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Integration of pasturing systems for cattle finishing programs

by

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A dissertation submitted to the graduate faculty
in partial fulfillment of the requirements for the degree of
DOCTOR OF PHILOSOPHY

Major: Animal Science

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Hayati Koknaroglu
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For the Major Program

Signature was redacted for privacy.

For the Graduate College

To my parents, Haydar and Telli.

TABLE OF CONTENTS

LIST OF FIGURES	v
LIST OF TABLES	vi
ABSTRACT	vii
CHAPTER 1. INTRODUCTION	1
CHAPTER 2. LITERATURE REVIEW	2
Grasses in soil conservation and stabilization	2
Cool-season grasses	4
Smooth brome grass	5
Ionophore	9
Monensin	11
Effect of monensin on protein metabolism	17
Effect of monensin on ruminal pH	20
Effect of monensin on performance	21
Compensatory growth	23
Forage quality and utilization	27
Pasture use and integration	35
CHAPTER 3. MATERIALS AND METHODS	43
Carcass measurement	48
Economic analysis	49
Statistical analysis	50
CHAPTER 4. RESULTS AND DISCUSSION	52
Price sensitivity analysis	81
CHAPTER 5. GENERAL CONCLUSIONS	90
APPENDIX. ECONOMIC ANALYSES WORKSHEETS	91
LITERATURE CITED	95
ACKNOWLEDGEMENTS	118

LIST OF FIGURES

Figure 1. Cycle of carboxylic ionophore indicating the proton exchange	10
Figure 2. Transmembrane flux of potassium, sodium and protons mediated by monensin	13
Figure 3. Structural formula of monensin sodium	14

LIST OF TABLES

Table 1. Performance of cattle both in feedlot and on pasture	53
Table 2. Carcass characteristics of cattle	63
Table 3. Performance variables for treatments	69
Table 4. Economics variables for treatments, 1 st option	72
Table 5. Economic variables for treatments, 2 nd option	75
Table 6. Economic variables for treatments, 3 rd option	78
Table 7. Economic variables for treatments, 4 th option	80
Table 8. Economic variables when carcass price increases 5 percent	83
Table 9. Economic variables when carcass price decreases 5 percent	84
Table 10. Economic variables when corn price increases 5 percent	86
Table 11. Economic variables when corn price decreases 5 percent	87
Table 12. Economic variables when feeder price increases 5 percent	88
Table 13. Economic variables when feeder price decreases 5 percent	89

ABSTRACT

A three-year study, using 84 fall-born and 28 spring-born calves of similar genotypes each year, was conducted to integrate pasturing systems with drylot feeding systems. Fall and spring-born calves were started on test in May and October, respectively. Seven treatments were imposed: 1) fall-born calves directly into feedlot; 2 and 3) fall-born calves put on pasture with or without an ionophore and moved to the feedlot at the end of July; 4 and 5) fall-born calves put on pasture with or without an ionophore and moved to the feedlot at the end of October; 6 and 7) spring-born calves put on pasture with or without an ionophore and moved to the feedlot at the end of October. A 12.1 ha bromegrass pasture divided into 16 paddocks was available. Each treatment group had access to one paddock at a time and was rotated approximately at 3 day intervals. The rotation was determined by forage sward heights and dormancy of the forage. In the feedlot, steers were provided an 82 % concentrate diet containing whole-shelled corn, ground alfalfa hay, a protein, vitamin and mineral supplement containing ionophore and molasses. When pens of cattle reached approximately 522 kg average live weight, they were processed and carcass traits were evaluated. Cattle on pasture receiving ionophore tended to gain faster ($P>0.1$), but lost this advantage in drylot ($P>.10$). Overall, cattle started directly in the feedlot gained faster ($P<.001$). Cattle receiving an ionophore on pasture had lower KPH fat than those that did not receive an ionophore ($P<.01$) and tended to have more backfat ($P=.09$). Treatment influenced yield grade ($P<0.001$), however all treatments were YG 2. All treatment groups graded 75 % Choice or higher. Using actual costs, cattle started directly in the feedlot were the least profitable (\$-46 vs \$2; $P<0.001$). Cattle receiving ionophore on pasture (JI, OI and SI versus JNI, ONI and SNI) were a little more profitable (\$5.87 vs \$4.25; $P>0.9$). These

results indicate that cattle fed on pasture for varying periods of time produced acceptable carcasses and that carcass price was an important variable affecting profitability. Thus, the timing of marketing is critical for optimizing profit.

CHAPTER 1. INTRODUCTION

As the world population increases more cereal grain is needed for human use. About one sixth of the energy required by livestock is derived from grains (Oltjen and Beckett 1996). Thus alternative methods using less cereal grains in animal production must be developed. Ruminant livestock production takes advantage of forage production on approximately 25 % of potentially arable land to minimize water and soil erosion. Cattle have the unique ability to use vast amounts of renewable resources from rangeland, pasture, and crop residues or other by-products and convert them into food. Economics and environmental issues such as soil conservation are becoming driving forces behind cattle feeding and thus one way to reduce the cost of production and improve soil conservation is to use pastures on highly erodable lands for grazing. However, all-forage systems for finishing cattle have not been particularly successful. The carcasses from cattle on the all-forage systems generally have not made the USDA Select grade level. Without grain, the final product typically has a poor quality and a milky or grassy flavor (Davis et al., 1981; Hedrick et al., 1983) and carcasses from these cattle are discriminated against by packers due to their lowered dressing percentage, higher cooler shrinkage and lower quality grade (Schroeder et al., 1980). There is research to indicate that finishing cattle on corn in the feedlot for anytime beyond 30 days improves tenderness (Harrison et al., 1978; Dolezal et al., 1982). Maximum tenderness and lean growth can be achieved with 50 to 100 days grain feeding (Hedrick et al., 1983; Larick and Turner 1990). Thus the objective of this study was to integrate cattle pasturing systems with conventional feedlot feeding systems and to compare the systems in terms of cattle feedlot performance, carcass characteristics and economics.

CHAPTER 2. LITERATURE REVIEW

Grasses in soil conservation and stabilization

When it comes to conserving and stabilizing soil, plants are the most cost-effective method. Soil conservation could be attained with forage plants, while they are used for forage production or grazing. For example, across much of the eastern US, tall fescue (*Festuca arundinacea* Schreb.) is an excellent forage, but it is also used extensively as a component of conservation plantings (SCS, 1992).

Surface runoff, which causes erosion in simplified form, equals precipitation minus infiltration. Thus the rate of infiltration becomes a key determinant of the nature of water yields downstream. Vegetation cover enhances water movement into the soil by protecting the surface from the damaging effects of pounding raindrops: vegetation retards runoff and keeps the surface open and receptive to infiltration (Sharp et al. 1995). Browning and Sudds (1942) found that the rate of water infiltration in an undisturbed sod of mixed grasses in an orchard was 12.7 cm h^{-1} , about five times that of adjacent areas that were cultivated and subjected to disturbance and compaction by farm equipment.

A 40 mm rain falling at the rate of 40 mm h^{-1} applies almost $700,000 \text{ kg m}^{-1}$ of energy on the surface of 1 ha (Wischmeier and Smith 1958). When the soil is not covered with vegetation the falling rain puddles it, increasing both runoff and soil loss. Saxton et al (1971) found that soil loss due to sheet erosion from the contoured-corn watersheds were 67 mt ha^{-1} whereas it was 0.67 mt ha^{-1} from a field-sized watershed of well-managed smooth brome grass pasture.

Studies summarized by Wadleigh et al. (1974) showed that in Wisconsin, Oklahoma and Iowa, a cropping system of continuous grass cover resulted in the least soil erosion

followed by rotational hay and soil losses were greater from contour row crops than from rotational grain and rotational hay. Glymph and Holton (1969) observed that at the Upper Mississippi Valley Conservation Experiment Station, La Crosse, Wisconsin, average annual runoff on Fayette silt loam with slope of 16 percent was 27.7 percent of rainfall for continuous corn; 20.6 percent for corn in rotation of corn-barley-red clover; 18.9 percent for barley in rotation; 11.5 percent for clover in rotation; and 5.5 percent for continuous bluegrass. The same results were obtained for the Red Plains Conservation Experiment Station, Guthrie, Oklahoma and the Missouri Valley Loess Conservation Experiment Station, Clarinda, Iowa.

Nearly 64 percent of pollution in rivers and 57 percent in lakes is from agricultural land and 47 percent of pollutants in rivers and 22 percent in lakes are from sediments. Sediment is the dominant pollutant in rivers and second biggest in lakes (Carey, 1991; USDA, 1968). On average more than 4 billion tons of sediment a year move from land to water channels.

If chlorinated hydrocarbon pesticides move from fields to water, sediment is the carrier (USDA, 1969). These chemicals are virtually insoluble in water but are readily adsorbed on the surfaces of clay particles. Phosphate moves by surface adsorption on sediment carried from fields to streams. Manure particles ride from fields, barnyards or feedlots to streams by the same hydraulic forces that move sediment (Wadleigh et al., 1974). "Thus the capacity of good grass cover to disperse the entry of rainfall, to maintain maximal infiltration capacity of soil, to minimize runoff, to nearly eliminate sediment delivery, to rectify polluted water and to tolerate and survive serious soil moisture stress so as to provide

continual protection of soil and water resources makes grasses of fundamental importance in many undertakings for improved environmental protection” (Wadleigh et al., 1974).

Cool-season grasses

Cool-season grasses are the major forage source for ruminants in temperate regions of the world and prefer cool environments for optimum growth (Moser and Hoveland, 1996). Even though they are mostly concentrated north of 30° N or south of 30° S latitude, they can grow during cool winter season or at higher altitudes of the tropical areas (Moser and Hoveland, 1996). Optimum growth of most cool-season grasses falls between 20 and 25 °C and below 10 °C growth drops rapidly. However slow growth often occurs at 5 °C. Growth is reduced when the temperature exceeds 25 °C and is greatly reduced or ceases above 30 to 35 °C (Moser and Hoveland, 1996).

Cool-season grasses show periodicity in their growth. A large proportion of growth occurs in the spring when the temperatures are near optimum and moisture level is sufficient. When the weather gets warmer in summer, growth slows and little to moderate growth occurs. However in fall, if rainfall occurs a second growth is observed (Moser and Hoveland, 1996).

Cool-season grasses have variations in terms of root depth and distribution and the greatest quantity of roots is in the top 15 cm of the soil profile. One exception for this is smooth brome grass, which has a larger portion of the roots at deeper soil depth, which gives drought tolerance to brome grass (Moser and Hoveland, 1996).

Cool-season grasses are also known as C₃ plants due to their CO₂ fixing pathway. In cool-season grasses CO₂ is fixed by the enzyme ribulose biphosphate carboxylase (RuBP or

Rubisco) which is in chloroplast of mesophyll cells. At the enzyme site, CO_2 reacts with ribulose biphosphate, which is a 5-carbon sugar to form two molecules of a 3-carbon acid called 3-phosphoglyceric acid or 3-PGA. Then 3-PGA moves out of the chloroplast to the cytoplasm where it is metabolized into hexose, sucrose and other compounds (Nelson, 1996).

There is another pathway in cool-season grasses in which the same active site on Rubisco catalyzes the reaction whereby O_2 reacts to cleave the ribulose biphosphate into a 2-carbon acid (phosphoglycolate) and one 3-PGA, which results in no net increase in photosynthate. The phosphoglycolate is respired to CO_2 as a loss. This reaction is called photorespiration and has little purpose and the proportion is higher at high temperatures. Thus, C_3 plants are more adaptable to cool environments and are more efficient in that environment (Nelson, 1996).

Rubisco makes almost 50 % of the soluble protein in C_3 leaves and is positively correlated with photosynthetic rate. Thus plants with high photosynthetic rates generally have high protein content. Mesophyll cells are easily degradable in the rumen; most of their proteins are released in the rumen where it's used by microbes (Nelson, 1996).

Smooth brome grass

Smooth brome grass is a cool-season, leafy, tall-growing sod-forming perennial which tillers right after emergence and continues to increase tiller numbers until late in the summer (Miller, 1984a; Vogel et al., 1995). The genus *Bromus*, which has 100 species, is grouped with the small grains in the grass subfamily of Pooideae (Gould and Shaw, 1983).

Smooth brome grass (*Bromus inermis* Leyss) is the most widely used of the cultivated brome grasses and is known by various other common names: Hungarian brome, Austrian

brome, Russian brome and brome grass (Casler and Carlson, 1995). It is well suited to both hay production and pasturing of livestock and persists well under grazing and is a good cover for erosion control (Casler and Carlson, 1995).

Smooth brome grass was introduced into the United States in the 1880's (Carlson and Newel, 1985) and became widely distributed in the prairie and plain states and north to Canada by 1900 (Knobloch, 1942; Casler and Carlson, 1995). In North America, smooth brome grass is mostly found in regions north of 40°N latitude and east of 100°W longitude and that get 500 mm or more annual precipitation or in areas that have the same temperature ranges because of elevation (Vogel et al., 1995).

Smooth brome grass has roots that go deep into soil. This makes it drought resistant and favored by livestock producers. In Iowa during the drought years of 1934-36 it survived and produced well and became preferred by producers due to these qualities (Metcalfe, 1950; Wheeler and Hill, 1957; Casler and Carlson, 1995).

Smooth brome grass is able to stand harsh winter temperatures as well as drought better than other cool-season grasses such as orchard grass (*Dactylis glomerata* L.). Limin and Fowler (1987) studied cold hardiness of forage grasses grown on the Canadian prairies and found that smooth brome grass tolerated temperatures to -28 °C before 50 % sod damage occurred whereas the same temperature was -23 °C for orchard grass. Optimum temperature range for smooth brome grass is 18 to 25°C and temperature above 35°C causes reduction in growth (Baker and Jung, 1968).

In a study, Morrow and Power (1979) examined the effect of soil temperature on development of perennial forage grasses and found that aboveground dry matter production for smooth brome grass increased with increasing temperature up to 18.3 °C and then started

declining above that temperature. They also observed that below ground dry matter production, which is basically the root system, for smooth brome grass followed the same temperature-growth trend as above ground dry matter production. Since the dry matter production remained relatively high even above the optimum soil temperature, it made smooth brome grass most adaptable to a range of soil temperatures for dry matter production.

Rapid response of dry matter production to increasing soil temperature makes smooth brome grass valuable for early spring grazing by livestock (Morrow and Power, 1979). Newel and Anderson (1962) reported that smooth brome grass was more palatable and kept its palatability longer than many other grasses. Marten and Donker (1968) found that heifers grazing smooth brome grass had higher consumptions than heifers grazing reed canary grass. Brome grass is a sod-forming grass that spreads by forming stolons and rhizomes (Miller, 1984b).

Northern and southern are the two major types of smooth brome grass (Newell, 1973). The southern-type smooth brome grass is superior to northern brome grass in terms of its aggressiveness in growth habit, greater yield in the corn-belt, better seedling vigor, easiness to establish, faster spring growth, faster formation of solid sod, and better drought resistance (Wright et al, 1967). Because southern-type produces a more complete sod, it's better suited for soil-conservation purposes and use in waterways (Miller, 1984a). Southern-types were shown to be as winter hardy in Canada as northern types and were more drought and heat tolerant than the northern types (Newell, 1973; Carlson and Newell, 1985).

Smooth brome grass maintains high forage quality throughout a wide maturity range, however highest quality levels are attained at pre-jointing stage (Miller, 1984a). Nutritive value of smooth brome grass declines as the forage matures. However dry matter production

increases with increasing stages of maturity (Wright et al., 1967). This brings grazing management forward and the process of decision making. The time between pre-joint stage at which the nutritive value is highest to past-bloom stage at which the nutritive value is lowest is 46 days for smooth brome grass (Miller, 1984a). Thus while making grazing or harvesting decisions this time span should be taken into consideration.

Smooth brome grass is more productive than other adapted cool-season grasses with reed canary grass being the exception (Marten and Donker, 1968). Reid et al. (1978) in West Virginia found that lambs grazing smooth brome grass had higher average daily gains than those grazing perennial ryegrass, orchard grass and tall fescue from April to October. Marten and Jordan (1974) obtained the same results demonstrating higher quality of smooth brome grass than orchard grass and reed canary grass in Minnesota with a grazing sheep trial.

Application of nitrogen fertilizer will increase yield on grass pastures. When smooth brome grass is raised in pure stand it requires regular nitrogen fertilization (Casler and Carlson, 1995). Comparing application of 50 or 504 kg N/ha, Horton and Holmes (1974) found increased animal production by 1 kg gain/1 kg N, and forage production by 8-9 kg DM/1 kg N.

In an experiment conducted in Indiana, Lechtenberg et al. (1974) found that fertilizing brome grass with nitrogen increased beef production 0.5 kg per kilogram of nitrogen applied.

When nitrogen is limiting the sod-bound condition, which is characterized by low forage yields, the production of only a limited number of fertile tillers may develop (Anderson et al., 1946).

One other effect of nitrogen fertilization on forage is that it increases protein content of the forage. McCaughey and Simons (1999) found that protein content of the forage showed increases of 2.2 to 4.3 % as nitrogen application rates increased from 0 to 160 kg N/ha. In the same experiment due to increase in protein content and probably in yield as well, protein yield per hectare also increased. Harapiak et al. (1992) also found that protein yield increased from 84 to 598 kg/ha as nitrogen application rate increased from 0 to 336 kg N/ha.

Ionophore

The ionophores, which come from Greek words ion and phore (i.e. ion and carrier, respectively), are substances which form lipid soluble, dynamically reversible, cation complexes which act as vehicles for transporting ions across biological membranes (Pressman and Fahim, 1982). Ionophores are considered as molecules with backbones that strategically space oxygen atoms. The backbone is capable of assuming critical conformations that focus these oxygen atoms about a ring into which complexible cations may fit more or less snugly (Pressman, 1976).

Ionophores are classified under two major subclasses: 1- neutral ionophores which form charged complexes with cations which serve to transport cations down their electrochemical gradients; 2- carboxylic ionophores which form electrically neutral zwitterionic complexes with cations which serve to promote an electrically neutral exchange diffusion of cations (Pressman and Fahim, 1982).

