 487kg.

Carcass measurements were recorded the day after slaughter. Measurements taken were hot carcass weight, preliminary yield grade, percent kidney, pelvic, and heart fat, ribeye area, marbling score and quality grade. Final yield grade was determined using the equation:

2.50 + (2.50*adjusted fat thickness,inches) + (0.20*percent kidney, pelvic and heart fat) + (0.0038*hot carcass weight,pounds) - (0.32*area rib eye,square inches), (Romans and Ziegler, 1977).

The statistical analysis for this study was completed using a one way analysis of variance of the General Linear Model procedure of Statistical Analysis Systems (SAS 1987). Dietary treatments in the starter phase, extrusion versus dry ground processing were compared using a significant F value. The data from the starter phase is presented as one period (Table 5). The data from the finishing phase is divided into eight periods and is presented by period (Tables 6 through 13). In the finishing phase the extruded barley diet and the dry rolled barley diet were tested by single degree of freedom contrast. The second comparison was between a dry rolled barley diet and a dry rolled corn diet. Difference between treatments was tested by using single degree of freedom contrast. Each period was tested by the use of a significant F value. The independent factors of the model were location, age, pen, weight and treatment. The dependent factors analyzed were average daily gain, feed to gain, gain to feed, daily intake, and carcass characteristics which were hot carcass weight, dressing percent, yield grade, quality grade, marbling score, fat thickness, ribeye area, kidney pelvic heart fat and abscessed livers. The model used was y=T1 (starter phase) and y=T2 (finishing phase).

RESULTS

The most interesting aspect of the nutrient analysis of the diets (Table 4) is the difference between the extruded diets and the non-extruded diets in ether extract (treatment 1 in both phases contains the same ingredients as in treatment 2). The ether extract concentration for the extruded diet in the starter phase is 35% and the extruded diet in the finishing phase is 42% of the value for its dry ground counterpart.

The following results are based on the consumption of the concentrate diet only. A discussion of straw intake will be presented later. Data is presented as the least square means except when individual animal data is given.

TABLE 5. THE INFLUENCE OF EXTRUSION OR DRY ROLLING OF A CALF STARTER DIET ON AVERAGE DAILY GAIN, FEED TO GAIN, GAIN TO FEED AND AVERAGE DAILY INTAKE.

Item	Extruded	SE[a]	Dry Rolled	SE[a]
Age, d	127.00	12[b]	125.00	11[b]
Final weight, kg	120.44	4.05	130.25	3.25
Ave daily gain, kg	.94	.05	1.06	.04
Feed to gain	2.13	.11	2.42	.09
Gain to feed	.47	.02	.41	.02
Ave daily intake, kg	2.00	.10	2.56	.08

[a] Standard error of the mean
[b] Standard deviation of the mean

There was a significant difference in the average daily intake between treatments ($p<.05$) with the extruded diet consuming less feed (Table 5). There is no difference in average daily gain ($p=.12$) however the extruded diet tends ($p=.09$) to use less feed per pound of gain.

TABLE 6. THE INFLUENCE OF AN EXTRUDED BARLEY DIET (EXTB), DRY ROLLED BARLEY DIET (DRB) AND A ROLLED CORN DIET (CORN) ON AVERAGE DAILY GAIN, FEED TO GAIN, GAIN TO FEED AND AVERAGE DAILY INTAKE. FINISH PERIOD 1=44 DAYS

Item	EXTB	SE[f]	DRB	SE[f]	CORN	SE[f]
Age, d	171	12[e]	172	11[e]	166	12[e]
Weight, kg	178.22	2.24	184.02	2.68	182.50	3.53
ADG[a], kg	1.18	.05	1.30	.06	1.27	.08
F/G[b]	2.85	.19	3.44	.23	3.22	.30
G/F[c]	.35	.02	.29	.02	.32	.03
ADI[d], kg	3.36	.22	4.43	.26	4.09	.34

[a] ADG=Average daily gain
[b] F/G=Feed to gain
[c] G/F=Gain to feed
[d] ADI=Average daily intake
[e] Standard deviation of mean
[f] Standard error of the mean

There was a significant difference ($p<.05$) in the average daily intake between extruded barley (EXTB) and dry rolled barley (DRB), with the extruded diet consuming less feed per day. The extruded diet tends to be more efficient than its dry rolled counterpart. The rolled corn ration (CORN) has a higher average daily gain and average daily intake than the dry rolled barley diet but the difference is not significant.

TABLE 7. THE INFLUENCE OF AN EXTRUDED BARLEY DIET (EXTB), DRY ROLLED BARLEY DIET (DRB) AND A ROLLED CORN DIET (CORN) ON AVERAGE DAILY GAIN, FEED TO GAIN, GAIN TO FEED AND AVERAGE DAILY INTAKE. FINISH PERIOD 2=42 DAYS.

Item	EXTB	SE[f]	DRB	SE[f]	CORN	SE[f]
Age, d	213	12[e]	214	11[e]	208	12[e]
Weight, kg	226.40	3.59	238.64	4.30	236.10	5.66
ADG[a], kg	1.15	.09	1.30	.10	1.28	.14
F/G[b]	3.86	.51	3.29	.61	2.96	.81
G/F[c]	.28	.04	.29	.04	.31	.06
ADI[d], kg	4.29	.49	4.33	.58	4.05	.77

[a] ADG=Average daily gain
[b] F/G=Feed to gain
[c] G/F=Gain to feed
[d] ADI=Average daily intake
[e] Standard deviation of mean
[f] Standard error of the mean

There is no significant difference between the extruded barley treatment and the dry rolled barley treatment or the dry rolled barley treatment and the rolled corn diet in any of the measurements shown for period two. The standard errors for the means have increased compared to period one.

TABLE 8. THE INFLUENCE OF AN EXTRUDED BARLEY DIET (EXTB), DRY ROLLED BARLEY DIET (DRB) AND A ROLLED CORN DIET (CORN) ON AVERAGE DAILY GAIN, FEED TO GAIN, GAIN TO FEED AND AVERAGE DAILY INTAKE. FINISH PERIOD 3=49 DAYS.

Item	EXTB	SE[f]	DRB	SE[f]	CORN	SE[f]
Age, d	262	12[e]	263	11[e]	257	12[e]
Weight, kg	264.68	6.20	272.06	7.44	274.26	9.78
ADG[a], kg	.77	.10	.67	.12	.76	.16
F/G[b]	5.41	1.18	7.12	1.42	6.59	1.86
G/F[c]	.19	.03	.15	.03	.15	.04
ADI[d], kg	4.21	.27	4.51	.32	5.05	.42

[a] ADG=Average daily gain
[b] F/G=Feed to gain
[c] G/F=Gain to feed
[d] ADI=Average daily intake
[e] Standard deviation of mean
[f] Standard error of the mean

A trend exists for the extruded treatment to be the most efficient feed, however the differences among treatments in all the measurements are not significant (Table 8). There is a reduction in overall performance in all three treatments during period three. All treatments show a reduction in average daily gain and gain to feed from period two. For the extruded barley treatment and the dry rolled barley treatment, average daily intake has remained virtually the same as it was in period two. Average daily intake has gone up slightly for the rolled corn diet. All treatments required more feed per unit gain during period three indicating a drop in efficiency.

TABLE 9. THE INFLUENCE OF AN EXTRUDED BARLEY DIET (EXTB), DRY ROLLED BARLEY DIET (DRB) AND A ROLLED CORN DIET (CORN) ON AVERAGE DAILY GAIN, FEED TO GAIN, GAIN TO FEED AND AVERAGE DAILY INTAKE. FINISH PERIOD 4=43 DAYS.

Item	EXTB	SE[f]	DRB	SE[f]	CORN	SE[f]
Age, d	305	12[e]	306	11[e]	300	12[e]
Weight, kg	315.74	4.94	312.07	5.93	323.19	7.80
ADG[a], kg	1.19	.11	.93	.14	1.14	.18
F/G[b]	4.49	.73	5.90	.87	6.30	1.15
G/F[c]	.22	.04	.20	.04	.17	.06
ADI[d], kg	5.42	.49	5.13	.59	6.87	.77

[a] ADG=Average daily gain
[b] F/G=Feed to gain
[c] G/F=Gain to feed
[d] ADI=Average daily intake
[e] Standard deviation of mean
[f] Standard error of the mean

The comparison between the extruded barley treatment and the dry rolled barley shows that there were no differences between the rations (Table 9). During period four the calves fed the dry rolled ration tended (p=.09) to have a lower average daily feed intake than the calves fed the rolled corn based diet.

TABLE 10. THE INFLUENCE OF AN EXTRUDED BARLEY DIET (EXTB), DRY ROLLED BARLEY DIET (DRB) AND A ROLLED CORN DIET (CORN) ON AVERAGE DAILY GAIN, FEED TO GAIN, GAIN TO FEED AND AVERAGE DAILY INTAKE. FINISH PERIOD 5=42 DAYS.

Item	EXTB	SE[f]	DRB	SE[f]	CORN	SE[f]
Age, d	347	12[e]	348	11[e]	342	12[e]
Weight, kg	388.71	6.47	361.76	7.76	394.68	10.20
ADG[a], kg	1.26	.06	1.18	.07	1.70	.09
F/G[b]	6.10	.53	4.84	.64	3.97	.84
G/F[c]	.17	.02	.22	.03	.24	.04
ADI[d], kg	7.37	.65	5.60	.78	7.62	1.03

[a] ADG=Average daily gain
[b] F/G=Feed to gain
[c] G/F=Gain to feed
[d] ADI=Average daily intake
[e] Standard deviation of mean
[f] Standard error of the mean

The dry rolled barley diet performed similarly to the extruded barley during period five (Table 10). The corn treatment has the highest average daily gain and this is significantly ($p<.05$) higher than the dry rolled barley ration.

TABLE 11. THE INFLUENCE OF AN EXTRUDED BARLEY DIET (EXTB), DRY ROLLED BARLEY DIET (DRB) AND A ROLLED CORN DIET (CORN) ON AVERAGE DAILY GAIN, FEED TO GAIN, GAIN TO FEED AND AVERAGE DAILY INTAKE. FINISH PERIOD 6=42 DAYS.

Item	EXTB	SE[f]	DRB	SE[f]	CORN	SE[f]
Age, d	389	12[e]	390	11[e]	384	12[e]
Weight, kg	402.50	11.47	396.91	14.01	434.86	18.14
ADG[a], kg	.78	.15	.82	.18	.94	.24
F/G[b]	10.15	1.98	8.96	2.42	11.50	3.13
G/F[c]	.11	.05	.18	.06	.13	.08
ADI[d], kg	7.13	.87	5.15	1.06	7.89	1.37

[a] ADG=Average daily gain
[b] F/G=Feed to gain
[c] G/F=Gain to feed
[d] ADI=Average daily intake
[e] Standard deviation of mean
[f] Standard error of the mean

Overall performance declined during period six compared to previous periods (Table 11). There are no significant differences among the treatments in any of the measurements. The dry rolled barley treatment is the most efficient in period six. The standard errors during this period have increased indicating a wider variation in animal performance.

TABLE 12. THE INFLUENCE OF AN EXTRUDED BARLEY DIET (EXTB), DRY ROLLED BARLEY DIET (DRB) AND A ROLLED CORN DIET (CORN) ON AVERAGE DAILY GAIN, FEED TO GAIN, GAIN TO FEED AND AVERAGE DAILY INTAKE. FINISH PERIOD 7=42 DAYS.

Item	EXTB	SE[f]	DRB	SE[f]	CORN	SE[f]
Age, d	431	12[e]	432	11[e]	426	12[e]
Weight, kg	439.60	13.17	429.71	15.79	475.46	20.76
ADG[a], kg	.91	.09	.82	.11	1.01	.14
F/G[b]	61.79	19.99	19.07	23.97	52.28	31.52
G/F[c]	.12	.02	.11	.02	.14	.03
ADI[d], kg	7.31	1.07	6.28	1.29	8.02	1.70

[a] ADG=Average daily gain
[b] F/G=Feed to gain
[c] G/F=Gain to feed
[d] ADI=Average daily intake
[e] Standard deviation of mean
[f] Standard error of the mean

For period seven the extruded barley diet has a higher rate of gain than the dry rolled barley diet (Table 12). The feed to gain values for the extruded barley diet and the rolled corn diet have been distorted by the performance of one animal in each of the groups.

TABLE 13. THE INFLUENCE OF AN EXTRUDED BARLEY DIET (EXTB), DRY ROLLED BARLEY DIET (DRB) AND A ROLLED CORN DIET (CORN) ON AVERAGE DAILY GAIN, FEED TO GAIN, GAIN TO FEED AND AVERAGE DAILY INTAKE. FINISH PERIOD 8=30 DAYS.

Item	EXTB	SE[f]	DRB	SE[f]	CORN	SE[f]
Age, d	461	12[e]	462	11[e]	456	12[e]
Weight, kg	482.61	13.36	469.59	16.02	511.01	21.07
ADG[a], kg	1.43	.16	1.33	.20	1.18	.26
F/G[b]	5.85	1.57	5.02	1.89	7.11	2.48
G/F[c]	.21	.10	.28	.11	.16	.14
ADI[d], kg	7.76	1.93	6.12	2.32	7.89	3.05

[a] ADG=Average daily gain
[b] F/G=Feed to gain
[c] G/F=Gain to feed
[d] ADI=Average daily intake
[e] Standard deviation of mean
[f] Standard error of the mean

TABLE 14. THE INFLUENCE OF AN EXTRUDED BARLEY DIET (EXTB), DRY ROLLED BARLEY DIET (DRB) AND A ROLLED CORN DIET (CORN) ON AVERAGE DAILY GAIN, FEED TO GAIN, GAIN TO FEED AND AVERAGE DAILY INTAKE. OVERALL=336 DAYS.

Item	EXTB	SE[f]	DRB	SE[f]	CORN	SE[f]
Age, d	461	12[e]	462	11[e]	456	12[e]
Weight, kg	482.61	13.36	469.59	16.02	511.01	21.07
ADG[a], kg	1.06	.04	1.02	.05	1.15	.06
F/G[b]	5.45	.58	5.09	.69	5.50	.91
G/F[c]	.19	.03	.21	.03	.19	.04
ADI[d], kg	5.75	.58	5.18	.69	6.38	.91

[a] ADG=Average daily gain
[b] F/G=Feed to gain
[c] G/F=Gain to feed
[d] ADI=Average daily intake
[e] Standard deviation of mean
[f] Standard error of the mean

The extruded barley diet, dry rolled barley diet and the rolled corn diet all performed similarly during period eight (Table 13).

There is no significant difference among the treatments for any of the performance measurements taken for the finishing period overall (Table 14). There is a trend for lower daily feed intake and therefore an improved feed conversion for the barley diets.

TABLE 15. THE INFLUENCE OF AN EXTRUDED DIET AND A DRY ROLLED DIET ON AVERAGE DAILY GAIN,FEED TO GAIN, GAIN TO FEED AND AVERAGE DAILY INTAKE.

Item	Extruded	SE[a]	Dry Rolled	SE[a]
Age, d	127.00	12[b]	125.00	11[b]
Weight, kg	470.42	16.23	473.48	17.53
Ave. daily gain, kg	1.03	.04	1.03	.04
Feed to gain	4.45	.52	4.51	.56
Gain to feed	.23	.03	.23	.03
Ave. daily intake, kg	4.52	.46	4.66	.49

[a] Standard error of the mean
[b] Standard deviation of the mean

Including the starting and finishing phase in a comparison between the extruded diet and the dry rolled diet there was no significant difference between the extruded diet or dry rolled diet in average daily gain, feed to gain, gain to feed or average daily gain (Table 15).

TABLE 16. THE INFLUENCE OF AN EXTRUDED BARLEY DIET (EXTB), DRY ROLLED BARLEY DIET (DRB) AND A ROLLED CORN DIET (CORN) ON CARCASS CHARACTERISTICS.

Item	EXTB	SE[h]	DRB	SE[h]	CORN	SE[h]
Carc wt kg[a]	269.04	7.41	263.17	8.89	287.52	11.69
Dressing %	55.69	.63	56.06	.75	56.19	.99
Yld grd[b]	2.47	.27	2.37	.33	2.69	.43
Qlty grd[c]	10.37	.33	9.92	.39	10.90	.52
Mblg score[d]	11.37	.33	10.92	.39	11.90	.52
Ft thckn cm[e]	.77	.10	.64	.12	.79	.15
Ribeye cm^2[f]	64.53	2.55	64.47	3.06	65.06	4.02
KPH fat %[g]	.82	.35	1.17	.42	1.13	.55

[a] Hot carcass weight
[b] Yield grade
[c] Quality grade; 13=Choice^{o}, 12=Choice^{-}, 11=Select^{+}, 10=Select^{o}, 9=Select^{-}, 8=Standard^{+}.
[d] Marbling score; 14=Small^{o}, 13=Small^{-}, 12=Slight^{+}, 11=Slight^{o}, 10=Slight^{-}, 9=Trace^{+}.
[e] Fat Thickness
[f] Ribeye area
[g] Kidney pelvic heart fat
[h] Standard error of the mean

There is no significant difference between the extruded barley diet and the dry rolled barley diet in any of the characteristics measured. The dry rolled barley diet and the rolled corn diet also performed similarly. The number of abscessed livers was also recorded and there was one animal with an abscessed liver from the extruded barley diet, one animal had an abscessed liver from the dry rolled barley diet and three animals had abscessed livers from the rolled corn diet.

TABLE 17. ESTIMATION OF STRAW INTAKE AS A PERCENT OF TOTAL DIET FOR AN EXTRUDED BARLEY DIET (EXTB), A DRY ROLLED BARLEY DIET (DRB) AND A ROLLED CORN DIET (CORN).

	Day							Average
Tmt	0	1	2	3	4	5	6	for week
EXTB	50.99	50.28	49.83	50.38	49.39	48.17	50.65	49.94
DRB	47.58	49.26	48.03	48.87	48.87	48.30	48.01	48.44
CORN	40.29	39.90	41.07	40.45	40.22	42.41	43.37	41.10

Table 17 presents the results of estimating the straw intakes for one week during the finishing phase of the trial. The extruded barley diet resulted in relatively more straw consumed as a percent of the total diet with the dry rolled barley diet and the rolled corn diet following.

DISCUSSION

In comparing the analysis of the diets the difference in extractable fat content between the extruded diet and its dry ground counterpart is not unusual. Heryford (1987) found that in extruded barley-soybean mixtures only 24-31% of the calculated values for fat could be recovered. This also corresponds with work done by Delort-Laval and Mercier (1976) in which extrusion cooking significantly reduced the amount of extractable fat in wheat and maize. Only 40-50% of the lipids present in the two materials could be extracted with ethyl ether after extrusion.

According to Mercier (1980) monoglycerides and free fatty acids form complexes with amylose during extrusion cooking. This could cause them to resist extraction with organic solvents.

Biohydrogenation of unsaturated fatty acids, the major fatty acids of feed origin for a ruminant, is an important mechanism for disposing hydrogen electrons from the reducing environment of the rumen (Church, 1988). If these lipid-amylose complexes were not saturated or degraded in the rumen they would be exposed to the environment of the small intestine. Holme et. al. (1983) found that one of these complexes was almost completely digested in studies done with rats. The implications here are whether or not the fat portion of the extruded diet then would escape being altered in the rumen, be digested in the small intestine and then have the potential of altering the lipid profile of the carcass of the ruminant animal. Rule and Beitz (1986) found that feeding a diet containing 14.3% full-fat extruded soybeans (which raised the fat content of the diet to 6%) increased the proportion of polyunsaturated fatty acids of the tissue lipids of cattle. They attributed this result to an increased amount of unsaturated fatty acids being available for absorption by the small intestine.

Performance of the calves among all the treatments is comparable to other trials that have been done using early-weaned dairy steers that were fed high concentrate barley diets. Trimble (1980) found that Friesian steers which had been weaned at 45 days old and were fed high concentrate barley diets had feed to gain ratios of approximately 3:1 from weaning to 135 days old. The calves in this study were weaned at an average age of 42 days and had feed conversions averaging 2.16 for the extruded starter diet and 2.43 for the dry ground diet. The calves' age averaged 126 days at the end of this period.

In the starting phase the extruded diet in this trial appears to have been utilized more efficiently than the dry rolled diet. The daily intake of the calves on the extruded diet was significantly lower ($p<.05$) than the calves eating the dry ground diet. The difference in feed conversions was significant ($p<.09$), with the extruded diet being more efficient. The extruded diet was extruded at a moisture level of approximately 20% to 22%. This would indicate some of the starch had been dextrinized and some had been gelatinized. The starch would absorb water more readily and would also be more susceptible to enzymatic attack in the rumen. This could improve the digestibility of the grain portion of the starting diet.

In the finishing phase of the trial the performance of the calves was acceptable during most of the periods. During period three newly received cattle were brought into the feedyard in close proximity to where these calves were housed. This may have exposed the calves in this study to an infectious disease organism. Although the calves had been vaccinated for a number of diseases many of the calves were treated for sickness during this period. As can be seen by Table 9 performance of all three diets was reduced, so it does not appear to be related to treatment. During period seven the feed to gain values (Table 13) for the extruded diet and the rolled corn diet are unusually high. In observing the individual data (Figure 2) for average daily gain of the extruded diet it can be seen that one animal suffered a depressed rate of gain during this period. The same problem is apparent with the individual data for average daily gain for the rolled corn treatment (Figure 4).

Overall performance in the finishing part of the trial was similar to Trimble (1980). Trimble found that early weaned dairy steer calves fed a high concentrate barley based diet had an average daily gain of 1.2kg and a feed to gain ratio of 5.7:1 during a period from 3 months of age to slaughter. As can be seen from Table 14 the calves in this trial had a similar rate of gain, but the feed conversions in the two barley treatments were better than what is reported by Trimble. There is no significant difference in performance during the finishing phase of the trial between the extruded barley diet and the dry rolled barley diet. It is possible that since barley starch seems to be readily digested in the rumen even under conditions of mild processing that extrusion might not have further increased starch digestibility. The rolled corn diet had a slightly higher rate of gain than the dry ground barley treatment, although the difference is not significant. The calculated metabolizable energy value for the extruded barley diet and the dry ground barley diet was 2.88mcal/kg and was 3.10mcal/kg for the rolled corn diet. This was done according to NRC (1984). Rust (1985) found that rolled barley performed as well as corn.

The management program for these calves was similar to a method that has been used previously in Northern Ireland. It was reviewed by Preston (1963) and again by Trimble (1980). The use of high concentrate barley diets in this type of management program was also reported by Geurin et.al. (1959). Their investigation showed that when barley was processed in a manner which preserved the roughage characteristics of the hull, the barley could be fed without any additional roughage. Preston et.al. (1963) performed a trial to investigate this feeding method. Using a diet of 85% rolled barley and 15% of a supplement which provided additional protein and minerals they were able to raise animals to a slaughter weight of 450 kg in a period of 365 days. From the liveweight range of 100 to 400 kg they had an average daily weight gain of 1260 gms.

A trial using this type of feeding system or using just barley that has been processed to retain its fiber characteristics needs to be applied to a beef cattle breed situation. In making comparisons between a dairy breed such as Holsteins and a beef breed such as Hereford, Garrett (1973) found that the Hereford was more efficient at retaining energy as carcass fat than the later maturing Holstein breed. Southgate et. al. (1988) and Kempster et. al. (1988) found that crossbred steers (beef breed sire x British Friesian dams) were generally more energy efficient than the later maturing dairy breeds such as a Canadian Holstein or a British Freisian. This seems to indicate that using the early weaning management system with a beef breed and feeding high concentrate barley rations could lessen the slaughter age of the beef animal. Fine tuning of the system could prevent the possibility of finishing an animal too soon if such a problem occurred.