While the carboxylic ionophores are not covalently cyclized, they have a common feature of a carboxyl group at the head of the molecule and one or two hydroxyl groups at the

tail. The molecules are cyclized by head-to-tail hydrogen bonding and further stabilized by the twist in the asymmetric centers and rings of the backbone. The oxygen ligands in the molecule consist of functional groups such as ether, carboxyl, hydroxyl, and carbonyl (Pressman, 1976).

Even though the carboxyl may or may not be involved in cation liganding, the carboxylic ionophores form cationic complexes only in their deprotonated anionic form. Ideally, they carry anions as electrically neutral zwitterions; however, they do have minor modes of transporting current as multimeric complexes. They are capable of carrying protons on their protonated carboxyl forms (Pressman, 1976). The cycle of a carboxylic ionophore-catalyzed cation-for proton exchange is shown in Figure 1.

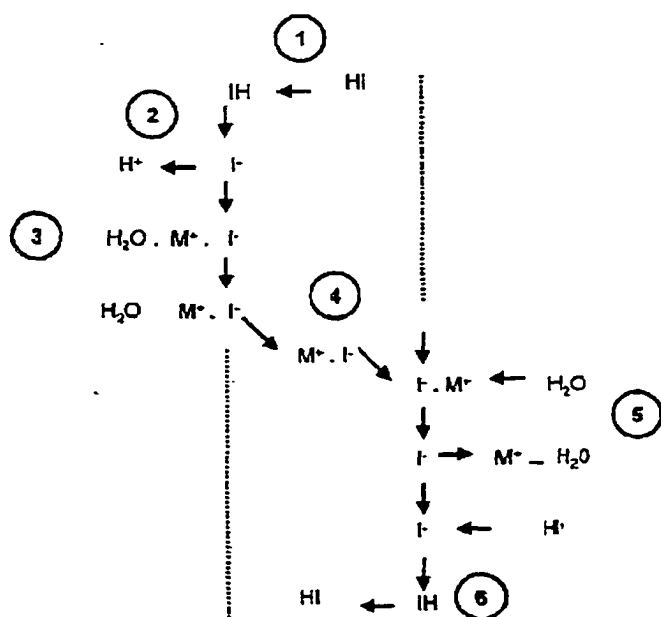


Figure 1. Cycle of carboxylic ionophore indicating the proton exchange (Pressman, 1976).

The order of events is as follows:

- 1) Protonated ionophore within a membrane diffuses to one interface.
- 2) Protonated ionophore within a membrane diffuses to one interface.
- 3) Release of proton; the ionophore is trapped at the polar interface due to increased polarity of charged anionic form.
- 4) Ionophore anion encounters a complexible M^+ and engulfs it thus displacing its water of solvation.
- 5) Zwitterionic complex being able to break away from the interface due to internally compensated charges diffuses to the opposite interface.
- 6) Release of cation coincident with resolution
- 7) Ionic ionophore combines with a proton thus lowering its polarity, the protonated ionophore leaves the interface and returns to the membrane interior to start another cycle.

Monensin

Monensin also commercially known as Rumensin is a feed additive. The active ingredient of monensin is the sodium salt of monensin, a polyether antibiotic produced by a strain of *Streptomyces cinnamonensis* (Haney and Hoehn, 1968). Monensin and lasalocid, which are ionophore antibiotics, were initially developed as coccidiostats for poultry. However, later research showed that they were effective on ruminal fermentation and in the mid-70s ionophores were approved as feed additives for rations in beef cattle in the US (Richardson et al., 1976; Russell and Strobel, 1989;).

The basic mode of action of monensin is to modify the movement of ions across biological membranes (Schelling, 1984). Monensin is an antiporter that facilitates a one-for-

one exchange of H^+ and Na^+ across cell membranes (Russell, 1987). However, monensin can mediate a K^+ and H^+ exchange as well (Pressman and Fahim, 1982). Monensin has 10 times the selectivity (binding preference) for Na^+ as K^+ (Pressman and Fahim, 1982).

The intracellular concentration gradient of K^+ is 3 times higher than that of Na^+ . However, when Russell (1987) treated *S. bovis* with 7.5 μM monensin the concentration gradient of K^+ was more than 25 times greater than the gradient for Na^+ . Because of the concentration gradient differences across the membrane, the efflux of K^+ via monensin was more exergonic than Na^+ efflux. Due to ion exchange between K^+ and H^+ there was a decrease in both intracellular K^+ concentration and intracellular pH (accumulation of H^+ ion). Once intracellular pH was lower inside than outside, the influx of Na^+ was driven by H^+ efflux. He mentioned that growth inhibition of *S. bovis* treated with monensin was not due to a decrease in intracellular pH. Because *S. bovis* is able to grow with internal pH as low as 5.4 (Russell and Hino, 1985), the reason for growth inhibition could have been the result of depletion of ATP pools due to increased ATPase activity to expel and excess H^+ from the cell (Russell, 1987).

A schematic describing the effect of monensin on transmembrane flux of potassium, sodium and protons is given in Figure 2.

The order of the events is as follows:

- 1- Movement of K^+ out of the cell and influx of H^+ due to large gradient across the cell membrane.
- 2- Monensin-mediated Na^+ influx in exchange for H^+
- 3- Expelling of H^+ with the help of ATPase pump in an attempt to maintain intracellular pH.

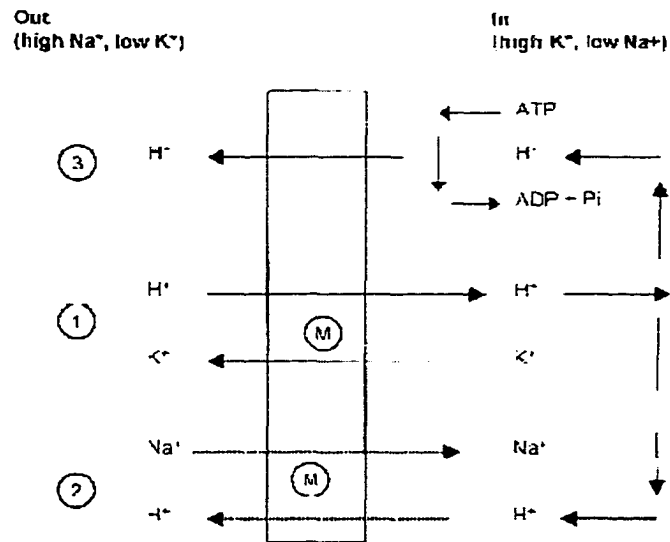


Figure 2. Transmembrane flux of potassium, sodium and protons mediated by monensin (From Russel, 1996).

When antibiotics started being used, some bacteria developed resistant bacterial mutants. The effectiveness of many antibiotic treatments has been reduced because genes encoding resistance factors are readily transferred from one strain to another (Russell and Strobel, 1989). Even though ionophores have been used for a relatively long time, they continue to improve efficiency of animal performance. This observation made Russell and Strobel (1989) suggest that the sensitivity of ruminal microorganisms was relatively stable and that the pattern of resistance is due to a fundamental difference between cells. Ionophore resistance is more closely related to cell wall structure (Russell and Strobel, 1989).

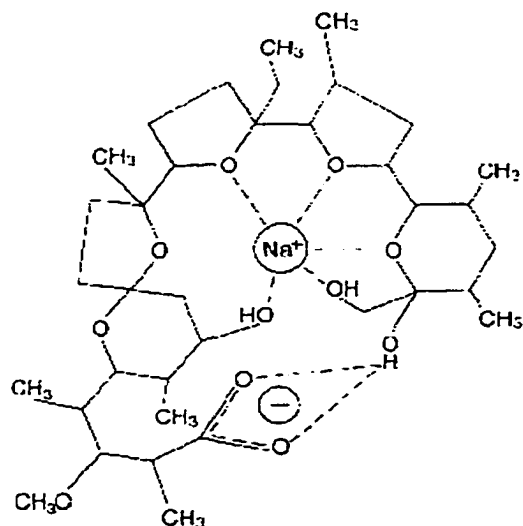


Figure 3. Structural formula of monensin sodium.

Bacteria having a gram-negative cell wall structure are not sensitive to the effects of monensin whereas those bacteria having gram-positive cell walls are (Leedle, 1993). An outer membrane that has phospholipids on the inner surface and irregular lipopolysaccharide chains on the outer surface characterizes gram-negative bacteria (Russell et al., 1990).

Porins mediate the solute movement through hydrophilic channels. Porins, which form hydrophilic channels through the hydrophobic outer membrane, have an exclusion limit of approximately 600 daltons (Nikaido and Nakae, 1979). Thus the outer membrane should serve as a protective barrier to ionophores since ionophores are extremely hydrophobic and have molecular sizes greater than 500 daltons.

Gram-positive bacteria, which lack a protective outer membrane, are generally sensitive to ionophores (Russell and Strobel, 1989). The reason for the sensitivity is that although gram-positive bacteria have a thicker peptidoglycon layer than gram-negatives, their porous

structure does not show an obstruction and ionophores can penetrate disturbing the integrity of the biological membranes (Russell, 1996).

Metabolic effects of ionophores on the rumen fermentation have been observed and reported in the literature. A brief list of these effects by Bergen and Bates (1984) is as follows:

- 1- Shift in acetate-propionate ratio toward more propionate.
- 2- Some increase of lactate to propionate production via the acrylate pathway.
- 3- Decreased ruminal protein breakdown and deamination thus lower ruminal ammonia-N.
- 4- Inhibition of gram-positive organisms producing H^+ or formate.
- 5- Decrease in methane production primarily due to lowered availability of H_2 and formate and depressed interspecies H_2 transfer.
- 6- Depression of lactic acid production under acidosis inducing conditions.
- 7- Survival of gram-negative organisms, of which many produce succinate (source of propionate) or have the ability for reductive tricarboxylic acid cycle to use bacterial reducing power.
- 8- Depressed rumen content turnover.
- 9- Decrease in rumen fluid viscosity in bloated animals.
- 10- Depressed growth yield efficiency of the ruminal microbes.

The most well documented effect of monensin on the rumen fermentation is the change in the pattern of VFA. Monensin increases molar proportions of propionate and decreases molar proportions of acetate and butyrate (Richardson et al., 1976; Van Nevel and Demeyer, 1977; Prange et al., 1978; Bergen and Bates, 1984; Beede et al., 1986; Callaway et al.,

1997). The shift in the VFA ratio in favor of propionate is a favorable change for meat producing animals (Schelling, 1984).

One reason that increased propionate production improves the efficiency of energy utilization from feed is because propionate production by rumen fermentation seems to be more efficient than that of acetate. Another reason is that propionate is utilized by the tissue more efficiently than acetate. One other reason is that propionate is more variable as an energy source than acetate. Propionate has the potential to be used for gluconeogenesis in addition to direct oxidation by the citric acid cycle. Thus having more substrate for glycolysis may offer significant energetic advantage to the ruminant animal by creating more reduced coenzyme outside the mitochondrial membrane (Schelling, 1984).

The ruminal fermentation balance suggests that the more propionate produced, the less methane is produced at the expense of acetate (Wallace et al., 1980). Effect of monensin on decreases in methanogenesis is well documented *in vitro* (Van Nevel and Demeyer, 1977; Bartley et al., 1979; Chalupa et al., 1980; Callaway et al., 1997;) and *in vivo* (Joyner et al., 1979; Thornton and Owens, 1981; Benz and Johnson, 1982).

In an experiment designed to study the effect of monensin and lasalocid-sodium on the growth of methanogenic and saccharolytic bacteria in a complex medium containing rumen fluid, Chen and Wolin (1979) found that the addition of 2.5 µg of monensin or lasalocid completely inhibited growth of *Ruminococcus albus*, *Ruminococcus flavefaciens* and three strains of *Butyrivibrio fibrisolvens*. However the same concentration of monensin inhibited growth of *B. ruminicola* for 24 hours and *B. succinogenes* for 72 hours. But growth was detected after longer incubation. Since monensin only caused a delayed growth response rather than complete inhibition of growth of methanogens they hypothesized that monensin

and lasalocid increase propionate production in the rumen because of selection for the succinate-producing *Bacterioides* and *S. ruminantium*. *Bacterioides* produce some formate and no H₂ and *S. ruminantium* produce little formate and minute amounts of H₂, thus they are less probable to produce precursors of methane than *R. albus*, *R. flavefaciens*, and *B. fibrisolvens*.

Results fortifying these findings were also obtained by Van Nevel and Demeyer (1977) who investigated the effect of monensin on rumen microorganisms metabolizing carbohydrate or protein substrates. They found that monensin decreased methane production and increased propionate production. However, when they added CO₂ and H₂ to mixed cultures containing monensin they observed an increase in methane production. Thus they concluded that inhibition of monensin on methanogenesis is not due to the toxic effect of monensin on the methanogenic bacteria, but rather an inhibition on microorganisms decomposing formate to CO₂ and H₂ which are most important substrates for methane producing bacteria.

Effect of monensin on protein metabolism

Another effect of monensin in ruminal fermentation is its protein sparing effect. Protein sparing effect comes from the decreased protein degradation and decreased ammonia production. This effect is well established in several *in vivo* (Dinius et al., 1976; Yang and Russell, 1993) and *in vitro* (Van Nevel and Demeyer, 1977; Whetstone et al., 1981) studies. Dinius et al. (1976) determined the effect of monensin on steers fed with forage and found that there was a decrease in ammonia production with monensin use.

Whetstone et al. (1981) studied the effect of monensin on breakdown of protein by ruminal microorganisms in a semicontinuous culture and found that there was a linear

decrease in ammonia production with increasing monensin level and there was an increase in nonammonia and nonmicrobial N and total peptides. They assumed that the nonmicrobial nitrogen was the nitrogenous compound that came from the diet, which escaped the degradation to ammonia. Thus as indicated in the Whetstone et al. (1981) study, decreasing the ruminal degradation of dietary protein would result in more protein escaping the rumen to the lower digestive tract, thus increasing the efficiency of dietary protein by the ruminant animal. In this way, monensin lowered the contribution of bactererial nitrogen to total nitrogen digested and absorbed postruminally, and increased the contribution of ruminally undegraded feed nitrogen digested postruminally (Muntifering et al., 1981).

Yang and Russell (1993) found that inclusion of 350 mg/day of monensin to the diet of nonlactating Holstein cows resulted in a decrease of ammonia production by more than 30 % and they attributed this difference to a 10-fold decrease in amino acid fermenting monensin sensitive bacteria.

In a study conducted to determine effect of methane inhibitors on amino acid fermentation *in vitro*, Russell and Martin (1984) obtained a more pronounced effect of monensin. They reported that monensin decreased ammonia production more than 50 % and explained the decrease in ammonia production by a decrease in microbial protein.

Research done by Bladen et al. (1961) reported that a variety of ruminal bacteria produced ammonia from protein and among them strains of *Megasphaera elsdenii* and *Bacteroides ruminicola* were most active. However, being gram-negative bacteria these bacteria were resistant to monensin. Thus the effect of monensin in decreasing ammonia production was contradictory with the current knowledge. This led Russell et al. (1988) to conduct an experiment to enrich and isolate ruminal bacteria with high specific activities of

ammonia production. They were able to find and isolate two gram-positive bacteria, a *Peptostreptococcus* and a *Clostridium*, which had specific activities of ammonia production much higher than known rumen bacteria. Thus isolation of these monensin sensitive highly active ammonia producer gram-positive bacteria explains the effect of monensin on ammonia production. Dinius et al. (1976) observed that when steers received monensin there was a decrease in loss of nitrogen in feces and urine and thus there was a tendency in nitrogen retention.

One other effect of monensin is on digestibility of feedstuffs. Muntefering et al. (1981) set up trials to determine the effect of monensin on the site and extent of protein and starch digestion of a corn-based diet. They found that organic dry matter digestion rate in the rumen decreased with monensin and quantity of dry matter digested in the rumen decreased. Thus, due to less digestion in the rumen, more organic matter entered the duodenum and the quantity digested in post ruminal digestion increased. Parallel to results obtained for organic matter digestion, starch digestion also followed the same tendencies. Callaway et al. (1997) also found that monensin and nicin inhibited starch fermentation in vitro by 30 and 60 %, respectively.

Beede et al. (1986) designed an experiment to study the effect of monensin on N utilization by growing steers and goats fed diets low in crude protein and measured apparent dry matter, gross energy, fiber digestibilities and growth performance of growing goats. They found that steers receiving monensin had higher apparent N digestibility, better N retention, better percentage of absorbed N that was retained, higher efficiency of utilization of dietary protein and less absorbed N being excreted in urine. Apparent digestibility of dry matter, gross energy and acid detergent lignin were also increased with monensin, however

ADF and NDF apparent digestibilities were not effected. Better utilization of N and better digestibility of dry matter were thought to be results of better N utilization at the tissue level and higher digestibility of acid detergent lignin with monensin feeding. In the same experiment, growing goats receiving monensin had higher average daily gains and better feed efficiencies and tended to have higher apparent digestibilities of dry matter and gross energy.

Effect of monensin on ruminal pH

Finishing rations, which consist of a high ratio of cereal grains are easily fermentable and this might result in accumulation of lactic acid in the rumen (Strobel et al., 1989). Because the number of lactate-utilizing bacteria is normally adequate to maintain equilibrium with production, lactic acid does not accumulate in the rumen above 5 μ M (Ogimoto, 1977). However when animals are gorged with grains without any adaptation to grain source or processing is changed frequently, lactic acid builds up in the rumen (Kotarski et al., 1992).

Lactic acid is 10 times more acidic than typical volatile fatty acids and thus accumulation of lactic acid should be avoided for normal functions of the rumen (Leedle, 1993). *Streptococcus bovis* is a gram-positive bacterium that usually grows rapidly when sources of glucose or cereal grains are available resulting in excessive lactate production and onset of rumen acidosis (Slyter, 1976). Thus potential use of monensin increases the ruminal pH by inhibiting the growth of *S. bovis* and decreases the occurrence of acidosis. As was mentioned earlier by Russell (1987) *S. bovis* is susceptible to monensin, however lactate-utilizing species in cattle *Megasphaera elsdenii* and *Selenomonas ruminantium* are resistant to monensin (Nagaraja and Taylor, 1987). Thus monensin increases ruminal pH by decreasing the lactate producing bacteria and not affecting the lactate-utilizing bacteria.