Diet treatment did not have a significant effect on any of the carcass measurements taken. There were three animals each from the extruded barley diet and the dry rolled barley diet and two animals from the rolled corn diet that graded choice. Although the average weight among all of the cattle was 487 kg the average weight of all the steers that graded choice was 512 kg. It's possible that the heavier weight could indicate the target weight for marketing dairy calves fed under this type of management scheme. Compared to cattle fed in this study, angus steers fed an 85% dry rolled barley finishing diet by Rust (1985) had a heavier carcass weight, higher dressing percent, more KPH fat, more fat thickness and higher yield grades, however the average live weight at slaughter was 529kg. This would indicate that the cattle went to slaughter with a higher degree of finish than the cattle in this trial. Garrett (1973) indicates that beef breeds may be more efficient at gaining fat than Holsteins. The variation within the measurements taken in this trial is rather large compared to other studies. Holsteins have been selected for milk production and this has resulted in more variation in performance in growth characteristics. For comparison a summary of standard errors for three trials reported by Rust (1983, 1985, 1986) are presented in Table 18.

TABLE 18. SUMMARY OF STANDARD ERRORS, RUST (1984, 1985, 1986).

Item	1984	1985	1986	AVE.
Adg	.03	.01	.04	.03
Feed/gain	.14	.19		.17
Gain/feed			.003	
Ave. daily intk.	.35	.20	.29	.28
Hot carcass wt.	3.82	1.18	4.75	3.25
Dressing percent	.24	.03	.26	.18
Yield grade	.08	.04	.10	.07
Fat thickness	.05	.03	.05	.04
Ribeye area	1.29	.45	1.42	1.05
Kidney pelvic heart fat		.03	.06	.05

Finishing period overall results (Table 14) and carcass characteristics (Table 16) show that the standard errors from this trial are substantially larger than those reported by Rust in several of the measurements taken. This could have allowed differences that actually occurred to be considered not significant. Variability could have been caused by measurement error or an actual wide variability in animal performance. Both feed to gain and gain to feed are reported as suggested by Brink and Lowry (1985). They reported that when animals are individually fed, a low gaining animal may skew the data for feed to gain calculations. The gain to feed data show less variability in some periods in this trial, however in other periods the opposite is true. Periods in which the gain to feed data has a larger coefficent of variation may indicate that feed intake was more variable than gain during that period.

In reporting the abscessed liver data this could indicate why some of the animals had reduced performance during the trial. Brown et. al. (1973) reported that cattle with abscessed livers suffered reduced performance. In the extruded barley diet animal #203 had a severely abscessed liver. This might explain this animal's poor performance during period number six (Figures 2,6,10). In the dry rolled barley diet animal # 122 had a severely abscessed liver, however this animal's performance was consistent through the trial (Figures 3,7,11). In the rolled corn diet animals #90, #501 and #126 all had severely abscessed livers. Animal #501 had erratic performance and animal #126 experienced depressed performance during period 6 (Figures 4,8,12). Animal #90 had a consistent performance throughout the trial.

The first week during period three was used to estimate straw intake as a percent of the diet. Daily fecal samples were taken and indigestible acid detergent fiber content was measured. Acid detergent fiber and indigestible acid detergent fiber content of the rations and the straw were also measured. Straw intake was estimated to be an average of 100.17% of the grain intake or 49.94% of the total diet for the extruded barley diet, 94.14% of the grain diet intake or 48.44% of the total diet for the dry rolled barley diet and 69.95% of the grain diet intake or 41.10% of the total diet for the rolled corn diet. These estimates are biased towards estimating less straw than was actually consumed. Two assumptions are made in these estimates: one, there is no ADF from the concentrate portion of the diet in the fecal output estimated from the concentrate portion of the diet; two, that all the ADF content of the total fecal output estimate is from straw. However the estimates reflect, in relative terms, which treatment consumed more straw as a percent of the concentrate diet (Table 17). In relative terms the extruded barley diet seems to have consumed the most straw as a percent of the diet.

The type of management scheme used in this trial is unique in that the barley fed calves were not allowed access to any other source of roughage besides the straw that was used for bedding. Factors that may have influenced the animal performance were; no ionophores such as monensin or lasalocid fed, no antibiotic such as tylosin was used and no animals were implanted. Since this system does not include a high roughage diet and uses barley as the major grain it could increase barley utilization. A calf that had been grown on a high roughage ration and then entered into a 120 day finishing diet containing 86% barley might consume 1.13 tons of barley. A calf grown and finished using the management system in this trial could consume approximately 2 tons of barley, thereby using an additional .8 ton of barley.

The feed to gain including starting and finishing phase is 4.77 for the extruded diet and 4.84 for the dry ground diet (Table 15). These are much better conversion rates than industry standards. However if estimated straw intake is included the figures become approximately 9.18 for the extruded diet and 8.87 for the dry ground diet. The relative improvement of the dry rolled ration reflects lower estimated straw consumption.

TABLE 19. PRICES USED IN COST PER POUND OF GAIN

Item	Price/unit
Corn	4.50/100lbs.
Oats	6.00/100lbs.
Barley	3.50/100lbs.
Dehydrated alfalfa pellets	4.00/100lbs.
Soybean meal	11.30/100lbs.
Full energy bean	12.80/100lbs.
Lean and Free mineral[a]	30.00/100lbs.
Calcium carbonate	3.15/100lbs.
Dicalcium phosphate	16.05/100lbs.
Salt	3.58/100lbs.
Potassium chloride	11.40/100lbs.
Trace mineral[b]	34.75/100lbs.
Vitamin A[c]	105.55/100lbs.
Processing	1.50/100lbs.

a Lean and Free Premix® , Triple "F" Feeds, Des Moines, Iowa.
b WF Ruminant trace mineral, Westfeeds, Billings, MT.
c Vitamin A-30, Westfeeds, Billings, MT.

Table 19 indicates prices used in calculating the cost per pound of gain for the concentrate diets fed in this trial. The cost for the concentrate diet was 22.70 cents and 22.60 cents per pound of gain for the extruded starting diet and the dry ground starting diet respectively. Feed costs for the concentrate diets in the finishing phase were 45 cents per pound of gain for the extruded barley diet, 42 cents for the dry rolled barley diet and 41.20 cents per pound of gain for the rolled corn diet.

It should also be noted that Holstein carcasses will receive a discount from the packer if marketed through the normal system. The day the steers in this trial were slaughtered, choice holstein carcasses weighing from 600 to 900 pounds were worth 3 to 4 dollars per hundredweight less than choice beef steer carcasses.