Effect of monensin on performance

Effect of monensin feeding on pasture and feedlot cattle has been well established. Monensin fed cattle have shown better performance and efficiencies. When Goodrich et al. (1984) summarized results of 228 trials involving 11,274 head of cattle fed control or monensin-containing diets, they reported that monensin fed cattle gained 1.6% faster, consumed 6.4% less feed and required 7.5% less feed/100 kg gain than cattle fed control diets. Potter et al. (1986) conducted a study to evaluate the addition of monensin at 200 mg/day to limited quantities of supplemental concentrate for growing cattle grazing pastures. They found that the addition of 200 mg of monensin to the supplement increased daily gain by 16.3%. In another trial they also compared monensin additions of 33 mg/kg air-dry diet to limited quantities of supplemental feed for cattle fed harvested forages in confinement. They found that monensin reduced feed intake by 3.1 %, improved average daily gain by 14.4 % and improved feed efficiency by 15.3 %.

Horn et al. (1981) studied the effects of monensin on ruminal fermentation, forage intake and weight gains of stocker cattle grazed on wheat pasture. They found that cattle fed a pelleted supplement that contained 100 mg monensin had significantly higher daily gain than those supplemented without monensin. Rouquette et al. (1980) conducted two trials to determine the effect of monensin on live weight gain and efficiency of forage utilization of calves grazing Bermudagrass. The results showed that the use of 200 mg monensin/head/day improved calf gains by 23 to 45% and increased estimated feed efficiencies by 21 to 36% on Bermudagrass.

Rush et al. (1996) in Nebraska grazed yearling steers on crested wheatgrass for 113 days. Steers received 2.2 pounds of supplement per day, which provided 200, 150 and 20 mg/head/day lasalocid (Bovatec), monensin (Rumensin) and bambarmycin (GainPro), respectively. Control cattle only received 2.2 pounds of supplement. They found that control cattle had significantly lower average daily gains than steers receiving Bovatec, Rumensin and GainPro treatments and the latter three treatments did not differ from each other. Improvements in average daily gains by all three additives averaged 17.8, 13.3 and 22.2% for Bovatec, Rumensin and GainPro, respectively.

Beede et al. (1986) conducted two digestion and metabolism trials to determine effects of monensin in low-protein diets. In the first experiment they fed 303 kg steers with a control diet that contained 8.7 % crude protein and monensin in the amount of 27 mg/kg of diet dry matter. Monensin supplementation increased apparent nitrogen digestibility and nitrogen retention and decreased the percentage of nitrogen apparently absorbed in urine. Apparent digestibilities of dry matter, gross energy and acid detergent lignin were increased. In growing wether goats, fed either 8.5% crude protein in the control diet or the control diet supplemented with monensin at the rate of 23 mg/kg of diet dry matter, monensin-receiving goats had better apparent nitrogen digestibility and apparent nitrogen absorption. Also efficiency of feed conversion and average daily gain were improved with monensin supplementation.

Zinn (1987) tested the effects of lasalocid and monensin plus tylosin on the comparative feeding value of steam-flaked versus dry-rolled corn in diets for feedlot cattle. He found that monensin-tylosin supplementation resulted in 12.3% reduced feed intake and in improved feed conversion by 5%. In an experiment involving pasture and feedlot cattle

feeding, Talbert et al. (1979) found that cattle on pasture receiving 300 mg/day gained faster than those not receiving monensin on pasture. When cattle were removed to the feedlot, cattle receiving monensin outgained cattle not receiving monensin in the feedlot. When cattle were removed to the feedlot and received monensin in the feedlot, cattle receiving 2 lb corn plus monensin on pasture gained less than those receiving 2 lb of corn without monensin on pasture

Compensatory growth

Compensatory gain is the greater growth rate exhibited by an animal after feed restriction has been lifted as compared with continuously fed counterparts. In his review of compensatory gain in beef cattle Carstens (1995) mentioned that the degree of compensation after feed restriction was variable and was affected by several factors including: 1- stage of maturity at start of growth restriction, 2- severity of growth restriction, 3- duration of growth restriction, and 4- pattern of growth during realimentation. He also pointed out the mechanisms which were involved in the more rapid and efficient growth following periods of growth restriction. These mechanisms were: 1- reduction in energy density of growth tissue, 2- reduction in maintenance energy requirements, 3- increase in net efficiency of tissue growth, 4- increase in feed intake and 5- increase in gut fill.

Cattle undergoing compensatory growth accumulate less carcass fat than continuous growth steers (Harris, 1994). Carsten et al. (1991) examining physical and chemical components of the empty body during compensatory growth in beef steers found that cattle previously restricted to 0.4 kg/d for 6 months and undergoing compensatory gain had 12 % more empty-body protein and 25 % less empty-body fat than continuous growth steers at 450

kg empty-body weight. Because of the more protein gain and less fat accumulation, empty-body composition resulted in an 18% decrease in NE_g requirement for compensatory growth steers.

However not all researchers found a decrease in fat accumulation. Tudor et al. (1980) and Abdalla et al. (1988) found an increase in fat deposition during compensatory growth. These conflicting results illustrate the importance of degree of maturity at the time of restricted growth. The experiments of Harris (1994) and Carsten et al. (1991), which demonstrated less fat deposition during compensatory growth, used cattle of 8 months or older. On the other hand Tudor et al. (1980) and Abdalla et al. (1988) used cattle that were less than 2 months of age at the start of the experiment and these cattle deposited more fat during compensatory gain.

Duration of growth restriction and severity of restriction also affect compensatory growth. Smith et al. (1977) restricted growth of small frame steers on a low energy diet (2.18 Mcal ME/kg) and on a moderate energy diet (2.40 Mcal ME/kg) before putting them on a high energy diet. They found that steers fed the low energy diet were leaner than those on a moderate energy diet and steers fed the high-energy diet continuously were fatter than restricted steers.

When Ledger (1973) fed steers to maintain body weight for 12 and 24 weeks of duration, he observed that during realimentation growth rates were 0.81 and 1.16 kg/d for cattle restricted for 12 and 24 weeks, respectively. The reason for the observed increase in performance of animals during realimentation is that there is a metabolic lag phase where ME_m stays at a low stage and efficiency of energy utilization remains high until the animal

becomes accustomed to the higher energy diet. Thus during this time less energy is expended for maintenance and energy is utilized for tissue growth.

The reason for the increase in ME_m is the increase in visceral organ mass. Even though visceral organs provide only 10 % of the total body weight, they account for 50 % of the energy expended by animals (Ferrel, 1988; Johnson et al., 1990). When animals are fed restricted diets, the weight of visceral organs decreases as a reaction to dietary energy restriction and thus energy requirements for maintenance are reduced (Carstens, 1995). Johnson (1985), who measured the proportional weights, affirmed the increase in visceral organ weights. In his experiment he measured proportional weights (g/kg EBW) of liver and fat-free GIT tissues in steers following feed restriction for 45 days and in which body weights were maintained. At days 15, 30 and 45 after realimentation he again measured the weights of liver and fat-free GIT tissue and found that proportional weights of liver were 30, 35 and 39 % larger and GIT tissue weights were 16, 20 and 22 % larger on days 15, 30 and 45 after realimentation, respectively.

One other mechanism that is responsible for compensatory growth in cattle is increased dry matter intake per unit of metabolic weight (Carstens 1995). NRC (1984) concluded that yearling cattle undergoing compensatory growth ate 10 % more feed than calves of similar weight and frame size.

Several researchers found 7 to 20 % differences in GIT fill in cattle displaying continuous and compensatory growth (Thomson et al., 1982; Wright and Russel, 1991 and Carstens et al., 1991). The underlying reason for this is the impulse to compensate for the earlier undernutrition during realimentation and thus increased DMI and greater GIT capacity (Carstens 1995).

During compensatory gain some changes have been observed in hormonal status. Hayden et al. (1993) fed steers an isonitrogenous forage-based diet containing low (restricted) or adequate energy (nonrestricted) levels during the restriction period, which lasted for 92 days, and then realimented them with a high energy whole shelled corn and corn silage diet. He found that during the restriction period there was decreased empty body protein and empty body fat accretion in steers fed the low energy diet. And during this period, plasma levels of glucose, IGF-I, insulin, T_3 , T_4 and rT_3 were decreased; plasma urea nitrogen, nonesterified fatty acid and growth hormone levels were increased and IGF-II concentrations were similar between restricted and nonrestricted steers. When animals were realimented, plasma urea nitrogen level in restricted animals decreased and glucose concentration increased to levels similar to those in the nonrestricted group. During realimentation plasma levels of T_4 , T_3 , rT_3 , IGF-I and insulin were positively, and growth hormone was negatively correlated with empty body protein and empty body fat accretion.

In another experiment, conducted on weaned Hereford crossbred heifers, Yambayamba et al. (1996) found that during 95 days of feed restriction, GH and nonesterified fatty acid (NEFA) were higher and concentrations of IGF-I, T_4 , T_3 , insulin and glucose were lower compared to heifers having ad libitum intake levels. During realimentation concentrations of IGF-I, insulin, glucose and NEFA in restricted heifers increased and no differences were observed between restricted and ad libitum fed heifers at day 10 of realimentation. During the first 10 days of realimentation, GH levels in restricted heifers stayed elevated whereas T_4 , T_3 concentrations stayed lower. After day 31 of realimentation, GH, T_3 , and T_4 levels leveled off and were similar to those of ad libitum fed heifers. Resting metabolic rate measured 5 days before realimentation indicated that the

metabolic rate in restricted heifers was slower. This was partly attributed to lower thyroid hormone concentrations, which are associated with basal metabolic rate (Murphy and Loerch, 1994).

Forage quality and utilization

Forage quality is the most important factor determining the performance of grazing animals and is defined as the relative performance of animals when herbage is fed ad libitum to livestock (Buxton et al., 1996). It's the product of nutrient concentration, intake potential, digestibility, and partitioning of metabolized products within the animal (Buxton et al., 1996).

In general, cool-season grasses and most other grasses are not able to meet the energy needs of moderate to high-producing herbivores because of low digestibility of their organic matter. This becomes more prominent especially when forages mature (Buxton et al., 1996).

Nutrients in plants that provide available energy for animals are carbohydrates, proteins and lipids (Buxton et al., 1996). However most of the energy is obtained from carbohydrates, which make up 80 percent of the energy and lipids which provide less than 5 percent of the energy obtained by ruminants (Van Soest, 1982).

According to Van Soest (1982), for forage quality evaluation plant cells are divided into cell wall and cell solubles. Cell walls are composed primarily of cellulose microfibrils embedded in hemicellulose and lignin matrix. Cell solubles are easily digested. Thus cell walls are the main reasons for variation in voluntary intake and digestibility of forages consumed by ruminants (Buxton, 1990).

In his review of histological and physical factors affecting digestibility of forages, Akin (1989) mentioned the response of tissue types to digestibility. When he categorized the relative digestibilities as rapid, slow to partial and nondegraded, he showed that mesophyll, phloem, epidermis, parenchyma bundle sheath (depending upon species and growth condition) in cool-season grass leaves were rapidly digestible. Whereas parenchyma bundle sheath (depending upon species and growth condition) and sclerenchyma were slow-to partially digestible and xylem and inner bundle sheath were nondegradable. In grass stems phloem and immature parenchyma were rapidly digestible, whereas medium age parenchyma was slow-to partially digestible and epidermis and sclerenchyma rings were nondegradable.

Lignin is the most significant factor affecting the availability of plant cell wall material to animals and anaerobic digestion systems (Van Soest, 1994). Sarkanen and Ludvig (1971) defined lignin as “polymeric natural products arising from an enzyme-initiated dehydrogenative polymerization of three primary precursors”. Those three precursors are coniferyl, sinapyl, and *p*-coumaryl alcohols (Jung and Deetz, 1993). Lignins are classified as core and non-core lignins (Jung, 1989).

Jung and Deetz (1993) defined core lignin as “the phenylpropanoid polymer deposited in the cell wall from polymerization of cinnamyl alcohols during secondary wall thickening” and non-core lignin as “*p*-coumaric and ferulic acid, and their dimers, present in the wall and deposited there during both primary and secondary wall development”.

Core lignins are covalently connected to hemicellulose in forage cell walls whereas among the non-core lignins, *p*-coumaric acid is linked to the core lignin fraction and ferulic acid is linked to the hemicellulose fraction (Jung 1989).

Even though Casler (1986) did not have the data available on the composition of lignins in smooth brome grass to support his hypothesis, he suggested that lignin concentration was the most important limiting factor for smooth brome grass fiber fermentability.

When Jung and Casler (1990) evaluated nine divergent smooth brome grass genotypes selected for high or low in vitro dry matter disappearance (IVDMD) in terms of their genotypic variation of lignin concentration and composition, they found that differences were observed between the IVDMD genotype groups for NDF, hemicellulose and cellulose concentration in leaf blade tissue, and NDF and hemicellulose concentration of stems. And core lignin concentration was greater in stems of the low IVDMD group but not leaves and yield of core lignin products was greater for the low IVDMD group leaf blades but not stem plus sheath tissue. In another study by Carpenter and Casler (1990), second divergent selection in the progenies of the same nine high IVDMD genotypes showed the same close association between lignin concentration and IVDMD. Thus Jung and Casler (1990) suggested that lignin concentration remained the major factor limiting the digestibility.

Environmental effects, such as ambient temperature and physiological maturity, influence cell wall concentration and digestibility. Ford et al. (1979) found that increasing ambient growth temperature resulted in higher lignin concentration in C₃ grass species, which fix CO₂ with ribulose biphosphate, a 5-carbon sugar, to form two molecules of a 3-carbon acid called 3-phosphoglyceric acid. However there was no change in C₄ grasses, which fix CO₂ into oxaloacetate, a 4-carbon acid, for total lignin. In an experiment designed to investigate the influence of soil moisture and ambient temperature on yield and quality of alfalfa forage, Vough and Marten (1971) found that under a controlled environment setting,

alfalfa grown at 27 C during the day and 21 C during the night produced less dry matter and had lower digestibility and higher ADF and ADL than alfalfa grown at 16 C during the day and 10 C during the night. They concluded that the reason for the decrease in IVDDM with increasing temperature was due to the decreased digestibility of stems and the reason for less dry matter yield for alfalfa grown at higher temperature was due to shorter growing periods to first bloom.

Jung et al. (1983) and Burrit et al. (1984) observed that there was an increase in concentrations of esterified non-core lignin components in grasses, but little change in alfalfa with the increased physiological maturity. Buxton et al. (1985) compared the nutritive value of stems and leaf blades and the change in nutritive value during advancing maturity in alfalfa, birdsfoot trefoil and red clover and found that in vitro digestible dry matter concentration in total herbage decreased with increased maturity and this was due to the rapid decrease in stem IVDMD. White (1983) determined the seasonal change in dry matter yield, estimated in vivo dry matter digestibility, and determined crude protein content of the vegetative floral tillers of western wheatgrass and green needlegrass on forage harvested from April through October in two years. He found that in terms of dry matter yield species had different patterns, but dry matter digestibility and crude protein content followed the same pattern and there was a decrease in dry matter digestibility and crude protein content with time. There was an increase in estimated in vivo dry matter digestibility of vegetative tillers of both species in both years from late April through mid-May. However from mid-May to late August dry matter digestibility of vegetative tillers of both species decreased an average of 0.16 percentage units per day in the first year and the second year this decrease was 0.25 and 0.22 percentage units per day for western wheatgrass and green needlegrass,

respectively. Crude protein in vegetative tillers of both grasses reached nearly 25 % during late April and early May in both years and decreased rapidly until mid-July and remained between 10 and 12 % during late summer and fall in first year and between 5 and 10 % in second year.

Buxton (1990) conducted an experiment to determine whether concentrations of NDF and cell wall components differed for divergent germplasms of four perennial grass species and to what degree this difference in composition accounted for variation in digestibility. He found that there was an increase in NDF and lignin concentration in total herbage with advancing time and top stems and leaves of reproductive tillers had lower concentrations of NDF than bottom stems in smooth brome grass. The results obtained from this research helped to explain the results obtained by Buxton and Russel (1988) who found that NDF digestibility of Orion orchardgrass stems was 18 % greater than that of Napier orchardgrass for immature stems and 8 % greater for mature stems. They stated that the major reason for the difference in IVDMD was due to the difference in NDF digestibility of stems resulting from differences in cell wall lignin concentration.

Mullahey et al. (1992) conducted an experiment to evaluate ruminal escape protein using an in situ rumen technique for switchgrass and smooth brome grass. Whole-plant, leaf and stem samples of smooth brome grass were harvested on June 4 (first-growth), July 15 (regrowth), July 31 (regrowth), August 19 (regrowth) and September 24 (regrowth) and forage was separated into leaf and stem fractions before incubation in situ. Results of the experiment showed that total crude protein generally decreased with maturity and was always higher for leaves than stems. Escape protein concentration was generally higher in leaves than stems, however, stems had a higher percentage of escape protein.

Stefanon et al. (1996) studied the effect of maturity on digestion kinetics of water-soluble and water-insoluble fractions of alfalfa and brome hay. They harvested brome on May 1, 8, 14, 21, and 28 and harvested alfalfa on May 8, 15, and 29, June 2 and 12. When species were harvested, the early samples were in the vegetative stage of growth and the latest brome samples were fully headed out and alfalfa samples were in early bloom. Chemical composition of forages showed that although organic matter remained nearly constant, crude protein and percentage solubles decreased and NDF and ADF increased with increasing forage maturity for both alfalfa and brome and fiber digestibility decreased with increasing maturity.

Adams et al. (1987) used eight ruminally fistulated and 5 esophageal-fistulated Angus X Hereford steers to study the effects of advancing forage maturity on rumen fermentation, fluid passage, fluid volume, and forage intake on native range from May 4 to November 5. They found that an increase in forage maturity was coupled with a reduction in individual and total ruminal fatty acid, ammonia nitrogen, pH, and fluid dilution rate and increased rumen fluid volume. They concluded that differences in rumen fluid passage, volume, and fermentation were due to forage maturity and protein supplementation might be valuable during late summer and early fall to increase or maintain animal production.