Fig.2 Ave. Daily Gain (kg.) by Treatment

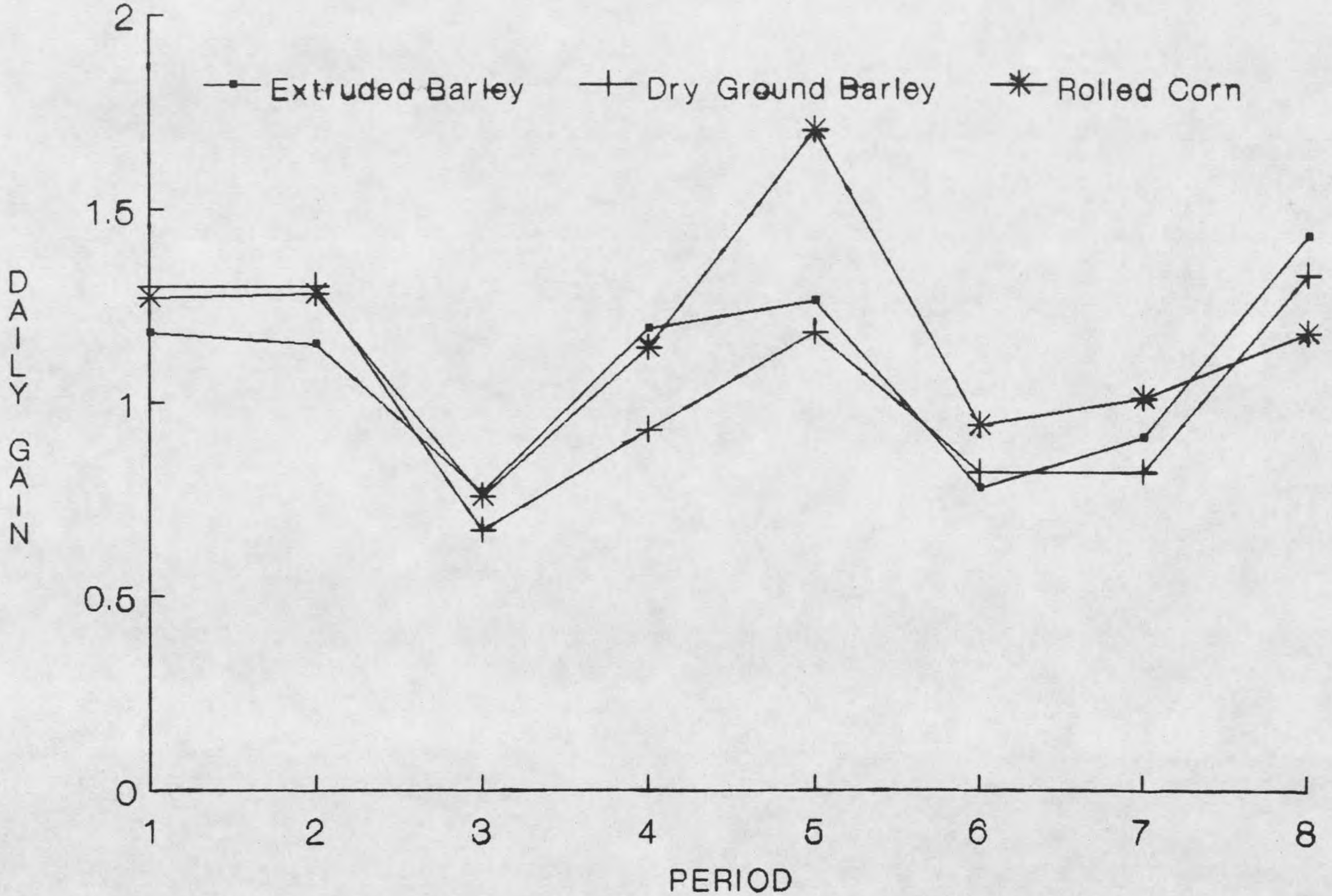


Fig.3 Ave. Daily Gain (kg.) by Animal
Extruded Barley Diet

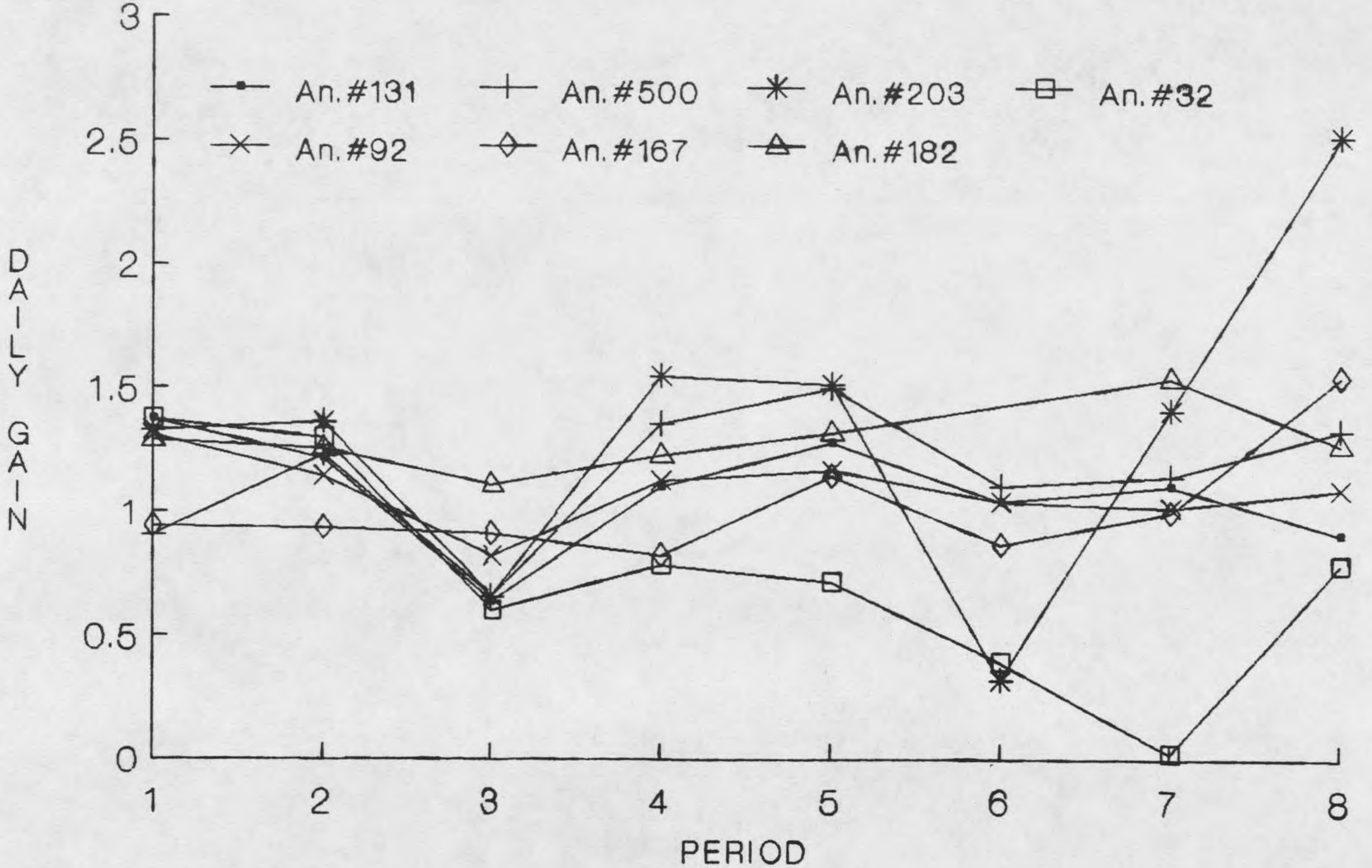


Fig. 4 Ave. Daily Gain (kg.) by Animal
Dry Rolled Barley Diet

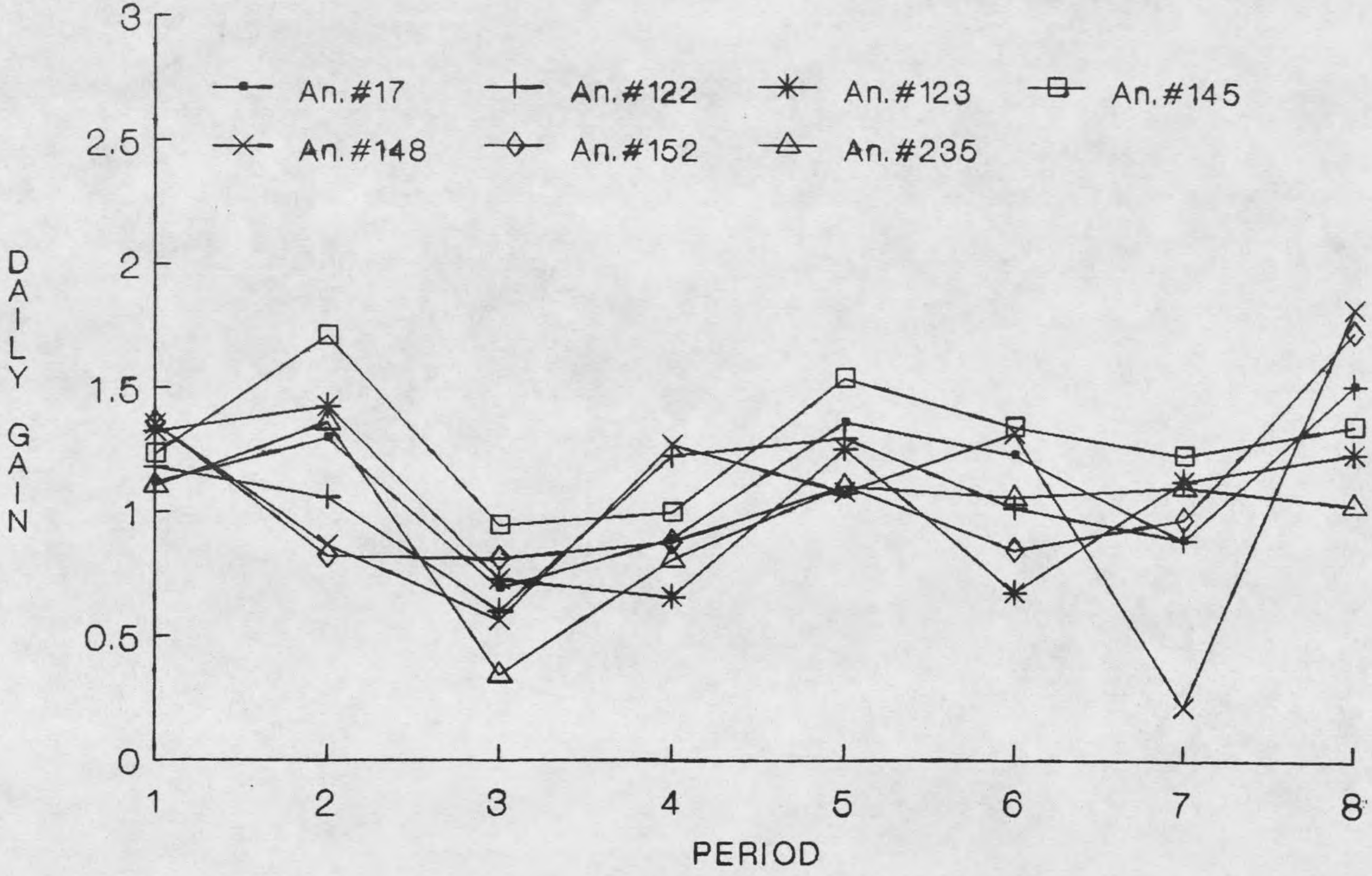


Fig. 5 Ave. Daily Gain (kg.) by Animal
Rolled Corn Diet

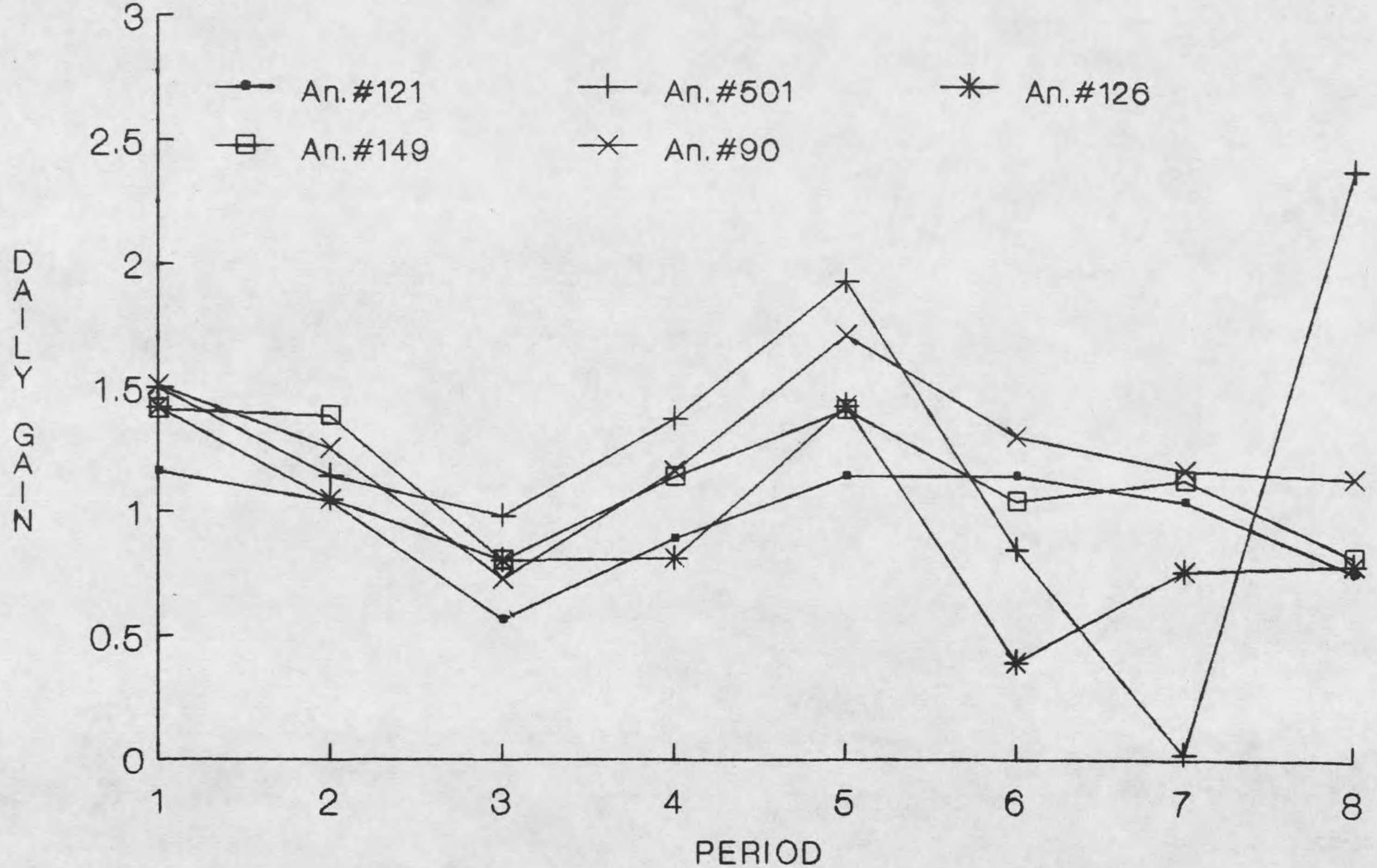


Fig. 6 Average Daily Feed Intake (kg.) by Treatment

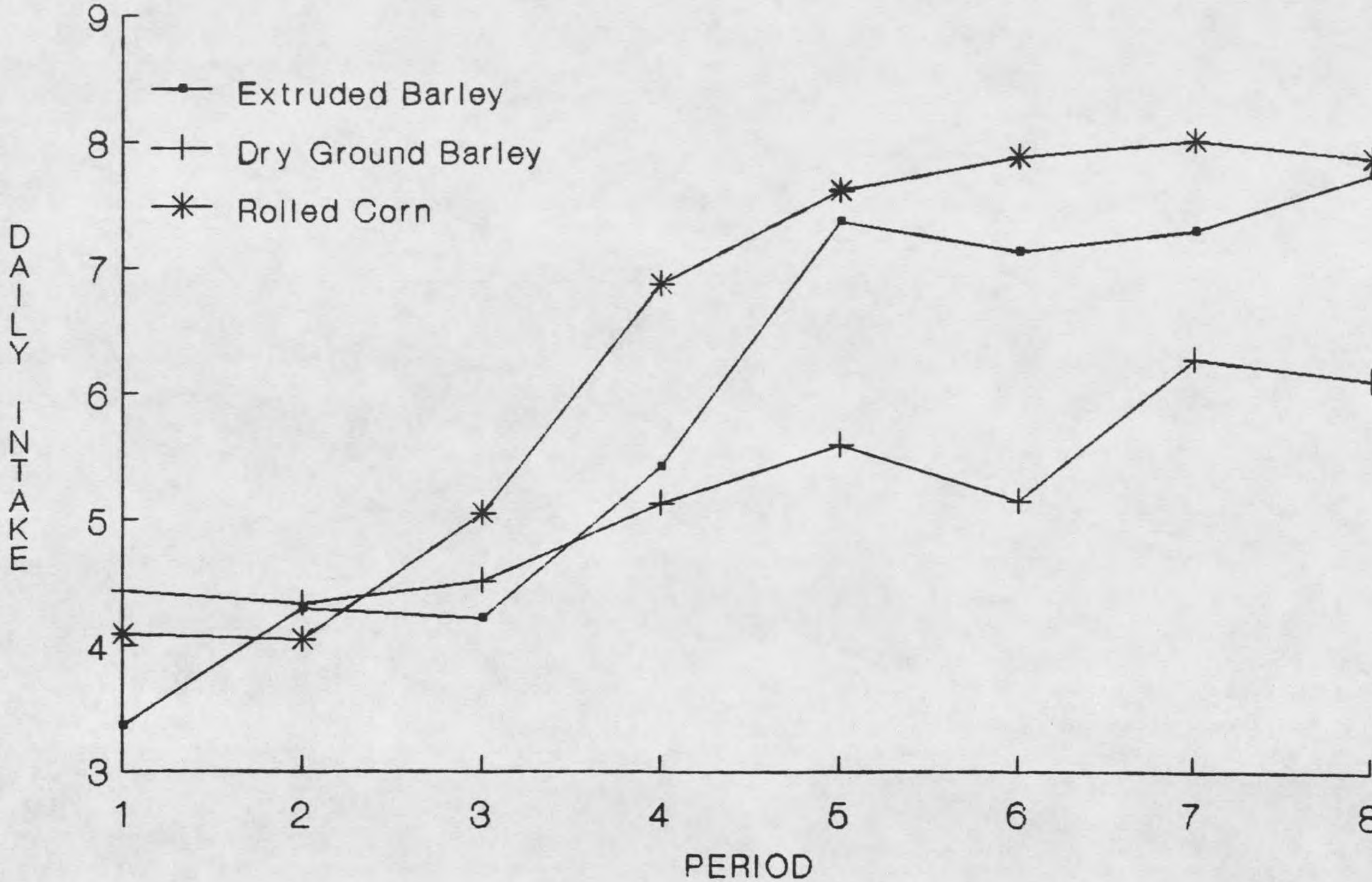


Fig. 7 Ave. Daily Feed Intake (kg.) by Animal, Extruded Barley Diet

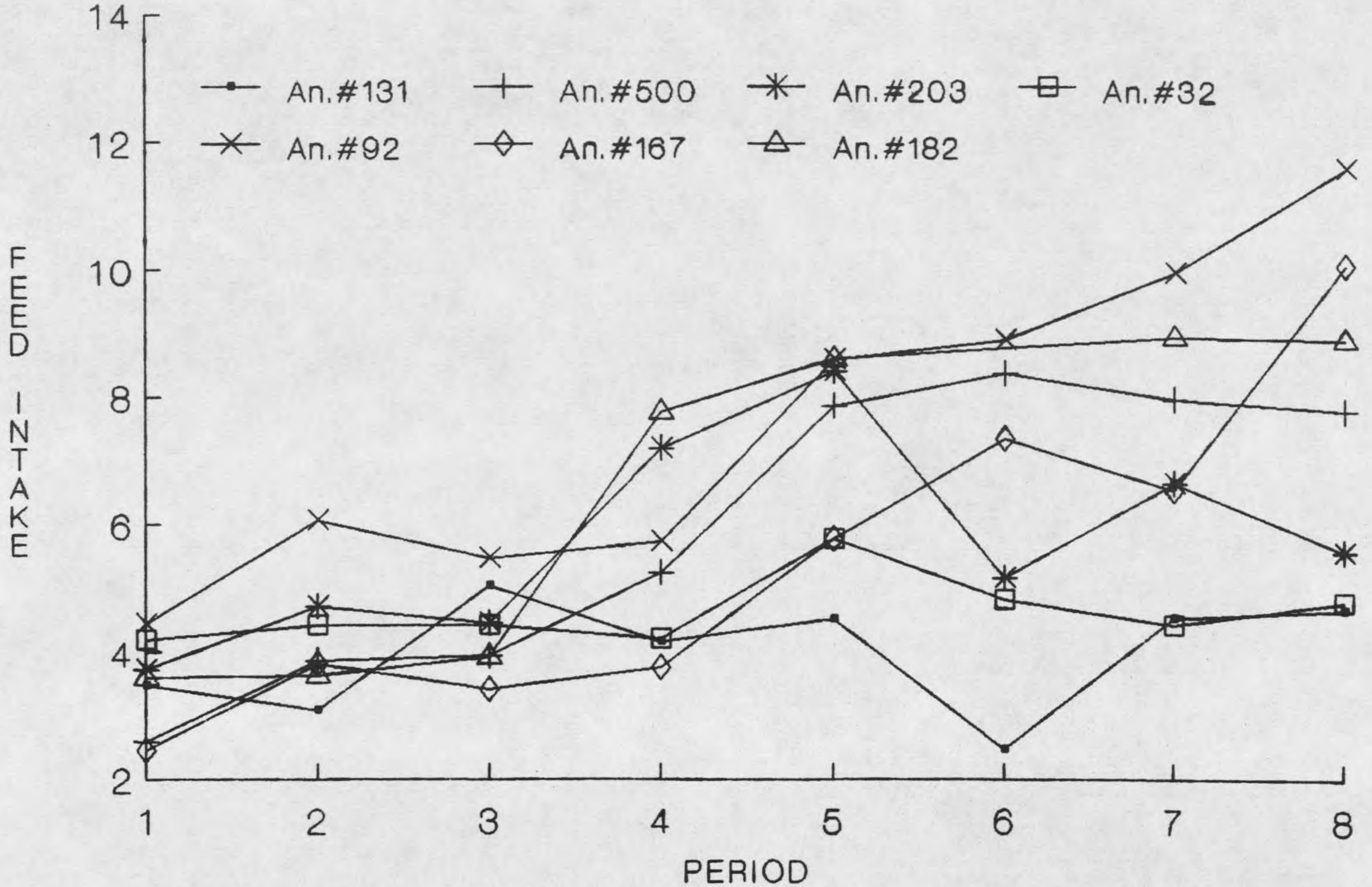


Fig. 8 Ave. Daily Feed Intake (kg.) by Animal, Dry Rolled Barley Diet

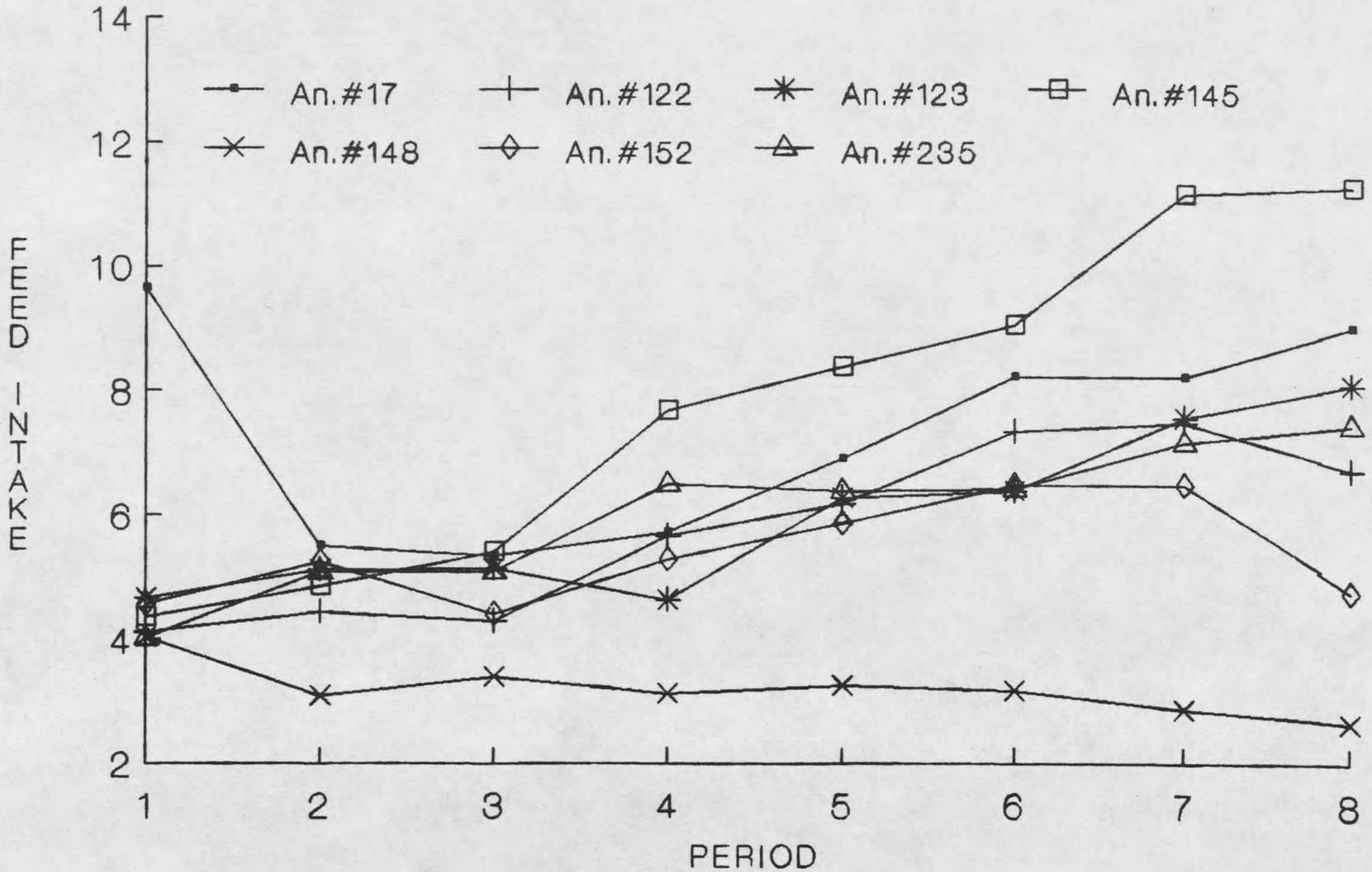


Fig. 9 Ave. Daily Feed Intake (kg.) by Animal, Rolled Corn diet