Cleale and Bull (1986) fed lactating and non lactating cows with mixed grass silages harvested at early and late maturities from the same field to determine maturity effects on ration digestibility when forages were fed alone or in complete rations. They also measured in situ dry matter disappearance using a rumen-fistulated steer. They found that percent digestible dry matter remaining in dacron bags was lower for early cut silage and disappearance rate was higher. When non-lactating cows received early cut or late cut forage

the dry matter, crude protein, ADF, and NDF digestibilities were better for early cut forage. Lactating cows receiving early cut forage had higher ADF, NDF digestibilities and better nitrogen balance. Concentrate to forage ratios necessary to meet energy requirements were 60:40 and 78:22 for diets containing early and late cut forage, respectively. Thus for each day of advancing forage maturity, approximately 1% more concentrate was needed in the total ration. Laredo and Minson (1975) fed sheep *ad libitum* with pangola grass, rhodes grass and *Setaria splendida* in the chopped and pelleted form to determine whether the differences in leaf and stem intake were caused by physical or chemical factors. They found that higher intake of leaves was associated with larger surface area, lower bulk density and lower NDF, ADF, and lignin contents. Chopped leaves stayed in the reticulo-rumen for a shorter time than the stem fraction. Grinding and pelleting increased the voluntary intake of leaf fraction by 88 % and stem fraction by 60 %. This increase in voluntary intake by grinding was due to the reduced retention time in the reticulo-rumen. Thus they concluded that higher intake of leaf fractions of grasses was due to lower retention time in the reticulo-rumen and the differences in retention time were caused by differences in physical properties and not chemical composition.

Burns et al. (1991) in a 2-year study examined dry matter intake, gastrointestinal tract fill of undigested dry matter, rate of digesta passage and digesta mean retention time for steers grazing tall fescue, switchgrass, flaccidgrass and bermudagrass. They found that steers grazing subtropical perennial grasses in June and July had different responses. Steers grazing in June had shorter mean retention time, higher rate of digesta flow, higher dry matter intake and higher digestible dry matter intake than steers grazing in July.

In Australia, Poppi et al. (1980) offered pangola grass and rhodes grass, which were cut at 6 and 12 weeks of regrowth, to four cattle and eight sheep fitted with ruminal cannula to examine the effect of forage maturity and leaf and stem fractions on the voluntary intake, digestibility and retention time in the reticulo-rumen. They found that voluntary intake, digestibility of dry matter and digestibility of NDF decreased as forage matured and cattle consuming leaf fractions had higher voluntary intake and better digestibilities of dry matter and NDF. In terms of retention time, apparent retention time of dry matter, organic matter, and NDF was lower for leaf fractions than for stem fractions and it increased as forage maturity advanced. With the same experimental setup described previously by Poppi et al. (1980), Poppi et al. (1981) tried to explain factors controlling the retention of feed in the reticulo-rumen and concluded that the retention time of NDF was closely correlated with the time lignin was retained in the rumen ($r=0.93$). Thus higher voluntary intake of leaf fractions was explained by their higher rate of passage of the NDF from the rumen and higher potential digestibility of NDF and apparent higher rate of digestion of NDF.

Park et al. (1994) grazed 6 ruminally cannulated Holstein steers on nonirrigated and intermediate wheatgrass pasture from April through December and took sample collections in May, June, September and November to study the effect of maturity on nutrient quality, forage intake, digesta kinetics, ruminal fermentation, and serum hormones and metabolites. They found that with increases in forage maturity total masticated N decreased and bound N increased, particle passage rate decreased and gastrointestinal mean retention time increased, extent and rate of NDF digestion decreased, ruminal NH_3 and total VFA concentrations decreased. Advancing forage maturity did not affect serum growth hormone concentrations and serum insulin-like growth factor decreased with advancing forage maturity.

Pasture use and integration

Animals compete with humans for cereal grains and this concern grows larger with the increase in human population. About one-sixth of the energy required by livestock is derived from grains. Poultry and swine utilize about 59 % of these cereals to produce about 39 % of the human food energy from livestock, and ruminants utilize about 37 % of grains fed to livestock but produce 61 % of human food energy from animal agriculture (Wheeler et al., 1981). With their unique ability to convert vast renewable resources from rangeland, pasture, and crop residues or other by-products into food, cattle are very important for sustainability (Oltjen and Becket, 1996). Pastures, rangelands, meadows, forests, and woodlands constitute 55 % of the world's land and have the potential of producing 5.8 trillion Mcal of metabolizable energy (Wheeler et al., 1981).

An option to grain feeding is increased level of pasture use for beef cattle production. Beef cattle can be finished on all-forage finishing systems. However all-forage finishing has not been very successful because carcasses from these cattle are discriminated against by packers due to their lowered dressing percentage, higher cooler shrinkage and lower quality grade (Schroeder et al., 1980). Research on the effects of pasture finishing on meat palatability have been inconclusive. Some research has indicated that without grain feeding, the carcasses usually have a poor grade and a milky or grassy flavor (Brown et al., 1979; Davis et al., 1981). Other reports have indicated desirable characteristics of forage-fed cattle (Oltjen et al., 1971; Cross and Dinius 1978) and some researchers have reported no differences in flavor between forage-finished and grain-finished cattle (Crouse et al., 1984; Bidner et al., 1985).

Some research has indicated that feeding a high energy diet before slaughter improved beef palatability, however little additional benefit in ultimate cooked beef palatability is attained by extending the feeding period (Zinn et al., 1970; Campion et al., 1975; Tatum et al., 1980).

Ridenour et al. (1982) designed an experiment with the objective of measuring performance and carcass characteristics of 365 crossbred steers. Five growing programs were as follows: 1) high concentrate diet throughout growing to 600 lb and finishing; 2) 50 % concentrate diet to 600 lb and then high concentrate; 3) 50 % concentrate to 800 lb and then high concentrate; 4) irrigated wheat pasture to 600 lb and then high concentrate and 5) irrigated wheat pasture to 800 lb and then high concentrate. They found that cattle put in the feedlot throughout the growing and finishing period had higher overall ADG than cattle that spent various times on pasture and as the time on pasture increased, finishing ADG in the feedlot decreased and overall ADG was higher for cattle that spent less time on pasture. In terms of carcass characteristics, it was shown that there were no significant differences in slaughter and carcass weights, fat thicknesses, and USDA yield grades. Steers put in the feedlot directly had higher dressing percentages, larger ribeye areas and more kidney, pelvic and heart fat than other treatments.

When Gill et al. (1993a) tested five management systems, which were: 1) early weaned and placed into a feedlot at 3.5 months; 2) weaned and placed in a feedlot at 7.9 months; 3) weaned at 7.9 months but grazed wheat pasture for 112 days before placing in a feedlot at 11.6 months; 4) weaned at 7.9 months but wintered on dry native range and then grazed on early intensively managed native range for 68 days before placing in a feedlot at 15.4 months; 5) weaned at 7.9 months, wintered on dry native range and then grazed native

range for 122 days before placing in a feedlot at 17.4 months. They found that early weaned calves at 3.5 months of age gained less and had better feed efficiency than cattle on the other treatments and the longer cattle spent time on pasture the less efficient they became in the feedlot. Reporting the economics and carcass characteristics of the previous experiment, Gill et al. (1993b) found that hot carcass weights of grazed and wintered calves were heavier than that of early-weaned and calves weaned at 7.9 months and placed into the feedlot. There was no difference in ribeye areas, yield and quality grades. Early weaned calves had the lowest breakeven, total cost of gain and thus highest profit, and cattle grazed or wintered and grazed before entering the feedlot had higher breakeven, total cost of gain and lower profit than those weaned at 7.9 months and placed into the feedlot. Regarding body composition, Gill et al. (1993c) found that protein and water as a percent of empty body weight was lowest for early weaned calves and higher for cattle grazed or wintered and grazed before entering the feedlot. A reverse trend in fat existed as opposed to protein content for percent empty body weight.

Lewis et al. (1990a) compared intensive versus extensive systems of beef production and beef cow milk production on postweaning performance. They used Charolais-sired calves from three groups of beef cows, similar in growth potential and mature size, but different in genetic potential for milk production. They allotted calves in an intensive system in which, at weaning, calves went directly into the feedlot for finishing (236 days), and in an extensive system in which calves at weaning were wintered on corn residues (195 days), followed by grazing pasture (115 days) and then placed into the feedlot and finished (122 days). They found that cattle from the intensive system had higher levels of subcutaneous and KPH than did cattle from the extensive system, indicating that they were fatter. In the

extensive system cattle had higher ADG and DMI in the feedlot than those from the intensive system.

Hedrick et al. (1983) fed 351 weaned Hereford-Angus crossbred steers to study the effect of production system on beef palatability and carcass characteristics. They found that carcasses from grass-fed cattle had lower quality grades, higher cutability, lower fat thickness, lower KPH and darker color lean and had loin steaks less desirable in flavor, juiciness, tenderness and overall acceptability than that of carcasses obtained from other cattle which received any amount of corn.

Perry et al. (1971) studied the utilization of pasture in a beef finishing program in comparison to feedlot finishing by putting a group of cattle on pasture on May 6 through July 2 for 58 days. The treatments on pasture were cattle only grazing, cattle grazing but additionally getting one-third of the ground ear corn feedlot cattle were receiving, cattle grazing and getting two-thirds of the ground ear corn feedlot cattle were receiving and cattle grazing and receiving the same amount of ground ear corn that feedlot cattle were receiving. They found that on pasture cattle receiving supplemental corn gained better than those not receiving corn and ADG was higher for cattle receiving higher amounts of corn. However, this trend was reversed in the feedlot when the cattle were removed to the feedlot. In the feedlot, cattle that had been in the feedlot throughout the feeding phase gained slightly higher than the other cattle. Perry et al. (1972) used the same experimental design, which was described earlier in Perry et al. (1971), however they grazed cattle on pasture between May 6 through September 18 for 135 days. They found the same results on pasture, however when cattle were removed to the feedlot, cattle not receiving any supplement on pasture performed better than those that received supplement and those fed in the feedlot throughout the feeding

trial. Regression analysis showed that for each 100 kg of extra gain obtained during the pasture period there was a decrease of 29 kg during the drylot finishing period.

Prichard et al. (1988) assigned 72 crossbred beef steers after weaning in the fall to the following feeding regimes: 1) zero backgrounded, placed directly on a finishing ration for 188 days; 2) delayed feedlot, wintered on hay and silage prior to finishing for 170 days; 3) backgrounded on cool-season annual pasture prior to finishing for 91 days; and 4) backgrounded on cool-season annual pastures prior to finishing for 126 days. They found that cattle zero backgrounded had higher ADG and better feed efficiencies in the feedlot than other cattle. Cattle backgrounded longer on cool-season annual pasture had higher ADG than those backgrounded for a shorter time. Cattle that went directly into the feedlot and cattle backgrounded on pasture for 91 days had more ribeye area per hundred pounds of carcass weight and better yield grades than carcasses from cattle backgrounded on pasture and fed for 126 days and carcasses from delayed feedlot steers fed for 170 days. Quality grade, KPH fat, lean color, lean texture and lean firmness did not differ among treatments.

Dufresne et al. (1995) studied the effects of grazing period on the performance of finishing Belgian Blue bulls compared with an indoor finishing system. They grazed 6 bulls on one acre of pasture (medium stocking rate) starting in the beginning of May and lasting 140 days, and grazed 8 bulls on one acre of pasture (high stocking rate) for 140 days starting the beginning of May and then finished these animals in the feedlot. They found that compared with the feedlot group, initially grazed groups had to spend more time to reach market weight and had lower gains in the feedlot and lower dressing percentages. Cattle grazed initially had higher dressing percentages, higher muscle and bone proportions and lower adipose tissue proportions compared with indoor fed cattle.

Gunter and Phillips (1998) compared the performance of 105 weaned fall-born calves managed under intensive-early (IES; 5 steers/acre for 70 days) or season-long stocking (SLS; 2.5 steers/acre for 140 days) starting on May 15. Treatments for SLS groups were given no supplement, one pound of ground corn per day per steer and 1.1 pounds of cottonseed meal per day per steer whereas treatments for IES were given no supplement, one pound of ground corn per day per steer. On pasture after the first 70 days, the SLS group gained better than the IES group and from days 71 to 140 the average daily gain of the SLS group declined rapidly. The IES group had a higher dressing percentage and higher fat thickness than the SLS group.

Davis et al. (1981) slaughtered 20 forage-fed, 20 limited grain finished and 19 grain finished steers to determine the effect of electrical stimulation on carcass quality and meat palatability. The results revealed that electrical stimulated carcass sides had higher lean color, firmness and texture scores and less heat-ring than non-stimulated sides. Grain finished cattle had higher slaughter and carcass weights, better dressing percentages, higher fat thickness, more KPH and bigger *Longissimus* muscle area than those of forage finished or limited grain finished cattle. In terms of palatability attributes, grain finished cattle had better tenderness, juiciness rating than forage finished cattle and tended to have better tenderness rating than limited grain fed cattle. They also had better flavor rating and overall desirability than both forage finished and limited grain finished cattle. They concluded that drylot grain feeding is necessary to produce an acceptable meat product and it was not reasonable to produce steers on all-forage or limited grain diets and expect loin steaks to have acceptable appearance and palatability even if carcasses are electrically stimulated.

Harrison et al. (1978) evaluated quality and yield characteristics of 38 crossbred steer carcasses from 4 nutritional regimes. The nutritional treatments were as follows: grass-fed = winter growing ration (2.18 Mcal ME/kg) followed by summer grazing; short-fed = same as grass-fed, followed by 49 days in feedlot on a high grain ration, (3.11 Mcal ME/kg); long-fed = same as short-fed, except fed 98 days in feedlot; and forage-fed = the same as grass-fed followed by 98 days in feedlot on a high forage ration, (2.84 Mcal ME/kg). They found that carcasses from cattle fed the longest time and the highest plane of nutrition had the most desirable quality and palatability characteristics.

Morris et al. (1996) studied the integration of winter growing, summer grazing and finishing period. They wintered calves at two rates of gain. One rate was slow (less than 1 pound) and another fast (approximately 2 pounds) and then split the calves from each winter treatment for summer grazing from May to July (for 62 days) or September (for 120 days). Following the grazing period all steers received a common 90 % concentrate finishing diet for 121 days (short) and 127 days (long). They found that extending the length of summer grazing decreased finishing gain and efficiency but increased final weight and total cost. Cattle wintered at the slower rate of gain gained faster on pasture than those wintered at the higher rate of gain. Steers that grazed for the full summer grazing period (120 days) had lower ADG than those short grazed but had the highest total gain on pasture. Cattle that were on pasture for the short grazing period had faster finishing gain in the feedlot and tended to be more efficient. In terms of economics there were no differences among breakeven prices.

Sapp et al. (1996) compared performance and carcass characteristics of cattle grazed on wheat-ryegrass, grazed on wheat-ryegrass pasture for 111 days and removed to the feedlot and cattle fed in the feedlot throughout the study. They reported that steers that were in the

feedlot throughout the study had higher daily gains and USDA yield and quality grades than pasture-fed steers and those grazed and removed to the feedlot later. Feedlot steers were fatter than those pasture-fed and those grazed and removed to the feedlot and this fact was reflected in their higher backfat, KPH, trimmable fat and lower lean to fat ratio.

Lewis et al. (1990b) examined the economics of extensive and intensive beef production systems. The intensive system was the system in which Charolais-crossbred calves were weaned and placed into a feedlot to finish on a high grain diet and the extensive system was the system in which calves were wintered on crop residues, grazed on summer pasture and finished on a high-grain diet in drylot. They found that overall, cost of gain and final breakeven price were lower for cattle finished through the extensive system except when the corn price was very low in relationship to other inputs. The reason for the lower final breakeven price for the extensive system was the additional weight produced through the system.

CHAPTER 3. MATERIALS AND METHODS

The three-year study was initiated with the establishment of a cool season grass pasture, smooth brome grass, in May 1995, at the Western Iowa Research and Demonstration Farm at Castana, Iowa, and was concluded in June 1999. In order to reduce the genetic variation and backgrounding differences among calves, the Stuart Ranch near Caddo, OK, was chosen as the provider of the calves. The composition of breed consisted of Hereford and Angus x Hereford cows and the cows were mated to either Angus or Hereford bulls to provide mainly crossbred calves. The cow herd was large enough to provide homogenous spring- and fall-born calves. Each year eighty-four fall-born calves were used in the initial phase of the study. The calves were backgrounded and given their calfhood vaccinations at the ranch. After 12 hours of transportation they arrived at the research farm on April 17, 1996, April 15, 1997, and April 15, 1998, in the first, second and third years of the study, respectively. In order to alleviate the transportation stress and make calves accustomed to their environment, calves were given ground, mid-bloom alfalfa hay on arrival until May 7, 1996, May 8, 1997, and May 5, 1998, in the first, second and third years of the study, respectively. As a health precaution calves received one gram per head per day of chlortetracycline, which was fed at the rate of 0.25 lb per animal of four gram per lb AS-700® crumbles, top-dressed on the hay each morning. To aid in controlling coccidiosis, Amprolium® was added to the water source for two weeks after arrival of the calves. Before being placed on test on May 7, 1996, May 8, 1997, and May 5, 1998, calves were identified with an ear tag, implanted with Compudose®, and injected with Ivomec® plus Flukocide®. Cattle were tagged with Saber™ insecticide ear tags in the first week of June and this was repeated in the first week of

August of each year. They were randomly allotted into 12 groups of 7 animals each, and weighed on the average 367, 350 and 432 lb in the first, second and third years, respectively.