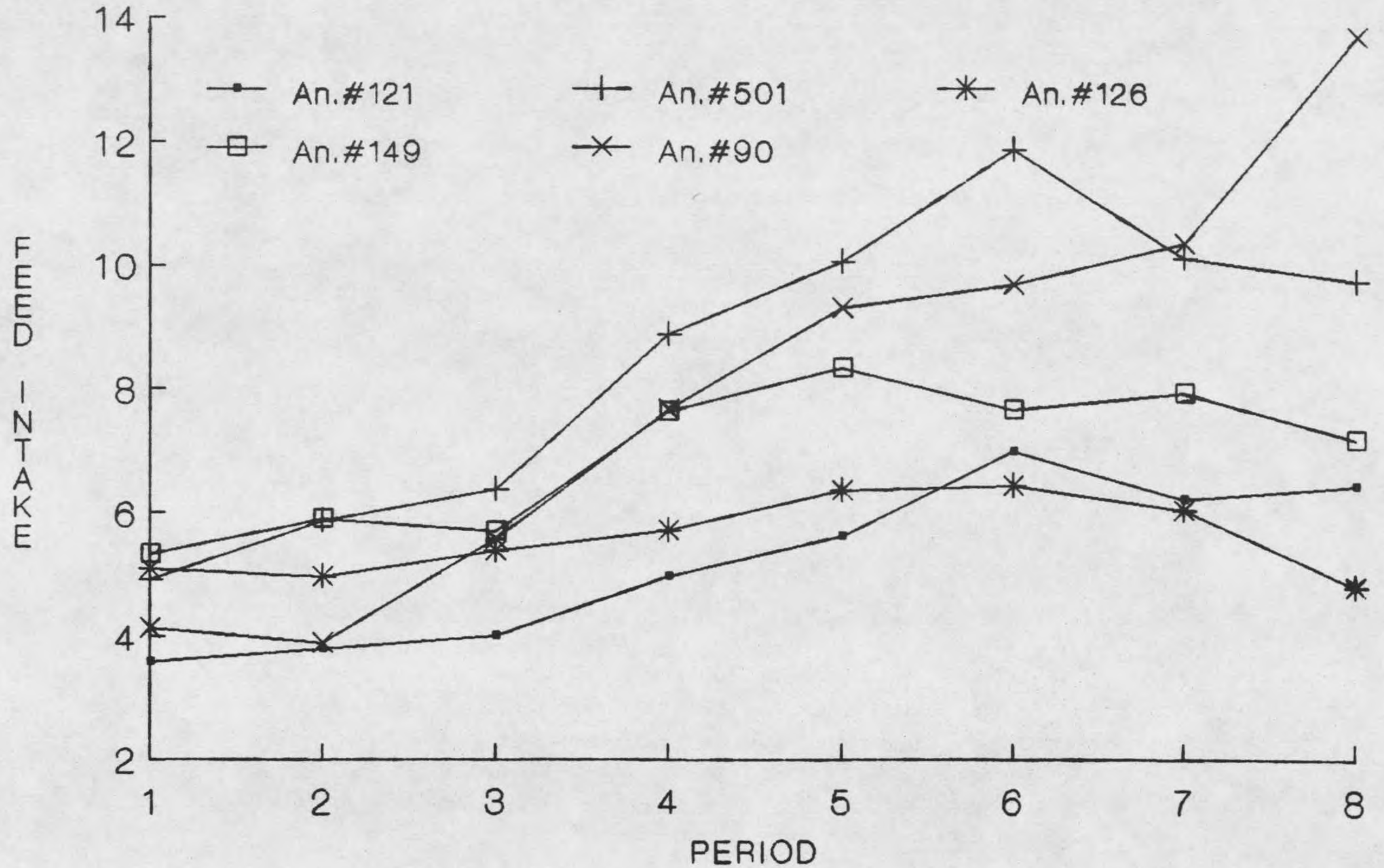


Fig. 10 Gain/Feed by Treatment

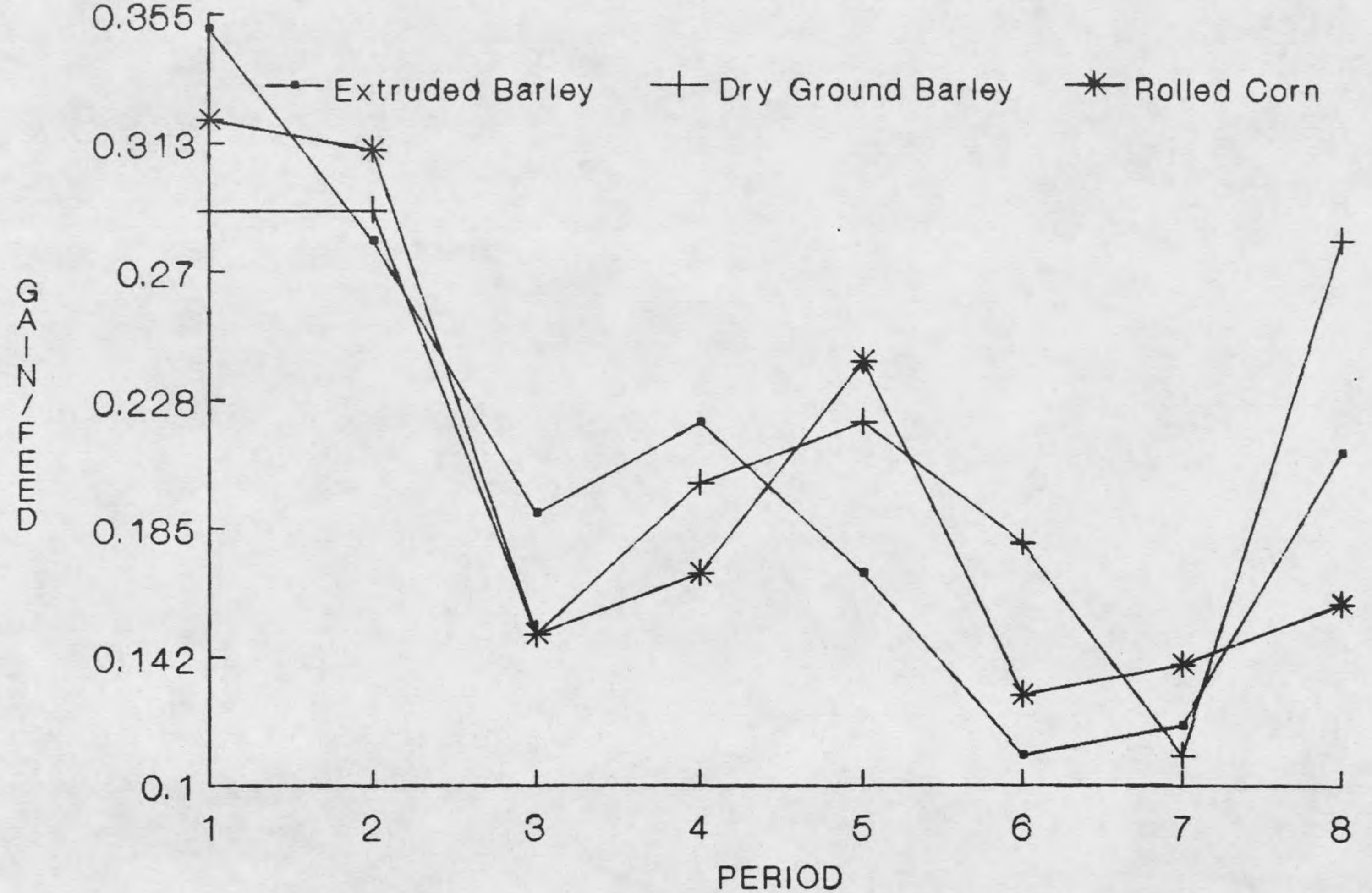


Fig.11 Gain/Feed by Animal
Extruded Barley Diet

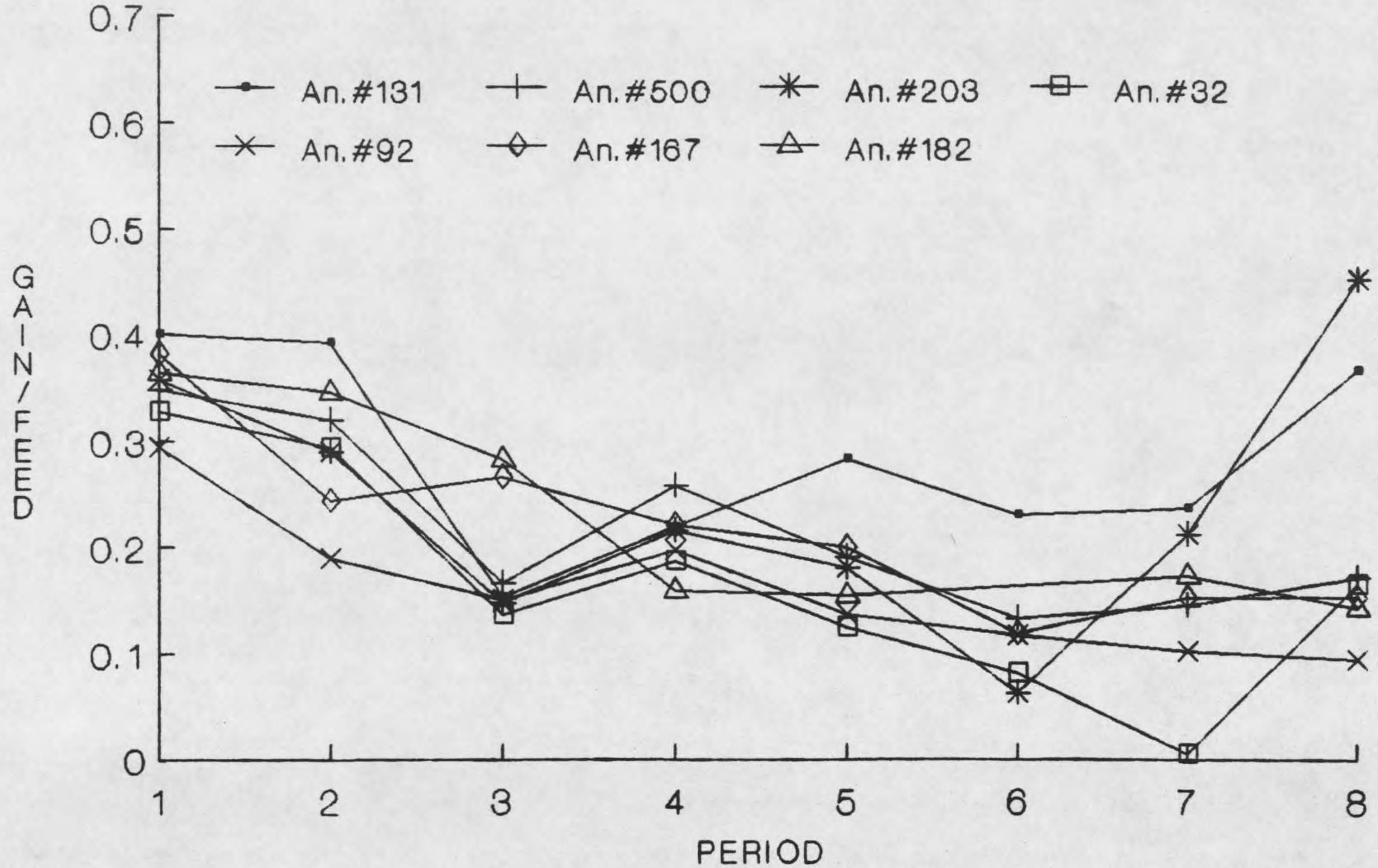


**Fig. 12 Gain/Feed By Animal,
Dry Rolled Barley Diet**

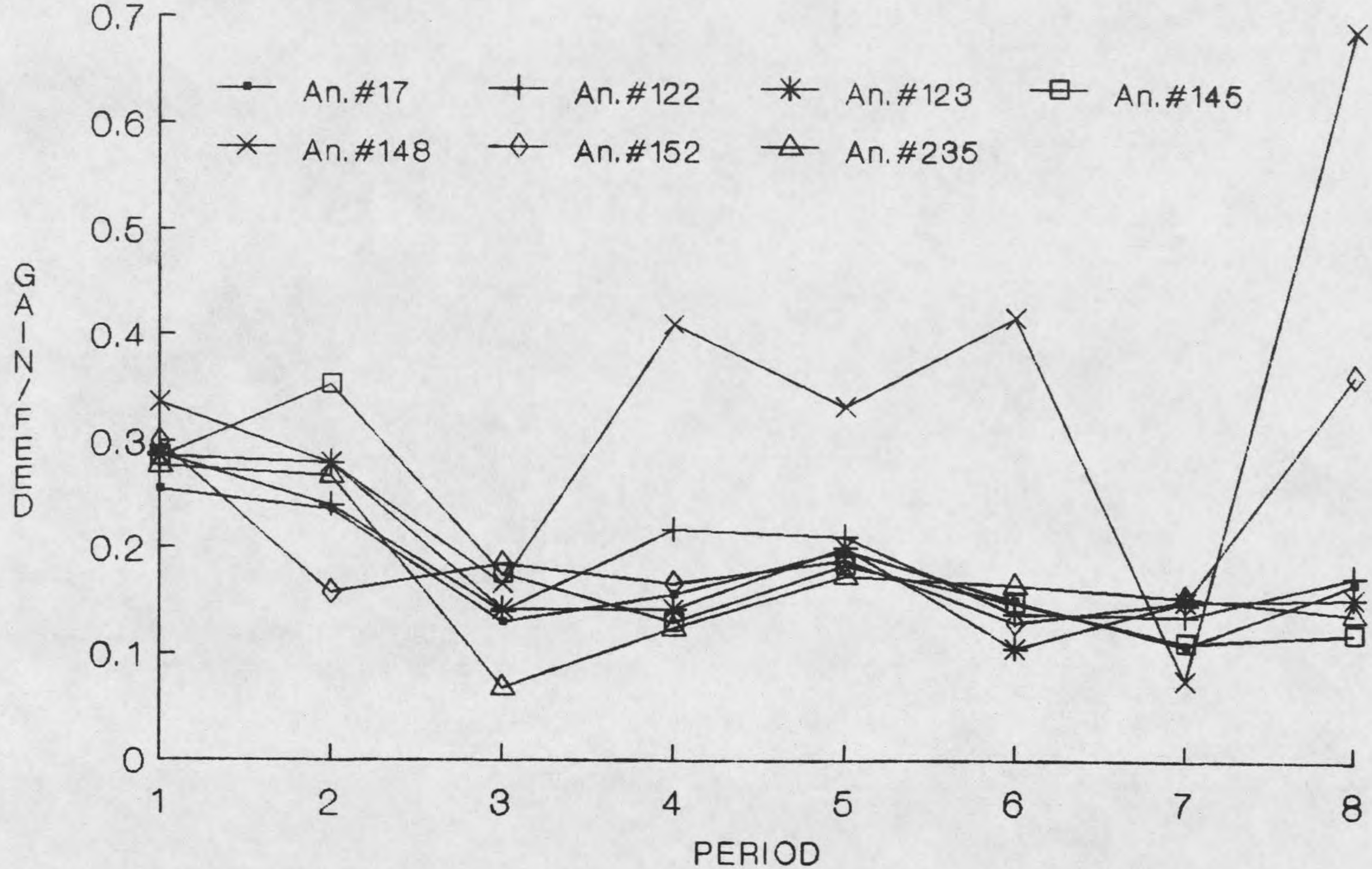


Fig. 13 Gain/Feed by Animal, Rolled Corn diet

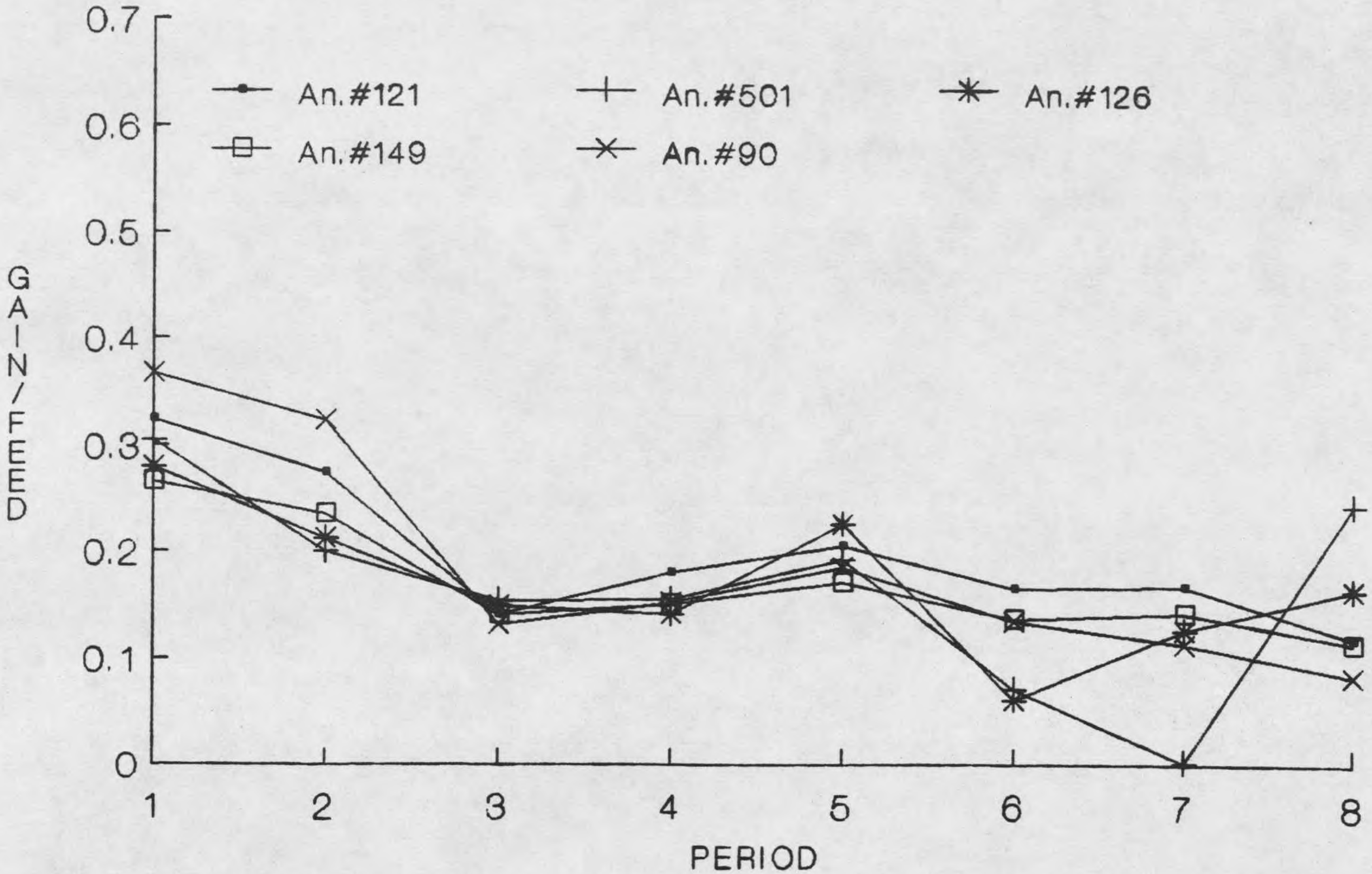
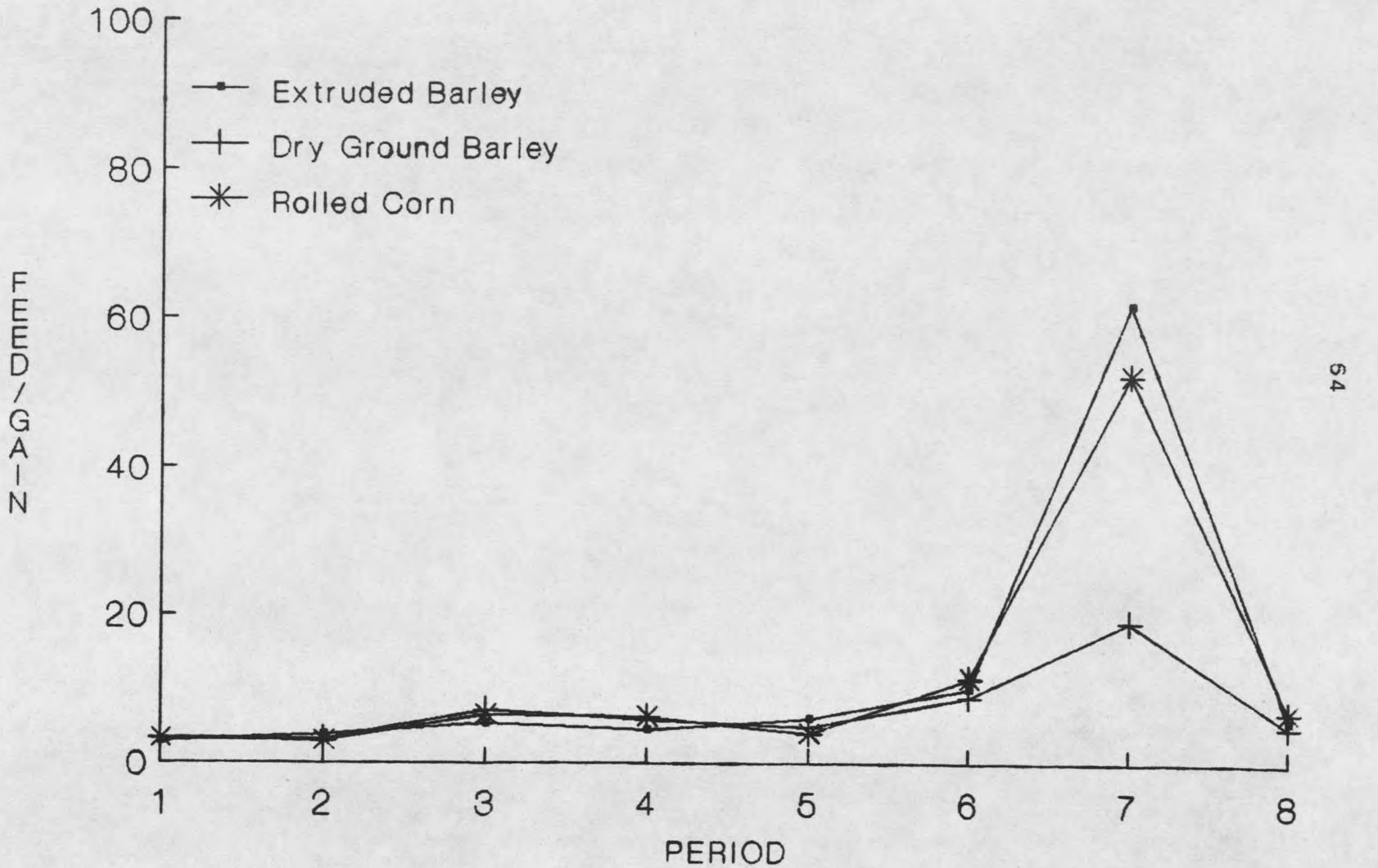


Fig.14 Feed/Gain by Treatment



CONCLUSION

The results of this trial indicate that the extrusion process has an effect on the extractability of the fat portion of a concentrate feed made up of either corn and oats-soybean or barley-soybean mixtures. Further investigations should be performed as to the ability of extruded polyunsaturated fats to escape hydrogenation in the rumen and thereby change the ratio of unsaturated fatty acids in the tissues of ruminant animals.

Extrusion processing of a corn, oats and soybean based calf starting ration may improve the efficiency of such a ration as compared to dry ground processing when fed to early-weaned dairy calves with unrestricted straw intake.

Extrusion processing of a barley-soybean based ration did not significantly improve the efficiency of such a diet when fed to early weaned calves whose only roughage source was clean barley straw. There was no treatment effect on average daily gain, gain to feed, daily feed intake or feed to gain during the finishing phase of this trial. There was also no significant treatment effect on the carcass characteristics of dairy steers that had been finished on extruded or dry ground barley-based diets.

In this trial the dry ground barley diet performed as well as a rolled corn based diet. There was no significant difference in average daily gain, gain to feed, daily feed intake and feed to gain. There was no significant difference in carcass characteristics among the steers fed either the dry ground barley diet or the rolled corn diet.

This study shows that this type of calf rearing and finishing program could have potential to further utilize existing farm resources for marketing dairy calves that are fed high concentrate barley diets.

LITERATURE CITED

AOAC. 1980. Official Methods of Analysis (13th Ed.). Association of Official Analytical Chemists. Washington, DC.

Aman, P. and K. Hesselman. 1984. Analysis of starch and other main constituents of cereal grains. J. Agr. Res. (Sweden) 14:135.

Barnes, B. J. and E. R. Orskov. 1982. Grain For Ruminants, Simple processing and preserving techniques. World Animal Review 42:38.

Bjorck, I. and N. G. Asp. 1983. The effects of extrusion cooking on nutritional value- a literature review. J. Food Eng. 2:281.

Bourne, D. T. and J. S. Pierce. 1970. B-glucan and B-glucanase in brewing. J. Inst. Brew. 76:328.

Briggs, D. E. 1978. Barley. Chapman and Hall, New York.

Brink, D. and S. Lowry. 1985. How should efficiency of feed utilization be evaluated. Beef Cattle Report. The Agricultural Experiment Station, Institute of Agriculture and Natural Resources, University of Nebraska, Lincoln, NE.

Brown, H., N. G. Elliston, J. W. McAskill, O. A. Muenster and L. V. Tonkinson. 1973. Tylosin phosphate (TP) and tylosin urea adduct (TUA) for the prevention of liver abscesses, improved weight gains and feed efficiency in feedlot cattle. J. Anim. Sci. 37:1085.

Church, D. C. 1977. Livestock Feeds and Feeding. Durham & Downey, Portland.

Church, D. C. 1988. The Ruminant Animal Digestive Physiology and Nutrition. Prentice Hall, Englewood, New Jersey 07632.

Chiang, B. Y. and J. A. Johnson. 1977. Gelatinization of starch in extruded products. Cereal Chem. 54:436.

Clark, E. P. and J. B. Collip. 1925. Modification of Kramer-Tisdall method for calcium determination. In: B. O. Oser (Ed.) Hawk's Physiological Chemistry (14th Ed.) pp 1133-1137. McGraw-Hill Book Co., New York.

Delort-Laval, J. and C. Mercier. 1976. Selection of treatments and study of their influence on the carbohydrate fraction of wheat, barley and maize. Ann. Zootechnie. 25:3.

El-Dash, A. A. 1981. Cereals, a Renewable Resource, Theory and Practice. Y. Pomeranz, L. Munck (Ed.'s). The American Association of Cereal Chemists, Inc., St. Paul, MN.

Engstrom, D. F. and G. W. Mathison. 1988. Effects of B-glucans and other factors on the digestion and utilization of barley by ruminants. 67th Annual Feeders' Day Report. University of Alberta, Edmonton, Alberta T6G 2G4.

Fisk, C. H. and Y. Sabbarow. 1925. Phosphorous determination. J. Biol. Sci. 66:375.

Fleming, M. and K. Kawakami. 1977. Studies of the five structures of B-D-glucans of barley extracted at different temperatures. Carbohydr. Res. 57:15.

Forrest, I. S. and T. Wainright. 1977. The mode of binding of B-glucans and pentosans in barley endosperm cell walls. J. Inst. Brew. 83:279.

Frederick, H. M., B. Theurer and W. H. Hale. 1973. Effect of moisture, pressure and temperature on enzymatic starch degradation of barley and sorghum grain. J. Dairy Sci. 56:595.

French, D. 1973. Chemical and physical properties of starch. J. Anim. Sci. 37:1048.

Garrett, W. N. 1965. Comparative feeding value of steam-rolled or ground barley and milo for feedlot cattle. J. Anim. Sci. 24:726.

Garrett, W. N. 1973. Energetic efficiency of beef and dairy steers. J. Anim. Sci. 32:451.

Geurin, H. B., J. L. Williamson, J. Cl Thompson, H. L. Wilcke and R. M. Bethke. 1959. J. Anim. Sci. 18:1489.

Gomez, M. H. and J. M. Aguileral. 1983. Changes in the starch fraction during extrusion-cooking of corn. J. Food Sci. 48:378.

Gomez, M. H. and J. M. Aguileral. 1984. A physiochemical model for extrusion of corn starch. J. Food Sci. 49:40.

Hale, W. H., L. Cuitun, W. J. Saba, B. Taylor and B. Theurer. 1966. Effect of steam processing and flaking milo and barley on performance and digestion by steers. J. Anim. Sci. 25:392.

Hale, W. H. and C. Brent Theurer. 1972. Feed Preparation and Processing in: D. C. Church (Ed.) Practical Nutrition in Digestive Physiology and Nutrition of Ruminants. OSU Bookstores, Corvallis, Ore.

Harris, L. E., 1970. Nutrition research techniques for domestic and wild animals. Vol 1. pg. 5051.

Harper, J. M. 1981. Extrusion of foods. CRC Press, Inc. 2000 N. W. 24th street, Boca Raton, Florida 33431.

Heryford, A. G. 1987. The Influence of Extrusion Processing on the Nutritional Value of Barley for Weanling Pigs and Broiler Chickens. M.S. Thesis, Montana State University, Bozeman, MT.

Holm, J., I. Bjork, S. Ostrowska, A. C. Eliasson, N. G. Asp, K. Larsson and I. Lundqvist. 1983. Digestibility of amylose lipid complexes in vitro and in vivo. Starch 35:294.

Kang, M. Y., Y. Sugimoto, I. Kato, S. Sakamoto and H. Fuwa. 1985. Some properties of large and small starch granules of barley (Hordeum vulgare L.) endosperm. Agric. Biol. Chem. 49:1291.

Karlsson, R., S. R. Olered and L.A.-C. Eliasson. 1983. Changes in starch granule size distribution and starch gelatinization properties during developement and maturation of wheat, barley and rye. Starch/Starke 35:335.

Kempster, A. J., G. L. Cook and J. R. Southgate. 1988. Evaluation of British Friesian, Canadian Holstein and beef breed x British Friesian steers slaughtered over a commercial range of fatness from 16-month and 24-month beef production systems. 1. Liveweight gain and efficiency of food utilization. Anim. Prod. 46:364.

Kempton, T. J. and J. F. Hiscox. 1983. The effects of cracking, pelleting and dry extrusion on in vitro degradation characteristics of cereal grains used as ruminant feeds. International Network of Feed

Information Centers. Symposium Feed information and animal production: proceedings of the Second Symposium of the International Network of Feed Information Centers. Farnum Royal, U.K. Commonwealth Agricultural Bureau. pp 403-406.

Kirkman, M. A., P. R. Shewry and B. J. Miflin. 1982. The effect of nitrogen nutrition on the lysine content and protein composition of barley seeds. J. Sci. Food Agr. 33:1.

Leninger, A. L. 1982. Principles of Biochemistry. Worth Publishers, Inc., 33 Irving Place, New York, NY. pp 287-289.

Lofgreen, G. P. and J. R. Dunbar. 1970. Feeders Day Report, Univ. of California.

MacGregor, A. W. and J. E. Morgan. 1984. Structure of amylopectins from large and small starch granules of normal and waxy barley. Cereal Chem. 61:222.

Mercier, C. 1980. Structure and digestibility alterations of cereal starches by twin-screw extrusion cooking. In: P. Linko, Y. Malkki, J. Olkku and J. Larinkari (Ed.) Food Processing Systems, Volume I. pp 795-807. Applied Science Publishers, London.

Montana Agricultural Statistics. 1986. Montana Agricultural Statistics Service. Helena, MT.

Morgan, C. A. and R. C. Campling. 1978. Digestibility of whole barley and oat grains by cattle of different ages. Anim. Prod. 27:323.

Morrison, F. B. 1956. Feeds and Feeding. 21st ed. The Morrison Publishing Co., Ithaca, NY.

Newman, C. W. and C. F. McGuire. 1985 Nutritional Quality of Barley. In: D. C. Rasmusson (Ed.) Barley. American Society of Agronomy, Crop Science Society of America and Soil Science Society of America, publishers. Madison, Wisconsin. pp 403-439.

Nielson, E. 1976. Whole seed processing by extrusion cooking. J. Am. Oil Chem. Soc. 53:305.

Nordin, M. and R. C. Campling. 1976. Digestibility studies with cows given whole and rolled cereal grains. Anim. Prod. 23:305.

NRC. 1984. Nutrient Requirements of Domestic Animals, No. 2. Nutrient Requirements of Beef Cattle. Sixth Revised Ed. National Academy of Sciences-National Research Council. Washington, DC.

Osman, H. F., B. Theurer, W. H. Hale and S. M. Mehen. 1970. Influence of grain processing on in vitro enzymatic starch digestion of barley and sorghum grain. J. Nutrition 100:1133.

Parrott III, J. C., S. Mehen, W. H. Hale, M. Little and B. Theurer. 1969. Digestibility of dry rolled and steam processed flaked barley. J. Anim. Sci. 28:425.

Perry, T. W., L. M. Harmmond, R. C. Peterson and W. M. Beeson. 1970. Cattle Feeders Day Report, Indiana Agric. Expt. Sta.

Preece, I. A. and K. G. MacKenzie. 1952. Non-starchy polysaccharides of cereal grains. I. Fractionation of the barley gums. J. Inst. Brew. 58:353.

Preston, T. R. 1963. Barley beef production. The Veterinary Record. 75:1399.

Robertson, J. B. and P. J. Van Soest. 1977. Dietary fiber estimation in concentrate feedstuffs. J. Anim. Sci. 45: Supple. 1:254.

Romans, J. R. and P. Thomas Ziegler. 1977. The Meat We Eat. The Interstate Printers & Publishers, Inc. Danville, Ill.

Roth, N. J. L., G. H. Watts and C. W. Newman. 1981. Beta-glucanase as an aid in measuring neutral detergent fiber in barley kernels. Cereal Chem. 58:245.

Rule, D. C. and D. C. Beitz. 1986. Fatty acids of adipose tissue, plasma, muscle and duodenal ingesta of steers fed extruded soybeans. J. Am. Oil Chem. Soc. 63:1429.

Rust, S. R. 1984. A comparison of lasalocid plus oxytetracycline or monensin plus tylosin for improving feed conversion and reducing incidence of liver abscesses. Special Report 10, Montana Agricultural Experiment Station, Montana State University, Bozeman, MT. pp 97-104.

Rust, S. R. 1985. Effects of processed corn and barley diets on performance and carcass characteristics of fattening steers. Special Report 14, Montana Agricultural Experiment Station, Montana State University, Bozeman, MT. pp 105-109.

Rust, S. R. 1986. Rapid adaptation of steers to high concentrate finishing rations with sodium bentonite in the diet. Special Report 21, Montana Agricultural Experiment Station, Montana State University, Bozeman, MT. pp 227-248.

SAS. 1987. Statistic Analysis Systems Institute, Inc. User's Guide. Cary, North Carolina.

Schake, L. M., E.T. Garnett and J.K. Riggs. 1970. Texas Agric. Expt. Sta. PR 2775-2800.

Shewry, P. R., S. W. J. Bright, S. R. Burgess and B. J. Miflin. 1984. Approaches to improving the nutritional value of barley seed proteins. In: The Use of Nuclear Techniques for Cereal Grain Protein Improvement, STI Pub. 664. Vienna. pp 227-240.

Shin, H. and J. I. Gray. 1983. Physiochemical assessment of quality characteristics of extruded barley under varied storage conditions. Korean J. Food Sci. Technol. 15:189.

Southgate, J. R., G. L. Cook and A. J. Kempster. 1988. Evaluation of British Friesian, Canadian Holstein and beef breed x British Friesian steers slaughtered over a commercial range of fatness from 16-month and 24-month beef production systems. 1. Liveweight gain and efficiency of food utilization. Anim. Prod. 46:364.

Trimble, D. 1980. Barley beef production. Agric. in Northern Ireland. 54:304.

Van Soest, P. J. 1982. Nutritional Ecology of the Ruminant. O & B Books, Inc., Corvallis, Ore.

MONTANA STATE UNIVERSITY LIBRARIES
3 1762 10147686 7