Five treatments, which involved four grazing and one control treatment, were assigned at random. On pasture supplement blocks either with monensin or without monensin were provided. The first treatment involved 14 steers (JI) receiving an ionophore and were stocked on smooth brome grass pasture on May 7, 1996, May 8, 1997, and May 5, 1998, respectively, and then moved to the feedlot on July 30, 1996, July 29, 1997, and July 28, 1998, respectively, to be fed the finishing diet during the remainder of the trial. A second treatment involved 14 steers (JNI) not receiving an ionophore and were stocked on smooth brome grass pasture on May 7, 1996, May 8, 1997, and May 5, 1998, respectively, and then moved to the feedlot on July 30, 1996, July 29, 1997, and July 28, 1998, respectively. A third pasture treatment involved 14 steers (OI) receiving an ionophore and were stocked on smooth brome grass pasture on May 7, 1996, May 8, 1997, and May 5, 1998, respectively, and then moved to the feedlot on October 22, 1996, October 21, 1997, and October 16, 1998 respectively. A fourth pasture treatment involved 14 steers (ONI) not receiving an ionophore and were stocked on smooth brome grass pasture on May 7, 1996, May 8, 1997, and May 5 1998, respectively, and then moved to the feedlot on October 22, 1996, October 21, 1997, and October 16, 1998, respectively. A control group (FEEDLOT), 28 steers (seven head per pen), was placed directly into the feedlot after acclimation and was gradually adapted to an 82 % concentrate diet containing whole shelled corn, ground alfalfa hay, and a natural protein, vitamin and mineral supplement containing an ionophore and molasses. Cattle moved from pasture to the feedlot at various times received the same feed the control group received. In the feedlot when animals reached 800 lb, the supplement was changed from

natural protein to a urea-based 40 % crude protein, vitamin and mineral premix. About 100 days prior to slaughter, cattle were implanted with Revelor®.

The remaining two treatments involved obtaining 28 spring-born calves from the same ranch on September 17, 1996, September 15, 1997, and September 15, 1998, respectively, and processing them in the same manner as fall-born calves. A sixth pasture treatment (SI) involved 14 spring-born steers receiving an ionophore and were stocked on smooth bromegrass pasture on October 1, 1996, September 30, 1997, and September 29, 1998, respectively, and then moved to the feedlot on October 22, 1996, October 21, 1997, and October 16, 1997, respectively, to be finished. A seventh pasture treatment (SNI) involved 14 spring-born steers not receiving an ionophore on pasture that were stocked on smooth bromegrass pasture on October 1, 1996, September 30, 1997, and September 29, 1998, respectively, and moved to the feedlot on October 22, 1996, October 21, 1997, and October 16, 1997, respectively, to be finished.

The pasture was enclosed by a 5 wire barbed wire fence with wood corner posts and 6 feet metal T-posts spaced every 20-25 feet. An electrified wire was placed on the inside of the barbed wire fence on "offset" insulators. The pasture consisted of 16 paddocks, each 1.7 acres in size and was subdivided using metal T-posts and braided 5-wire electric cable. Posts were spaced every 25 feet with 3-inch wooden posts in draws and high spots. Two wires were strung with the bottom 9 notches high and the top 16 notches high.

Each grazing group had access to one paddock at a time. Cattle on the pasture were rotated on the basis of forage availability. In early summer, the cattle were not capable of consuming adequate forage to match the growth of the forage in all the paddocks, therefore they were rotated to a new paddock every three to four days. However later in the season

when grass growth slowed, cattle were rotated about every two days to a new paddock.

Nitrogen fertilizer was applied in two applications: one application of 100 lb per acre applied in late April and the other of 80 lb per acre applied in mid-August.

The feedlot facility consisted of pens with concrete floors, 26.5 meters by 4.3 meters, with 7 meters of overhead shelter at the north end of each lot. Steers were fed in fence-line concrete bunks, providing 53 cm of feedbunk space per animal, on the south side of the lot and one automatic waterer was shared between every two pens.

Feed allotment was determined daily prior to the morning feeding. Cattle were fed *ad libitum* and feed intake levels were provided such that feed was always available in the feedbunks. Feed provided was increased when the bunks in approximately one-half of the pens were completely empty at 0700 prior to the morning feeding.

Daily DMI was determined for each pen by recording the amount of air-dry feed fed from a feed wagon equipped with a digital scale, and converting the amount to a DM basis. Feed samples were collected twice per week for dry matter determination. Every 28 days steers were weighed individually and average daily gain for that period and throughout the experiment were calculated. Dry matter intake by individual steers was represented by pen dry matter intake. In order to predict individual dry matter intake in pen fed feedlot cattle, equations developed by Perry and Fox (1997) and later revised by Loy (personal communication) were used.

The equations for predicting individual dry matter intake are as follows:

$$EBW = 1.316CW + 32.29.$$

$$EBF\% = (0.351EBW + 21.6YG - 80.8)/100 \times EBW.$$

$$AFBW = (EBW + ((28 - EBF\%) \times 19))/0.891.$$

$$SBW = EBW/0.891.$$

$$EQSW = SBW (467/AFBW).$$

$$EQEBW = EQSW \times 0.891.$$

$$AVEW = (SBW + \text{Initial weight})/2.$$

$$EBG = 0.956 \times ADG.$$

$$RE = 0.0625EQEBW^{0.75} \times EBG^{1.097}.$$

$$FFG = RE/\text{diet } NE_g.$$

$$FFM = 0.077 \times AVEW^{0.75}/\text{diet } NE_m$$

$$\text{Sum FFG for all animals in pen (FFG}_p\text{)}.$$

$$\text{Sum FFM for all animals in pen (FFM}_p\text{)}.$$

$$\text{Sum total period DMI for pen (DMI}_p\text{)}.$$

$$\text{Subtract FFG}_p \text{ and FFM}_p \text{ from DMI}_p.$$

Prorate the remainder (FFM_{adj}) according to metabolic weight (divide the remainder by the sum of the AVEW^{0.75} for all animals and divide this number by each animals' AVEW^{0.75}).

$$DMI = FFG + FFM + FFM_{adj}.$$

Where:

EBW = Empty body weight.

CW = Carcass weight.

EBF% = Empty body fat, %.

YG = Yield grade.

AFBW = Final shrunk body weight adjusted to 28 % fat.

SBW = Shrunk body weight.

EQSW = Equivalent empty shrunk weight.

EQEBW = Equivalent empty body weight.

AVEW = Average shrunk body weight during the feeding period.

EBG = Empty body gain.

RE = Retained energy.

FFG = Feed for gain.

FFM = Feed for maintenance.

FFM_{adj} = Term for surplus or deficit NE_m to adjust for environment and error.

Carcass measurements

When the average weight of the pen of steers reached 1,150 lb, cattle were shipped for processing into beef to IBP in Denison, IA, which was 52 km from the farm. Cattle were shipped at 1700 the evening prior to slaughter and remained overnight in pens with access to water but not to feed at the packing plant. Steers were slaughtered between 0600 and 0730 following the overnight stay at the plant. Presence of liver abscesses was determined within 15 minutes after slaughter when the livers and other internal organs were removed on the processing line.

After a 24-hour chill, backfat and ribeye area were measured on the 12th rib on the left half of each carcass. Backfat was measured to the nearest 0.05 inches using a ruler along the edge of the ribeye area grid. Ribeye area was measured to the nearest 0.1 square inch using a plastic grid with 10 dots per square inch.

Carcass quality, yield grades and % KPH fat were called by USDA Meat Grading Service personnel. Quality grades, as provided by the USDA Meat Grading Service, to the nearest one-third of a grade, were converted to a numerical value. A quality grade of Select was

equal to a value of five, high Select was equal to a value of six, low Choice was equal to a value of seven, average Choice was equal to a value of eight.

Economic analyses

A budget worksheet was prepared based on the “Finishing Yearling Steers” budget worksheet in *Livestock Enterprise Budgets for Iowa* by John Lawrence, extension economist and Alan Vontalge, extension associate. Values used in the calculations were from the corresponding year of the experiment.

When calves were bought from Stuart Ranch money was paid for the group of calves. Thus feeder price per calf was calculated by dividing total money paid by total purchase weight of the calves which was the average weight at which cattle were started on feed and multiplying this figure by the individual weight of the calves. It was assumed that 100 % of the money spent on buying cattle was borrowed and interest rate on that money was 10 %. Days on feed were from the day cattle started on test through the day they were weighed and shipped to the packing plant. Thus interest on feeder cattle price differed among treatment due to their days on feed at the farm. Prices received by farmers for each month in Iowa for corn and alfalfa were used in calculating corn and alfalfa costs. Natural and urea based supplement prices were obtained from the *Livestock Enterprise Budgets for Iowa*. Soybean meal prices for each month of each year were obtained from a source in Decatur, Illinois. Molasses prices were obtained from “Feedstuffs” which is a weekly newspaper for agribusiness. In Feedstuffs the molasses price for Iowa was not mentioned, thus the average of Kansas City and Minneapolis was used as the price for Iowa. Improved pasture prices per

acre were obtained from Livestock Enterprise Budgets for Iowa and pasture cost by treatments was calculated by considering the time cattle spent on pasture.

Interest on feed and other variable costs was 10 % and was calculated as interest on these variables for half the days on feed.

Total revenue for each individual animal was obtained by multiplying hot carcass weight in pounds with the price received for the carcass grade for that individual animal. The discount for Select and yield grade 4 carcasses differed each year and was included in the calculation.

Total variable costs were the sum of the feeder animal cost, feed cost, veterinary and health, machinery and equipment, marketing and miscellaneous and interest on feed and other costs. Fixed costs were associated with machinery, equipment and housing.

Income over variable cost was the product of subtraction of total variable cost from total revenue. Income over all costs, which is the equivalent of profit, was obtained by subtracting fixed costs from income over variable cost. Breakeven selling price for all costs was obtained by dividing the sum of total variable costs and fixed costs by the actual sale weight.

For price sensitivity analysis, the effect of a 5 % increase or decrease in feeder price, carcass price and corn price was determined to observe their effects on profitability and breakeven price.

Statistical analyses

The experimental unit is a pen of cattle consisting of seven steers. There are seven treatment combinations, six with two replications and one with four replications. The analysis will take the form of a one-way analysis of variance with six degrees of freedom for

treatments and 9 degrees of freedom within treatments or experimental error. The data were analyzed using the General Linear Model procedure of SAS and contrast statements were used to compare treatments.

CHAPTER 4. RESULTS AND DISCUSSION

Performance of cattle both in feedlot and pasture is provided in Table 1. Cattle, which spent more time on pasture, gained faster while on pasture than those that spent less time. OI and ONI groups gained considerably faster than JI, JNI and SI and SNI groups. SI and SNI cattle were the slowest gainers overall. OI cattle gained significantly faster than JNI, SI and SNI ($P < 0.03$). ONI, JI and JNI cattle were intermediate in terms of ADG, however they differed significantly from SI and SNI ($P < 0.0001$).

The reason for OI and ONI cattle gaining faster on pasture is their larger frame size and age. Those cattle were stocked until the end of October and when they were moved to the feedlot they were weighing 622 pounds whereas JI and JNI cattle were weighing on average 494 pounds when placed in the feedlot. Thus, they have greater intestinal tract capacity relative to body size while basal metabolic rate is related to surface area of the animal (Van Soest, 1982). This assumes the animal's capacity to consume forage increases faster than its surface area thus resulting in an increasing proportion of the consumed forage utilized for gain rather than maintenance (Bagley and Feazel, 1988).

Another reason for SI and SNI cattle gaining less than others is the forage availability and quality. These cattle were stocked on pasture in the beginning of October and were removed around the end of October when the forage availability and quality was lower than other months. Forage quality and availability and its dependence upon season and physiological maturity have been studied extensively. Jung et al. (1983) and Burrit et al. (1984) found that there was an increase in concentration of esterified non-core lignin components in grasses with the increased physiological maturity. Casler (1986) suggested

that lignin concentration was the most important limiting factor for smooth brome grass fiber fermentability. Cell walls, which are composed primarily of cellulose microfibrils embedded in hemicellulose and lignin matrix are the main reasons for variation in voluntary intake and digestibility of forages consumed by ruminants (Van Soest 1982; Buxton, 1990). Mullahey et al. (1992) using an in situ rumen technique evaluated switchgrass and smooth brome grass harvested on June 4, July 15, July 31, August 19, and September 24 and separated the grasses into leaf and stem fractions before incubation in situ. They found that total crude protein generally decreased with maturity.

Table 1. Performance of cattle both in feedlot and on pasture

Variable	FEEDLOT	JI	JNI	OI	ONI	SI	SNI
Pasture gain, lb/day	-	1.43 ^{ac}	1.23 ^c	1.53 ^a	1.35 ^{ac}	0.63 ^b	0.41 ^b
Feedlot gain, lb/day	2.89 ^{ab}	2.90 ^{ab}	2.96 ^a	2.66 ^c	2.76 ^{bc}	2.90 ^{ab}	2.93 ^a
Overall gain, lb/day	2.89 ^d	2.51 ^c	2.49 ^c	2.14 ^f	2.11 ^f	2.70 ^g	2.70 ^g
DMI (in feedlot), lb/day	17.91 ^d	18.62 ^c	18.56 ^c	18.64 ^c	18.52 ^c	18.33 ^f	18.29 ^f
FE (in feedlot), lb feed/lb gain	6.26 ^h	6.47 ^h	6.38 ^h	7.20 ⁱ	6.89 ⁱ	6.44 ^h	6.31 ^h

^{abc} Means with different superscripts in the same row are significantly different (P<0.03).

^{defg} Means with different superscripts in the same row are significantly different (P<0.01).

^{hi} Means with different superscripts in the same row are significantly different (P<0.02).

Forage characteristics changing with maturity also affect digestion kinetics in cattle. Burns et al. (1991) found that steers grazing subtropical perennial grasses in June and July had different responses, with steers grazing in June having shorter mean retention time, higher rate of digesta flow, higher dry matter intake and higher digestible dry matter intake than steers grazing in July. Poppi et al. (1980) found that voluntary intake, digestibility of dry matter and digestibility of NDF decreased as forage matured and cattle consuming leaf

fractions had higher voluntary intake and better digestibilities of dry matter and NDF. In terms of retention time, apparent retention time of dry matter, organic matter and NDF was lower for leaf fractions than for stem fractions and it increased as forage maturity advanced. Retention of feed in the reticulo-rumen was closely related ($r=93$) with the time lignin was retained in the rumen (Poppi et al. 1981). Thus, higher rate of passage of the NDF from the rumen and higher potential digestibility of NDF and apparent higher rate of digestion of NDF would explain higher voluntary intake of leaf fractions and matured grasses.

Cattle receiving an ionophore (OI, JI) tended to gain faster than their non-receiving ionophore counterparts ($P > 0.1$). SI cattle performed a little better than SNI cattle ($P > 0.09$). Similar results to this were also observed by others (Schwartz et al., 1977; Talbert et al., 1979; Rouquette et al., 1980; Potter et al., 1986; Rush et al., 1996). The reason for monensin receiving cattle performing better is the change in the pattern of VFA. Monensin increases molar proportion of propionate and decreases molar proportions of acetate and butyrate (Richardson et al., 1976; Van Soest and Demeyer, 1977; Prange et al., 1978; Bergen and Bates, 1984; Beede et al., 1986; Callaway et al., 1997). The shift in VFA ratio in favor of propionate is a favorable change for meat producing animals (Schelling, 1984). Because production of propionate by rumen fermentation is more efficient than acetate, tissue utilizes propionate more efficiently than acetate due to a lower heat of metabolism (Thornton and Owens, 1976) and propionate has the potential to be used for gluconeogenesis in addition to direct oxidation by the citric acid cycle. Monensin use increases the amount of dietary energy available to the animal (Horn, 1977; Schelling, 1984).

Another reason for monensin to increase gain on pasture is its inhibition on methane production. In beef cattle fed a low-roughage diet, methane production is 9 liters/h (Thorton and Owens, 1981). Monensin addition can reduce methane production by 20 to 30% (Thorton and Owens, 1981; Schelling, 1984). Since monensin inhibits growth of microorganisms decomposing formate to CO_2 and H_2 which are most important substrates for methane producing bacteria, it reduces methane production in the rumen (Van Newel and Demeyer, 1977). When reducing equivalents (H^+) previously used to produce methane are used instead to reoxidize reduced cofactors, this results in more production of more reduced end products such as propionate (Wolin and Miller, 1988).

Another effect of monensin in ruminal fermentation is its protein sparing effect. Its protein sparing effect comes from the decreased protein degradation and decreased ammonia production in the rumen (Dinius et al., 1976; Yang and Russell, 1993). With the use of monensin, decreasing the ruminal degradation of dietary protein would result in more protein escaping the rumen to the lower tract thus increasing the efficiency of dietary protein by the ruminant animal (Whetstone et al., 1981).

When animals were moved into the feedlot, the trend seen on pasture was reversed and fall-born cattle which spent less time on pasture (JI, JNI) gained faster than those fall-born cattle that spent more time on pasture (OI, ONI; $P < 0.05$). Spring-born cattle (SI, SNI) also gained faster than fall-born cattle spending longer time on pasture (OI, ONI; $P < 0.05$). FEEDLOT cattle performed better than OI and ONI ($P < 0.04$) but did not differ from JI, JNI, SI and SNI ($P > 0.9$). It seems that cattle that spent less time on pasture (JI, JNI, SI and SNI) compensated for their relatively low gains on pasture by gaining faster when they were moved to the feedlot. On the other hand, cattle spending more time on pasture (OI and ONI)

did not compensate while they were in the feedlot. Similar results were obtained by Ridenour et al. (1982) when they grazed steers on wheat pasture until they reached 273 and 364 kg which kept them on pasture another 133 and 201 days, respectively. They found that on wheat pasture, cattle that grazed longer had higher ADG than those that spent less time on pasture and when they were moved to the feedlot they had lower gains than those that spent less time on wheat pasture. These findings agree with Perry et al. (1972) who found that cattle gaining faster on pasture gained less in the feedlot when they were moved to the feedlot. OI and ONI had higher body weights than other treatments when they were moved to the feedlot. Thus one would expect them to gain faster in the feedlot since they were heavier. These results disagree with Koknaroglu et al. (2000) who found that as initial weight increases ADG increases.

It seems that the effect of monensin on pasture was reversed in the feedlot when cattle not receiving monensin on pasture tended to perform better ($P>0.7$). Of the cattle not receiving monensin on pasture the ones which spent more time on pasture had more prominent improvement in the feedlot than their monensin receiving counterparts (2.76 vs 2.66). The reason for improvement in ADG in the feedlot by cattle not receiving ionophore on pasture could be the compensation of the cattle due to having lower gains during the grazing period. The difference in gain in the feedlot became more prominent among OI and ONI cattle. ONI cattle spent more time on pasture than JI, JNI, SI and SNI and had considerably lower gains than OI on pasture. Thus when they were moved to the feedlot, they had more opportunity to compensate than OI.

When Perry et al. (1971) fed a group of cattle in the feedlot and other groups of cattle on pasture receiving no concentrate, one third, two thirds and the same amount of concentrate

as the ones in the feedlot, they found that ADG on pasture increased with increasing concentrate supplementation and when those cattle were moved to the feedlot, those which gained less on pasture gained faster in the feedlot.

Gain throughout experiment is also given in Table 1. As can be observed from the table, FEEDLOT cattle had the highest gain throughout the experiment ($P<0.001$). Since FEEDLOT cattle spent all their time in the feedlot their lot gain is their gain throughout the experiment. Because of this fact this difference would be expected. SI and SNI groups were second in terms of gain throughout the experiment and differed significantly from other treatments ($P<0.001$). This group spent a relatively short time on pasture and most of their time in feedlot. That's why they had better gains than JI, JNI and OI, ONI groups. Gains throughout the experiment for SI and SNI cattle were identical (2.7 lb; $P>0.96$) and they were significantly different from other treatments ($P<0.001$). SNI cattle had lower gain on pasture but their higher gain in the feedlot compensated for this difference and overall they performed as good as the SI group. Overall gain throughout the experiment for JI and JNI did not differ from each other ($P>0.8$), however it was different from other treatments ($P<0.002$). In terms of gain throughout the experiment, JI had a little higher gain than JNI (2.51 vs 2.49 lb/day, respectively). JNI group's better performance in feedlot helped them to narrow the advantage JI had on pasture. The same pattern seen with the JI and JNI groups was observed with OI and ONI groups. OI and ONI also did not differ from each other ($P>0.6$) but differed from other treatments ($P<0.001$). ONI cattle had higher gain in the feedlot than OI and thus they were able to alleviate the disadvantage they had on pasture. On pasture, difference in gain between JI and JNI was a little higher than that of OI and ONI (0.20 vs 0.18 lb/day, respectively), however in the feedlot the difference in gain between OI

and ONI was higher than that of JI and JNI (0.10 vs 0.06 lb/day). Thus even though OI and ONI groups spent more time on pasture their overall gain throughout the experiment did not differ much from each other because of gains in the feedlot.

The overall gain results are in agreement with Oltjen et al. (1971). In their study steers fed 77 days initially on a forage diet gained less than those fed a concentrate diet and when forage receiving cattle received concentrate during the second period they did not sufficiently outgain the steers on a continuous high concentrate diet. Thus, the steers on a continuous high concentrate diet in their study showed a slight advantage in ADG over the entire feeding trial. Similar results were also obtained by Perry et al. (1972), Flipot et al. (1986) and Berge et al. (1991) who reported experiments in which a feedlot system was compared with a system in which cattle were grazed initially and then finished in feedlot. The results of their experiments showed higher gains for the continuous feedlot cattle for the overall periods.

FEEDLOT cattle had lower DMI than other treatments ($P < 0.001$). SI and SNI cattle had lower DMI than JI, JNI, OI and ONI cattle ($P < 0.004$). SI and SNI cattle had similar DMI (18.33 and 18.29 lb/d; $P > 0.5$). JI and JNI did not differ from each other ($P > 0.6$) and had similar DMI with OI and ONI ($P > 0.83$). OI and ONI also did not differ from each other ($P > 0.08$). The same results were obtained by Gill et al. (1991) who double stocked (more cattle per acre) and grazed steers for 84-days in an intensive early stocking (IES) system or single stocked and grazed season long (SLS) for 153 days. When steers moved to the feedlot, the IES cattle consumed less feed than the SLS cattle (25.1 vs 29.2) lb DM/day. Gill et al. (1992) repeated the previous experiment (Gill et al., 1991) with heifers by grazing them either for a 150-day season-long grazing period or an 80-day intensive early grazing period

and finishing them in the feedlot for 145 days. They found that the SLS group had higher feed intake than IES group (23.6 vs 22.2 lb/day, respectively). Myers et al. (1999) evaluated performance of steers fed ad libitum a high concentrate diet after weaning in comparison to steers grown on pasture for 82 days followed by high-concentrate finishing. They found that steers put in the feedlot after weaning had lower feed intake than steers first put on pasture before placing them on a high concentrate diet in the feedlot.

Sindt et al. (1991) reported that steers grazed on bromegrass followed by sudangrass consumed 14.9 % more feed in the feedlot than cattle grazed on bromegrass and then finished.

Lower dry matter intake of cattle started in the feedlot compared to cattle started on pasture and then moved to the feedlot later has been documented by other researchers (Oltjen et al., 1971; Lewis et al., 1990a; Gill et al., 1993a; Myers et al., 1999).

A similar result on effect of monensin on feed intake was obtained by Talbert et al. (1979). They supplemented two groups of cattle on pasture with 2 lb of corn and one group received 200 mg monensin per head per day. When cattle moved to the feedlot both groups received monensin and they found that cattle not receiving monensin on pasture had lower dry matter intake than cattle that received ionophore on pasture.

One of the reasons for cattle not receiving ionophore on pasture to have a lower dry matter intake in the feedlot could be due to the monensin they received in the feedlot. Baile et al. (1979) found that cattle receiving feed containing monensin showed an immediate and marked aversion to feed. A decrease in feed intake by cattle is frequently observed during the first four weeks of introduction of monensin (Gill et al., 1976; Perry et al., 1976; Dinius and Baile, 1977).

FEEDLOT cattle had lower dry matter intakes than other cattle because of their relatively young age and their lighter initial weights. In order to relate initial body weight (IBW) to dry matter intake (DMI), NRC (1996) used initial weight and DMI data obtained from commercial feedlots. When simple linear regression equations were developed with initial body weight as an independent variable to predict DMI, the new general equation of $DMI = 4.54 + 0.0125 \times IBW$ was founded. The equation states that DMI increases with increase in initial weight. The same results were observed by Koknaroglu et al. (2000) when they used data collected through the feedlot monitoring program developed by Iowa State University. Ralston et al. (1970) studied the response of two groups of yearling steers, weighing 636 and 816 pounds, to different time intervals on a finishing ration. They found that steers started on feed at heavier weights had higher ADG than those started at lighter weights.

Saubidet and Verde (1976) concluded that feed intake is related more to age than to weight. FEEDLOT cattle were younger and smaller framed when they were put in the feedlot therefore they consumed less feed.

Cattle spending less time on pasture had better FE than those spending more time. FEEDLOT, SI, SNI, JI and JNI did not differ in terms of FE ($P > 0.9$) even though SI and JI had a little higher FE than their counterparts (SNI and JNI) and FEEDLOT. OI was the least efficient and was followed by ONI and these two groups differed from other treatments ($P < 0.02$) but not from each other ($P > 0.08$). Cattle not receiving an ionophore on pasture tended to be more efficient than their monensin receiving counterparts ($P > 0.08$). It is reasonable to expect that cattle not receiving an ionophore on pasture to have a better feed efficiency since they tended to eat less in the feedlot and gain faster than those that received

an ionophore on pasture. FEEDLOT, SI and SNI had better feed efficiency than OI and ONI. The reason for these animals to be more efficient was their relatively younger age when they entered the feedlot. These cattle spent less time on pasture (SI and SNI) or did not spend any time at all (FEEDLOT) and when they were finished they were younger than OI and ONI treatments. These results agree with Ralston et al. (1970), and Gaili and Osman (1979) whose findings suggest that lighter animals are more efficient than heavier animals. The same results were also obtained by Oltjen et al. (1971), Lancaster et al. (1973), Ridenour et al. (1982), Lewis et al. (1990a), Gill et al. (1991), Gill et al. (1992), Gill et al. (1993a), Brandt et al. (1995) and Myers et al. (1999). They compared either longer grazed cattle with shorter grazed cattle and finished in the feedlot or initially grazed cattle finished in the feedlot with those that went directly to the feedlot.

The fact that lighter or younger animals are more efficient than heavier or older animals can be explained by their growth potential due to growth hormone level circulating in their blood plasma. Verde and Trenkle (1987) found that the concentration of growth hormone was highest in young cattle and gradually decreased with increasing age. As cattle age, concentration of hormones circulating change and extent of chewing feed decreases. As hormones may change body composition and less chewing can reduce digestibility of incompletely processed diets, aging can reduce energetic efficiency (Gill et al., 1993a). As Gill et al. (1992) suggested, cattle spending more time on pasture could be less efficient because of prolonged intakes of lower quality forages' effect on chewing extensiveness and digestibility or on maintenance requirements.

Another reason for OI and ONI to have lower FE could be their higher empty body protein and increased size of the alimentary tract. Gill et al. (1993c) measured body

composition upon entry into the feedlot and found that season long stocked (SLS) cattle had greater amounts of protein in the empty body than did intensive early stocked (IES) cattle and feed efficiency was inversely related to increased amounts of protein in the empty body of the SLS cattle. Thus, this shows the energetic cost in maintaining lean body mass. Rompala et al. (1990) showed that increased roughage or bulk intake stimulates the growth of organs making up the alimentary tract. Increase in size of these organs further increases maintenance requirements. Thus the combined increases in maintenance energy requirements for higher empty body protein and the larger alimentary tract will reduce the efficiency of this group.

Carcass characteristics of cattle are given in Table 2. Attempts were made to finish cattle at 1150 lb and as can be observed in Table 2 there were some small deviations from this weight. FEEDLOT cattle tended to be heavier than ONI ($P>0.09$) and all other treatments had similar final weights ($P>0.9$).

JNI had the highest dressing percentage and differed significantly from FEEDLOT, OI, ONI and SI ($P<0.02$) but not from JI and SNI ($P>0.3$). Conversely FEEDLOT cattle had the lowest dressing percentage and were significantly lower than JI, JNI and SNI cattle ($P<0.05$). Generally cattle not receiving an ionophore tended to have higher dressing percentages than their counterparts not receiving an ionophore ($P>0.3$) except OI cattle, which had a slightly higher dressing percentage than ONI cattle (61.3 vs 61.2; $P>0.8$). Most of the weight lost during transit is due to urinary and fecal losses. Because of this, the cattle having more feed consumption would be expected to defecate more per day and have a larger amount of fecal loss in transit and thus shrink more.

Table 2. Carcass characteristics of cattle

Variable	FEEDLOT	JI	JNI	OI	ONI	SI	SNI
Final weight, lb	1179	1170	1178	1161	1148	1168	1160
Dressing percentage	61.1 ^a	61.8 ^{bc}	62.2 ^b	61.3 ^{ac}	61.2 ^{ac}	61.3 ^{ac}	61.8 ^b
Ribeye area, inch ²	12.55	12.57	12.60	12.30	12.48	12.70	12.67
Back fat, inch	0.55 ^a	0.54 ^a	0.49 ^{ac}	0.44 ^{bc}	0.42 ^c	0.50 ^{ab}	0.45 ^{bc}
KPH, %	2.28 ^d	2.49 ^{ef}	2.55 ^f	2.14 ^d	2.19 ^d	2.29 ^{de}	2.68 ^f
Yield grade	2.68 ^a	2.62 ^a	2.63 ^a	2.35 ^b	2.29 ^b	2.34 ^b	2.39 ^b
Quality grade	7.73 ^g	7.43 ^{gi}	7.47 ^{gi}	6.98 ^h	7.19 ^{hi}	6.81 ^h	6.97 ^h

^{abc}Means with different superscripts in the same row are significantly different (P<0.05).

^{def}Means with different superscripts in the same row are significantly different (P<0.04).

^{ghi}Means with different superscripts in the same row are significantly different (P<0.03).

This might have been the case for OI and ONI to have a lower dressing percentage and the reason for cattle receiving ionophore on pasture to have lower dressing percentage.

Treatment did not have an effect on ribeye area (P>0.9). OI and ONI cattle, which spent more time on pasture, tended to have smaller REA than other treatments (P>0.7). Cattle receiving ionophore on pasture had slightly smaller REA (P>0.9) than those not receiving ionophore, with the exception of SI having larger REA than SNI (P>0.9). Even though it was not significant SI and SNI had larger REA areas than other treatments (P>0.7).

FEEDLOT cattle had the highest backfat and differed significantly from OI, ONI and SNI cattle (P<0.004), but did not differ from JI, JNI and SI cattle (P>0.8). On the other hand there was a tendency for cattle spending more time on pasture to deposit less backfat. ONI had less backfat than FEEDLOT, JI, SI cattle (P<0.05). OI cattle had lower backfat than FEEDLOT and JI cattle (P<0.02). When contrast statements were used they showed that

cattle receiving ionophore on pasture had higher backfat than those not receiving ionophore ($P>0.09$).

KPH values are provided in Table 2. As can be observed, cattle spending more time on pasture (OI, ONI) had lower KPH than cattle spending less time on pasture (JI, JNI and SNI; $P<0.006$). When cattle receiving an ionophore on pasture and those not receiving an ionophore were compared with contrast statements, it was shown that there was a significant effect of ionophore on KPH ($P<0.009$). SNI and JNI had the highest KPH and it was significantly different from FEEDLOT, OI, ONI and SI cattle ($P<0.02$).

Cattle receiving an ionophore on pasture had lower KPH and higher backfat than cattle not receiving an ionophore on pasture. This result disagrees with Lancaster et al. (1973), Davis et al. (1981), Bertrand et al. (1985), Duckett et al. (1993), Schaake et al. (1993), Sapp et al. (1996), who found that there was a positive relationship between backfat and KPH meaning that cattle which had more backfat also had more KPH. However, similar results to ours have been observed by Prichard et al. (1988), Bennet et al. (1995), and Sainz et al. (1995) who found that backfat decreased as KPH increased (Sainz et al. (1995) or backfat increased as KPH decreased (Prichard et al., 1988; Bennet et al., 1995). Sainz et al. (1995) interpreted their results as not conclusive but suggested that there may be differential changes in different fat depots that may be related to the timing of the growth restriction. Limited intake of dietary energy during the period of subcutaneous adipose tissue development could have lasting effects on deposition of lipid in this depot without impairing fat accretion in later developing sites.

The growth rate of fatty tissues varies widely according to their location and the period of growth, early or late postnatal (Robelin, 1986). During the second phase of the

postnatal life of Friesian cattle, from 120-kg body weight to maturity, there are increases in the proportions of omental fat, kidney fat and subcutaneous fat (Robelin 1986). The growth of fatty tissue is mainly due to hypertrophy of adipose tissue cells and this growth in size is accompanied by an increase in lipid content of the fatty tissue. Thus subcutaneous fat develops later whereas internal fat matures earlier (Robelin, 1986). Ingle et al. (1972a) conducted in vivo experiments to quantitatively assess the lipogenic capacity of various tissues of both growing lambs and market weight lambs by injecting with acetate-1-¹⁴C. They found that the greatest incorporation of acetate into fatty acids on a tissue weight basis occurred in perirenal and omental adipose tissue in both groups of lambs. Various subcutaneous depots of adipose tissue (abdominal, shoulder and backfat) as well as mesenteric adipose tissue were similar in lipogenic activity but significantly lower than perirenal and omental adipose tissue.

Ingle et al. (1972b) compared the lipogenic capacity of adipose tissue obtained from different body sites and found that the internal fat depots were most active in younger lambs and calves, while the subcutaneous fat sites tended to have the greatest activity in mature ruminants (sheep and steers). In their study, substrate studies indicated that acetate was the predominant carbon source for lipogenesis in ruminant adipose tissue from both internal and subcutaneous fat depots. Smith and Crouse (1984) investigated relative contributions of acetate, lactate and glucose to lipogenesis in bovine intramuscular and subcutaneous adipose tissue and found that acetate provided 70-80% of the acetyl units to in vitro lipogenesis in subcutaneous adipose tissue but only 10-25% in intramuscular adipose tissue. Conversely, glucose provided 1-10% of the acetyl units in subcutaneous adipose tissue, but 50-75% in the intramuscular depot.

Research conducted on monensin documented that monensin altered relative rates of rumen VFA production displayed as an increase in the concentration of propionate and a decrease in the concentration of acetate and butyrate (Chen and Wolin, 1979; Bergen and Bates, 1984; Schelling, 1984; Sauer et al., 1989; Weiss and Amiet, 1990).

One of the effects of using monensin could be the increased glucose production. Lomax and Baird (1983) and Armentano and Young (1983) found that propionate was the predominant precursor of glucose production and contributed up to 46 and 25 to 32% of the glucose output by the liver in lactating cattle and Holstein steers.

Even though glucose carbon is little used for fatty acid synthesis in ruminant adipose tissue, additions of glucose increased the rate of fatty acid synthesis from acetate by 3-10 times and by 20-50 times in caprine adipose tissue (Ballard et al., 1972; Yang and Baldwin, 1973; Liepa et al., 1978). On the other hand, acetate inhibited fatty acid synthesis from glucose in bovine and caprine adipose tissue in vitro (Bartos and Skarda 1970; Whitehurst et al. 1978).

The reasons for cattle not receiving ionophore on pasture to have higher KPH could be the fact that these cattle had higher proportions of acetate in the VFA. And since the acetate is the main substrate for lipogenesis and inhibits fatty acid synthesis from glucose, they had a higher rate of lipogenesis and the relative early development of internal fat depots might have occurred during higher lipogenesis time.

In addition, the reason for cattle receiving monensin on pasture to have a higher backfat could be the fact that these cattle had higher ratios of propionate in total VFA production and thus higher glucose production. Since glucose increases fatty acid synthesis

from acetate by several folds this increase in lipogenesis coinciding with fat deposition in subcutaneous adipose tissue might affect backfat.

Cattle spending longer time on pasture (OI and ONI) were leaner than other cattle. The reason for this is the relatively longer time spent on pasture. During the restrictive period, beef calves continue to develop skeletal structure, accumulate less body fat and more body protein than calves fed at a higher rate of gain (Phillips et al., 1991). Some research has shown that differences in body composition induced during feed restriction could be retained through the finishing period (Fox et al., 1972; Coleman and Evans, 1986).

Cattle spending longer time in the feedlot were fatter than those spending less time in the feedlot. Smith et al. (1984) reported that backfat thickness and the activities of several enzymes involved in lipogenesis were greater in steers fed a high concentrate, corn based diet versus steers fed a forage based, alfalfa pellet diet, even though the metabolizable energy intake was higher for the pelleted alfalfa diet. Thus a longer stay in the feedlot increased fat accumulated in the body. Duckett et al. (1993) used 48 yearlings to assess the effect of time on feed on the nutrient composition of beef longissimus muscle. Day-0 served as grass fed control cattle and other cattle were fed concentrate and were serially slaughtered at 28 day intervals during a 196 day feeding period. They found that fat thickness, KPH and yield grade increased with increase time on feed.

In general cattle spending longer time in the feedlot had better quality grades and higher yield grades. The only exceptions for this were spring-born cattle which spent a long time in the feedlot and had low yield and quality grades. Harrison et al. (1978), Schroeder et al. (1980) and Skelley et al. (1978) found that increasing time in the feedlot increased

marbling scores and quality grades and Tatum et al. (1980) and Hedrick et al. (1983) reported that feeding steers concentrates increased yield grades.

Even though it wasn't significant cattle not receiving an ionophore on pasture tended to have higher quality grades than their ionophore receiving counterparts ($P>0.24$). This does not seem to be the direct result of monensin on pasture, but rather the change might have occurred in VFA concentration in the feedlot after those cattle moved to the feedlot. In feedlot cattle not receiving monensin on pasture they might have had higher production of VFA and higher proportion of propionate than those not receiving monensin. In the feedlot, cattle not receiving monensin on pasture tended to have better feed efficiency than those receiving ionophore on pasture and this could be the result of VFA production. Monensin can potentially improve the efficiency of digestible feed energy fermentation and utilization by decreasing methanogenesis and increasing propionate at the expense of acetate (Richardson et al., 1976; Armentano and Young, 1983; Russel and Strobel, 1989).

Monensin increases propionate production, which in turn increases glucose production (Lomax and Baird, 1983; Armentano and Young, 1983). Glucose was found to be the main contributor (50-75%) of acetyl units in intramuscular fat depots (Smith and Crouse, 1984). Thus the reason for cattle not receiving monensin on pasture to have better quality grades could be that cattle not receiving an ionophore on pasture produce more VFA and probably more propionate and thus the effect of propionate on glucose production and intramuscular fat deposition.

Some performance variables are presented in Table 3. The values in the table are for a better understanding of the experiment and clarification for economics discussion.

Table 3. Performance variables for treatments

Variable	FEEDLOT	JI	JNI	OI	ONI	SI	SNI
Initial weight, lb	383	383	384	384	383	501	500
Off pasture weight, lb	-	502	486	638	607	515	508
Final weight, lb	1179	1170	1178	1161	1148	1168	1160
Days on pasture	-	83	83	166	166	22	22
Days in feedlot	273	238	238	197	197	223	223
Total days fed	273	321	321	363	363	245	245

For the economics part, four scenarios were considered. In the first scenario, the economics discussed used actual prices paid for feeder cattle and feed components and prices received for carcasses. In the second scenario, it was assumed that the cattle received the same feeder and fed cattle price using a 10 year average for feed components, feeder and fed cattle prices. For the third option, the same criteria as the second option were assumed except prices for feed components were derived from the corresponding months. In the fourth option, prices for corresponding months for feeder, fed cattle and feed components were used.

The reason for considering other scenarios is that feeder cattle, fed cattle and feed prices change depending upon time of purchase and marketing. In order to determine how profitability and other variables change based upon time it was decided to use this approach.

Scenario 1: Some economics variables are given in Table 4. Spring-born cattle had lower feeder price than fall born cattle (\$84.30 vs \$94.58). Even though spring-born cattle had lower feeder price they had higher purchase price ($P < 0.0001$) due to their heavier purchase weights. Hot carcass weights obtained for JNI cattle were heavier than those obtained for

ONI ($P<0.03$) and these two treatments were not different from other treatments ($P>0.9$).

The reason for the difference in hot carcass weight between JNI and ONI is the difference in their dressing percentage and their final weights (both favoring JNI).

Carcass price received for cattle is also given in Table 4 and it reveals the importance of marketing time on carcass price received. Carcass price was lowest for FEEDLOT cattle ($P<0.001$) even though they had a higher percentage of Choice grading carcasses than OI, ONI, SI and SNI ($P<0.03$). ONI cattle received the second lowest carcass price and it was significantly lower than other treatments except OI ($P<0.024$).

FEEDLOT cattle had significantly lower total revenue than JI, JNI, SI and SNI cattle ($P<0.04$) and similar total revenue with OI and ONI cattle ($P>0.8$). ONI cattle also had lower total revenue and significantly differed from JI and JNI cattle ($P<0.02$). The reason for these two groups to have low total revenue is that total revenue is a product of carcass price and hot carcass weight and FEEDLOT cattle had lower carcass price and ONI cattle had low hot carcass weight and thus received relatively low revenue.

Feed cost was highest for FEEDLOT and lowest for SI and SNI cattle ($P<0.001$). Fall-born cattle removed from pasture in July and in October had significantly different feed costs than each other and than other treatments ($P<0.001$). It is expected for the FEEDLOT cattle to have the highest feed cost because of their longer days in the feedlot.

Even though SI and SNI cattle spent more time in the feedlot they had lower feed costs than OI and ONI. The reason for this is that pasture cost associated with grazing was included in the feed cost section and since OI and ONI spent more time on pasture they had higher pasture costs. Coffey and Moyer (1992) grazed a group of cattle for 75 days and another group 207 days and then finished them in the feedlot and obtained similar results.

Cattle, with the shorter grazing period remained 56 days longer in the feedlot and had higher dry matter consumption, total feed cost and higher cost of gain than cattle grazed longer on pasture.

Corn cost was directly related to time spent in the feedlot and thus cattle spending longer time in the feedlot had higher corn consumption. In terms of corn cost, the cattle receiving the same pasture treatment and excluding the ionophore treatment (JI vs JNI, OI vs ONI, SI vs SNI) did not differ from each other ($P>0.9$), however they differed significantly from other pasture treatments ($P<0.0001$).

Total variable cost, which includes purchase price, feed cost, interest, and all other costs, was highest for FEEDLOT and lowest for ONI cattle. Total variable cost for ONI cattle was significantly lower than other treatments except OI cattle ($P<0.06$). FEEDLOT cattle had higher total variable cost than OI and ONI cattle ($P<0.03$). Other treatments were intermediate and they did not differ from each other ($P>0.9$). The reason for FEEDLOT cattle to have higher total variable cost is the high total feed cost. On the other hand, ONI and OI cattle had low total variable cost because of their low feed cost. Even though SI and SNI cattle had lower total feed cost than OI and ONI cattle they still had higher total variable cost. The reason for this is the higher purchase price paid for these cattle due to their heavier initial weights.

Table 4. Economic variables for treatments, 1st option

Variable	FEEDLOT	JI	JNI	OI	ONI	SI	SNI	P<
Feeder price, \$/cwt	94.58	94.58	94.58	94.58	94.58	84.30	84.30	-
Purchase price, \$/head	367.05 ^a	366.77 ^a	367.42 ^a	367.73 ^a	366.51 ^a	418.97 ^b	418.39 ^b	0.0001
Hot carcass weight, lb	720.96 ^{ab}	723.05 ^{ab}	731.97 ^a	711.17 ^{ab}	701.17 ^b	715.57 ^{ab}	717.24 ^{ab}	0.03
Carcass price, \$/cwt	100.42 ^a	105.26 ^b	104.91 ^b	104.07 ^{bc}	103.30 ^c	104.83 ^b	104.74 ^b	0.02
Total revenue, \$/head	715.89 ^a	753.48 ^{bc}	760.36 ^b	732.65 ^{ac}	718.41 ^{ad}	742.92 ^{bcd}	744.09 ^{bcd}	0.06
Total feed cost, \$/head	250.33 ^a	237.93 ^b	239.59 ^b	216.24 ^c	216.17 ^c	193.30 ^d	194.82 ^d	0.0001
Corn cost, \$/head	163.89 ^a	139.13 ^b	140.89 ^b	111.29 ^c	111.35 ^c	122.56 ^d	123.99 ^d	0.0001
Interest, \$	39.41 ^a	41.45 ^b	41.57 ^b	43.62 ^c	43.36 ^c	35.90 ^d	35.82 ^d	0.02
Total variable cost, \$/head	741.86 ^b	726.70 ^{bc}	728.26 ^{bc}	710.32 ^{ac}	704.16 ^a	735.25 ^b	735.28 ^b	0.06
Total cost, \$/head	762.86 ^a	742.70 ^{bc}	744.26 ^{ab}	726.32 ^{bc}	720.16 ^c	756.25 ^a	756.28 ^a	0.054
Cost of gain, \$/cwt	49.93 ^a	47.73 ^b	47.68 ^b	46.34 ^b	46.66 ^b	51.24 ^{ac}	51.53 ^c	0.03
Breakeven price, \$/cwt hot carcass	105.77 ^a	102.71 ^b	102.11 ^b	102.32 ^b	103.29 ^{bc}	105.86 ^{ac}	105.72 ^{ac}	0.04
Profit, \$/head	-46.08 ^a	11.53 ^b	16.86 ^b	6.96 ^{bc}	-1.13 ^{bc}	-12.62 ^c	-11.48 ^c	0.04

^{abcd} Means with different superscripts in the same row are significantly different with respect to their P-values.

Breakeven price, which is calculated as a total of all costs divided by sale weight, is given in Table 4 for hot carcass weight. JI, JNI and OI cattle had the lowest breakeven hot carcass price and it was significantly lower than FEEDLOT, SI and SNI cattle ($P<0.04$). JNI and OI cattle had a little lower breakeven hot carcass price than JI and ONI because of their heavier hot carcass weights. Even though SI and SNI had almost identical total variable costs as JI and JNI, they had higher breakeven hot carcass prices because of their lighter carcasses.

Cost of gain for 100 pounds is also given in Table 4. The formula for total cost of gain is the total of all costs excluding purchase price divided by final weight minus initial weight. Total cost of gain eliminates the impact of purchase price on profitability and reflects the cost of production associated with performance of the cattle on pasture and in the feedlot. Total cost of production was related to time spent on pasture and in the feedlot. OI, ONI, JI and JNI cattle had lower total cost of gain than FEEDLOT, SI and SNI cattle ($P<0.03$). SNI had the highest cost of gain and significantly differed from FEEDLOT cattle. Cattle spending longer time on pasture had a lower cost of gain because the weight they gained on pasture was at a relatively cheaper cost. In their investigation of effect of backgrounding and season of birth on growth and cost of gain in cattle of two frame sizes, Buchanan-Smith et al. (1995) found that fall-born cattle which were not backgrounded had lower cost of gain than spring-born cattle which were backgrounded and not backgrounded.

FEEDLOT cattle had the lowest profitability ($P<0.001$). JI and JNI had the highest profitability and significantly differed from SI and SNI ($P<0.04$) and did not differ from OI and ONI ($P>0.7$). FEEDLOT cattle had the lowest profitability because of their revenue due to lower carcass prices received and the higher corn consumption reflected in the total feed

consumed in the feedlot. JNI had better profitability than other treatments because of their heavier carcass weights and relatively higher total revenue. Even though SI and SNI had less money spent on feed they had similar total variable costs with FEEDLOT, JI and JNI because of their heavier initial weights. SI and SNI cattle had lower feeder prices, however, heavier initial weights.

Scenario 2. Economic variables for the second scenario are presented in Table 5. SI and SNI cattle had higher purchase prices than other treatments ($P<0.001$) because of their heavier initial weights. Treatments did not differ from each other in terms of total revenue ($P>0.1$).

Corn cost in the feedlot was highest for FEEDLOT cattle and lowest for OI and ONI cattle and these treatments were different from other treatments ($P<0.0001$). JNI cattle had higher corn costs than SI cattle ($P<0.04$) and similar corn costs as JI and SNI cattle ($P>0.6$). Since 10 year average prices of corn for FEEDLOT, JI and JNI cattle in the second scenario were lower and those for OI, ONI and SI cattle were higher than the corresponding monthly corn prices used in scenario one, FEEDLOT, JI and JNI cattle had lower and OI, ONI, SI and SNI cattle had a little higher corn cost than the same treatments in scenario one.

SI and SNI cattle had the lowest feed costs in the feedlot ($P<0.0001$) whereas FEEDLOT cattle had the highest feed cost ($P<0.0001$). SI and SNI cattle had higher total variable costs and total all costs ($P<0.0001$) than other treatments, and all other treatments had similar values ($P>0.9$). Cost of gain for 100 pounds was higher for SI and SNI cattle ($P<0.001$) and JI and JNI cattle had lower cost of gain and differed from ONI cattle ($P<0.03$).

Table 5. Economic variables for treatments, 2nd option

Variable	FEEDLOT	JI	JNI	OI	ONI	SI	SNI	P<
Feeder price, \$/cwt	98.59	98.59	98.59	98.59	98.59	90.29	90.29	-
Purchase price, \$/head	377.75 ^a	377.46 ^a	378.16 ^a	378.51 ^a	377.22 ^a	452.41 ^b	451.77 ^b	0.0001
Fed cattle price, \$/cwt	69.46	69.46	69.46	69.46	69.46	69.46	69.46	-
Hot carcass weight, lb	720.96 ^{ab}	723.05 ^{ab}	731.97 ^a	711.11 ^{ab}	701.17 ^b	715.57 ^{ab}	717.24 ^{ab}	0.03
Carcass price, \$/cwt	113.75 ^a	112.54 ^{bc}	111.88 ^b	113.50 ^{ac}	113.64 ^{ac}	113.37 ^a	112.43 ^{bc}	0.03
Total revenue, \$/head	811.01	804.88	809.87	798.32	792.67	802.92	797.92	NS
Total feed cost, \$/head	223.72 ^a	209.82 ^b	211.29 ^b	211.75 ^b	211.40 ^b	194.89 ^c	195.98 ^c	0.0001
Corn cost, \$/head	149.40 ^a	131.74 ^{bd}	133.28 ^b	112.86 ^c	112.64 ^c	127.00 ^d	128.04 ^{bd}	0.04
Interest, \$	39.34 ^a	41.88 ^b	42.00 ^b	44.95 ^c	44.70 ^c	38.10 ^d	38.01 ^d	0.05
Total variable cost, \$/head	726.95 ^a	718.10 ^a	719.51 ^a	725.01 ^a	718.70 ^a	774.73 ^b	774.31 ^b	0.0001
Total cost, \$/head	747.95 ^a	734.10 ^a	735.51 ^a	741.01 ^a	734.70 ^a	795.73 ^b	795.31 ^b	0.0001
Cost of gain, \$/cwt	46.81 ^a	45.25 ^b	45.21 ^b	46.75 ^{ab}	47.04 ^a	52.00 ^c	52.31 ^c	0.03
Breakeven price, \$/cwt live weight	63.45 ^a	62.56 ^a	62.44 ^a	63.63 ^a	63.85 ^a	68.17 ^b	68.40 ^b	0.0001
Breakeven price, \$/cwt hot carcass	103.83 ^a	101.42 ^b	100.75 ^b	104.28 ^a	105.23 ^a	111.38 ^c	111.05 ^c	0.05
Profit, \$/head	63.94 ^a	72.53 ^a	76.11 ^a	58.93 ^a	57.89 ^a	7.89 ^b	3.32 ^b	0.0001

^{abcde} Means with different superscripts in the same row are significantly different with respect to their P-values.

SI and SNI cattle had higher breakeven prices for hot carcass weight ($P<0.001$). ONI and OI cattle had the next highest breakeven prices (\$105.23 and 104.28, respectively) after SI and SNI cattle and were significantly different from JI and JNI cattle ($P<0.04$). SI and SNI cattle had high breakeven prices for hot carcass weight because of their heavier initial weight and thus higher purchase price. Cost of gain per 100 pounds for SI and SNI was around \$52 and these cattle were heavier than fall-born cattle at the beginning of the study by about 118 pounds. Thus, if these cattle had been started on feed at the same weight as fall-born cattle, it would have cost \$61 for gaining 118 pounds whereas for this 118 pounds they were paid about \$74 more than fall-born cattle. This \$13 difference reflected in breakeven price would be \$ 1.18 which is the product of division of \$13 by hot carcass weight by SI and SNI $((13/717) \times 100)$. OI and ONI cattle also had higher breakeven hot carcass prices because of their lower overall ADG due to the longer time they spent on pasture.

SI and SNI had the lowest profitability ($P<0.001$) and JNI tended to differ from OI and ONI ($P>0.08$ and $P>0.065$, respectively). FEEDLOT cattle had similar profitability with JI, JNI, OI and ONI ($P>0.6$). Dikeman et al., (1985) found that cattle placed in the feedlot directly had lower breakeven live price, lower cost of retail product and were more profitable than those that were backgrounded on prairie hay and sorghum grain then later finished in the feedlot. They mentioned that rate of growth and carcass cutability were the main reasons for cost of retail product.

Scenario 3. Since the same prices were used for feeder and fed cattle prices as in the second scenario, values and significance levels for feeder price, purchase price, carcass price, total revenue were the same as the ones in the second scenario.

FEEDLOT cattle had the highest feed cost followed by JI and JNI cattle ($P<0.002$). SI and SNI cattle had the lowest feed costs and were significantly different from OI and ONI ($P<0.002$) which were intermediate in terms of total feed cost.

Corn cost was higher for cattle spending longer time in the feedlot. Spring-born cattle and fall-born cattle removed to the feedlot in July and in October had different corn costs except those, which received the same treatment on pasture except for monensin ($P<0.005$).

Total cost including variable and fixed cost was higher for SI and SNI cattle ($P<0.0005$). OI and ONI had the lower total costs and differed from FEEDLOT cattle ($P<0.055$).

JI, JNI and ONI cattle had lower cost of gain than other treatments ($P<0.03$). SI and SNI cattle had the highest cost of gain whereas FEEDLOT and ONI cattle were intermediate.

SI and SNI had higher total variable costs, costs of gain and breakeven prices for hot carcass and final weights and lower profitability than other treatments ($P<0.0001$). SI and SNI cattle had lower profitability than other treatments because of their higher purchase price due to heavier initial weights. They also had higher costs of gain because of their heavier initial weights. Since animals were finished around 1150 pounds they put on about 650 lb, whereas cattle on other treatments put on 770 lb. Thus SI and SNI cattle had higher costs of gain due to fixed costs and other variable costs reflected in their gain.

Table 6. Economic variables for treatments, 3rd option

Variable	FEEDLOT	JI	JNI	OI	ONI	SI	SNI	P<
Feeder price, \$/cwt	98.59	98.59	98.59	98.59	98.59	90.29	90.29	-
Purchase price, \$/head	377.75 ^a	377.46 ^a	378.16 ^a	378.51 ^a	377.22 ^a	452.41 ^b	451.77 ^b	0.0001
Fed cattle price, \$/cwt	69.46	69.46	69.46	69.46	69.46	69.46	69.46	-
Hot carcass weight, lb	720.96 ^{ab}	723.05 ^{ab}	731.97 ^a	711.11 ^{ab}	701.17 ^b	715.57 ^{ab}	717.24 ^{ab}	0.03
Carcass price, \$/cwt	113.75 ^a	112.54 ^{bc}	111.88 ^b	113.50 ^{ac}	113.64 ^{ac}	113.37 ^a	112.43 ^{bc}	0.03
Total revenue, \$/head	811.01	804.88	809.87	798.32	792.67	802.92	797.92	NS
Total feed cost, \$/head	228.89 ^a	215.16 ^b	216.68 ^b	205.47 ^c	205.31 ^c	188.64 ^d	189.76 ^d	0.002
Corn cost, \$/head	153.24 ^a	135.53 ^b	137.10 ^b	112.57 ^c	112.37 ^c	125.76 ^d	126.82 ^d	0.005
Interest, \$	39.53 ^a	42.05 ^b	42.18 ^b	44.79 ^c	44.53 ^c	37.91 ^d	37.83 ^d	0.02
Total variable cost, \$/head	732.31 ^a	723.62 ^{ab}	725.08 ^{ab}	718.56 ^{ab}	712.45 ^b	768.29 ^c	767.88 ^c	0.053
Total cost, \$/head	753.31 ^a	739.62 ^{ab}	741.08 ^{ab}	734.56 ^b	728.45 ^b	789.29 ^c	788.88 ^c	0.055
Cost of gain, \$/cwt	47.49 ^a	45.95 ^b	45.92 ^b	45.95 ^b	46.27 ^a	51.06 ^c	51.33 ^c	0.03
Breakeven price, \$/cwt live weight	63.90 ^a	63.08 ^a	63.04 ^a	63.26 ^a	63.53 ^a	67.73 ^b	68.04 ^b	0.0001
Breakeven price, \$/cwt hot carcass	104.57 ^a	102.18 ^{bd}	101.51 ^b	103.38 ^{ab}	104.35 ^{ad}	110.47 ^c	110.13 ^c	0.05
Profit, \$/head	58.58 ^a	67.02 ^a	70.55 ^a	65.39 ^a	64.12 ^a	14.34 ^b	9.75 ^b	0.0001

^{abcd} Means with different superscripts in the same row are significantly different with respect to their P-values.

Scenario 4. SI and SNI cattle had higher purchase prices than other treatments ($P<0.0001$) even though they had lower feeder prices. Carcass prices, adjusted by using fed cattle price and dressing percentage, were lower for SI and SNI ($P<0.01$) because of their lower fed cattle price. Because of their heavier carcass weights or higher carcass prices FEEDLOT, JI, JNI and OI cattle had higher total revenue than spring-born cattle ($P<0.04$). ONI cattle had higher total revenue than SNI cattle ($P<0.04$) but had similar total revenue with SI ($P>0.09$).

Spring-born cattle and fall-born cattle removed to the feedlot in July and in October had different corn costs except those, which received the same treatment on pasture except for monensin. FEEDLOT cattle had the highest and SI and SNI cattle had the lowest feed costs ($P<0.002$).

In terms of corn cost, feed cost increased as time in the feedlot increased. FEEDLOT cattle had the highest corn cost and OI and ONI had the lowest corn cost and differed from each other ($P<0.005$). Cattle removed from pasture and placed in the feedlot at different times had different corn costs ($P<0.005$) except the cattle removed from pasture at the same time but differing in their monensin treatment on pasture.

ONI cattle had lower total cost than FEEDLOT and SI and SNI cattle ($P<0.06$). FEEDLOT and SI and SNI cattle had higher total cost because of higher purchase price (SI and SNI) and higher feed costs (FEEDLOT).

Cost of gain for SI and SNI was higher than other treatments ($P<0.0001$) and cattle spending more time on pasture (except ONI) had lower cost of gain than FEEDLOT cattle ($P<0.04$). JNI had the lowest breakeven price for hot carcass and live weight and this was reflected in their profitability.

Table 7. Economic variables for treatments 4th option

Variable	FEEDLOT	JI	JNI	OI	ONI	SI	SNI	P<
Feeder price, \$/cwt	103.92	103.92	103.92	103.92	103.92	87.21	87.21	-
Purchase price, \$/head	397.08 ^a	397.87 ^a	398.61 ^a	398.98 ^a	396.47 ^a	436.98 ^b	436.36 ^b	0.0001
Fed cattle price, \$/cwt	70.80	71.94	71.94	71.54	71.54	68.22	68.22	-
Hot carcass weight, lb	720.96 ^{ab}	723.05 ^{ab}	731.97 ^a	711.11 ^{ab}	701.17 ^b	715.57 ^{ab}	717.24 ^{ab}	0.03
Carcass price, \$/cwt	115.94 ^a	116.55 ^{ac}	115.88 ^a	116.89 ^a	117.39 ^c	111.34 ^b	110.43 ^b	0.01
Total revenue, \$/head	826.65 ^a	833.62 ^a	838.79 ^a	822.23 ^a	813.32 ^{ac}	788.58 ^{bc}	783.68 ^b	0.04
Feed cost, \$/head	228.89 ^a	215.16 ^b	216.68 ^b	205.47 ^c	205.31 ^c	188.64 ^d	189.76 ^d	0.002
Corn cost, \$/head	153.24 ^a	135.53 ^b	137.10 ^b	112.57 ^c	112.37 ^c	125.76 ^d	126.82 ^d	0.005
Interest, \$	41.07 ^a	43.84 ^b	43.97 ^b	46.82 ^c	46.55 ^c	36.88 ^d	36.80 ^d	0.001
Total variable cost, \$/head	754.21	745.82	747.36	741.06	734.81	751.81	751.44	NS
Total cost, \$/head	775.21 ^a	761.82 ^{ab}	763.36 ^{ab}	757.06 ^{ab}	750.81 ^b	772.81 ^a	772.44 ^a	0.06
Cost of gain, \$/cwt	47.68 ^a	46.18 ^b	46.15 ^b	46.21 ^b	46.54 ^{ab}	50.90 ^c	51.17 ^c	0.04
Breakeven price, \$/cwt live weight	65.76 ^{ab}	64.98 ^a	64.94 ^a	65.20 ^{ab}	65.49 ^{ab}	66.31 ^{ab}	66.62 ^b	0.045
Breakeven price, \$/cwt hot carcass	107.61 ^{ab}	105.25 ^{ac}	104.57 ^c	106.54 ^{ab}	107.56 ^{ab}	108.17 ^b	107.84 ^{ab}	0.05
Profit, \$/head	52.33 ^a	73.56 ^b	77.18 ^b	66.80 ^{ab}	64.15 ^{ab}	16.48 ^c	11.95 ^c	0.01

^{abcd} Means with different superscripts in the same row are significantly different with respect to their P-values.

Generally spring-born cattle had higher costs of gain, breakeven price and lower profit than other treatments. The reason for SI and SNI having higher costs of gain, breakeven prices and lower profitability is because of their heavier initial weights and thus this is reflected in the calculations.

Price sensitivity analysis

Carcass price: Price sensitivity analysis for carcass price is given in Table 8 and Table 9. The values in Table 8 are the values when carcass price increases 5 % and Table 9 values represent the values when carcass price decreases 5 %. Since carcass price does not affect production and buying costs all the values except carcass price, total revenue and profit are the same for the treatments as the ones in Table 4. When carcass prices increased 5 % from the actual case, FEEDLOT cattle still had negative profitability and other treatments had higher profitability with the same rankings as in the actual case. When carcass price decreased 5 % all the treatments had negative profitability. This price sensitivity analysis for carcass price shows the importance of carcass price on profitability. Since the carcass is the end product that brings in revenue, the price received highly affects overall profitability. A better example of this was shown in the original case in which FEEDLOT cattle had similar carcass breakeven prices with SI ($P>0.9$) however they had lower profitability due to the lower carcass prices they received during marketing time. This illustrates the importance of marketing time.

Fluctuations in the fed cattle price exist depending upon the time cattle arrive at the market. Analyzing the data obtained from Iowa cattle producers using the Iowa State University Feedlot Performance and Cost Monitoring program between January 1988 and December 1997 Koknaroglu et al. (2000) found that cattle started on feed in the feedlot in spring had lower fed cattle prices than those that started in summer and fall.

Table 8. Economic variables when carcass price increases 5 percent

Variable	FEEDLOT	JI	JNI	OI	ONI	SI	SNI	P<
Feeder price, \$/cwt	94.58	94.58	94.58	94.58	94.58	84.30	84.30	-
Purchase price, \$/head	367.05 ^a	366.77 ^a	367.42 ^a	367.73 ^a	366.51 ^a	418.97 ^b	418.39 ^b	0.0001
Hot carcass weight, lb	720.96 ^{ab}	723.05 ^{ab}	731.97 ^a	711.17 ^{ab}	701.17 ^b	715.57 ^{ab}	717.24 ^{ab}	0.03
Carcass price, \$/cwt	105.44 ^a	110.53 ^b	110.15 ^b	109.28 ^{bc}	108.46 ^c	110.08 ^b	109.98 ^b	0.024
Total revenue, \$/head	751.69 ^a	791.15 ^b	798.38 ^b	769.28 ^{ab}	753.50 ^{ac}	780.07 ^{bc}	781.30 ^{bc}	0.04
Total feed cost, \$/head	250.33 ^a	229.53 ^b	231.23 ^b	209.18 ^c	209.11 ^c	192.57 ^d	194.09 ^d	0.0001
Corn cost, \$/head	163.89 ^a	139.13 ^b	140.89 ^b	111.29 ^c	111.35 ^c	122.56 ^d	123.99 ^d	0.0001
Interest, \$	39.41 ^a	41.45 ^b	41.57 ^b	43.62 ^c	43.39 ^c	35.90 ^d	35.81 ^d	0.02
Total variable cost, \$/head	741.86 ^b	726.70 ^{bc}	728.26 ^{bc}	710.32 ^{ac}	704.26 ^a	735.25 ^b	735.28 ^b	0.06
Total cost, \$/head	761.97 ^a	741.95 ^{bc}	743.51 ^{ab}	725.69 ^{bc}	719.63 ^c	755.54 ^a	755.57 ^a	0.054
Cost of gain, \$/cwt	49.93 ^a	47.73 ^b	47.68 ^b	46.34 ^b	46.66 ^b	51.24 ^{ac}	51.53 ^c	0.03
Breakeven price, \$/cwt hot carcass	105.77 ^a	102.71 ^b	102.11 ^b	102.32 ^b	103.29 ^{bc}	105.86 ^{ac}	105.72 ^{ac}	0.04
Profit, \$/head	-10.29 ^a	49.21 ^b	54.87 ^b	43.59 ^{bc}	33.88 ^{bc}	24.52 ^c	25.73 ^c	0.05

^{abcd} Means with different superscripts in the same row are significantly different with respect to their P-values.

Table 9. Economic variables when carcass price decreases 5 percent

Variable	FEEDLOT	JI	JNI	PI	PNI	SI	SNI	P<
Feeder price, \$/cwt	94.58	94.58	94.58	94.58	94.58	84.30	84.30	-
Purchase price, \$/head	367.05 ^a	366.77 ^a	367.42 ^a	367.73 ^a	366.51 ^a	418.97 ^b	418.39 ^b	0.0001
Hot carcass weight, lb	720.96 ^{ab}	723.05 ^{ab}	731.97 ^a	711.17 ^{ab}	701.17 ^b	715.57 ^{ab}	717.24 ^{ab}	0.03
Carcass price, \$/cwt	95.40 ^a	100.00 ^b	99.66 ^b	98.87 ^{bc}	98.13 ^c	99.59 ^b	99.50 ^b	0.024
Total revenue, \$/head	680.10 ^a	715.81 ^b	722.34 ^b	696.01 ^{ab}	681.74 ^{ac}	705.78 ^{bc}	706.88 ^{bc}	0.04
Total feed cost, \$/head	250.33 ^a	229.53 ^b	231.23 ^b	209.18 ^c	209.11 ^c	192.57 ^d	194.09 ^d	0.0001
Corn cost, \$/head	163.89 ^a	139.13 ^b	140.89 ^b	111.29 ^c	111.35 ^c	122.56 ^d	123.99 ^d	0.0001
Interest, \$	39.41 ^a	41.45 ^b	41.57 ^b	43.62 ^c	43.39 ^c	35.90 ^d	35.81 ^d	0.02
Total variable cost, \$/head	741.86 ^b	726.70 ^{bc}	728.26 ^{bc}	710.32 ^{ac}	704.26 ^a	735.25 ^b	735.28 ^b	0.06
Total cost, \$/head	761.97 ^a	741.95 ^{bc}	743.51 ^{ab}	725.69 ^{bc}	719.63 ^c	755.54 ^a	755.57 ^a	0.054
Cost of gain, \$/cwt	49.93 ^a	47.73 ^b	47.68 ^b	46.34 ^b	46.66 ^b	51.24 ^{ac}	51.53 ^c	0.03
Breakeven price, \$/cwt hot carcass	105.77 ^a	102.71 ^b	102.11 ^b	102.32 ^b	103.29 ^{bc}	105.86 ^{ac}	105.72 ^{ac}	0.04
Profit, \$/head	-81.88 ^a	-26.14 ^b	-21.16 ^b	-29.67 ^{bc}	-37.89 ^{bc}	-49.77 ^c	-48.68 ^c	0.05

^{abcd} Means with different superscripts in the same row are significantly different with respect to their P-values.

Corn price: Price sensitivity analysis for corn price is provided in Tables 10 and 11. When corn price increased or decreased 5 %, corn cost increased or decreased accordingly and this price change in corn cost naturally affected feed costs and other costs associated with production. Change in corn price affected FEEDLOT cattle more than other cattle since they had higher corn consumption than other cattle. Five-percent change in corn price resulted in FEEDLOT cattle's feed cost changing \$8.19 whereas it was \$6.24 on average for other treatments. When corn price increased or decreased 5 %, the effect of this change reflected on hot carcass breakeven price was \$1.19 for FEEDLOT cattle and it was \$0.89 for SI and SNI cattle.

Since cattle in Midwest feedlots are fed a ration consisting mostly of corn, the price of corn and the time cattle spent in the feedlot become more important. When the corn is relatively cheaper feeding cattle in the feedlot might be more advantageous, whereas when corn is relatively expensive utilization of pasture might be to the advantage of producers.

Feeder cattle price: Price sensitivity analysis for feeder cattle price is given in Tables 12 and 13. Since feeder cattle purchase price is a part of total variable costs and consequently the total of all costs, the change in feeder cattle price was reflected in hot carcass breakeven price and profit. SI and SNI cattle were heavier than other treatments when cattle were bought and thus they were influenced more by changes in feeder cattle price.

When feeder price increased or decreased 5 %, SI and SNI cattle had higher change in their profitability (\$23.23) than FEEDLOT cattle (\$19.68).

Table 10. Economic variables when corn price increases 5 percent

Variable	FEEDLOT	JI	JNI	OI	ONI	SI	SNI	P<
Feeder price, \$/cwt	94.58	94.58	94.58	94.58	94.58	84.30	84.30	-
Purchase price, \$/head	367.05 ^a	366.77 ^a	367.42 ^a	367.73 ^a	366.51 ^a	418.97 ^b	418.39 ^b	0.0001
Hot carcass weight, lb	720.96 ^{ab}	723.05 ^{ab}	731.97 ^a	711.17 ^{ab}	701.17 ^b	715.57 ^{ab}	717.24 ^{ab}	0.03
Carcass price, \$/cwt	100.42 ^a	105.26 ^b	104.91 ^b	104.07 ^{bc}	103.30 ^c	104.83 ^b	104.74 ^b	0.02
Total revenue, \$/head	715.89 ^a	753.48 ^{bc}	760.36 ^b	732.65 ^{ac}	718.41 ^{ad}	742.92 ^{bcd}	744.09 ^{bcd}	0.06
Total feed cost, \$/head	258.53 ^a	236.49 ^b	238.28 ^b	214.74 ^c	214.68 ^c	198.70 ^d	200.29 ^d	0.0001
Corn cost, \$/head	172.08 ^a	146.09 ^b	147.93 ^b	116.85 ^c	116.92 ^c	128.68 ^d	130.19 ^d	0.0005
Interest, \$	39.41 ^a	41.45 ^b	41.57 ^b	43.62 ^c	43.36 ^c	35.90 ^d	35.81 ^d	0.02
Total variable cost, \$/head	750.05 ^a	733.66 ^{ab}	735.30 ^{ab}	715.88 ^{bc}	709.73 ^c	741.38 ^a	741.48 ^a	0.02
Total cost, \$/head	770.17 ^a	748.90 ^b	750.55 ^{ab}	731.25 ^{bc}	725.10 ^c	761.67 ^{ab}	761.77 ^{ab}	0.05
Cost of gain, \$/cwt	50.96 ^a	48.61 ^b	48.57 ^b	47.06 ^b	47.38 ^b	52.17 ^c	52.47 ^c	0.04
Breakeven price, \$/cwt hot carcass	106.91 ^a	103.67 ^b	103.07 ^b	103.10 ^b	104.08 ^{bc}	106.71 ^{ac}	106.58 ^{ac}	0.04
Profit, \$/head	-54.28 ^a	4.58 ^b	9.81 ^b	1.39 ^{bc}	-6.70 ^{bc}	-18.75 ^c	-17.68 ^c	0.05

^{abcd} Means with different superscripts in the same row are significantly different with respect to their P-values.

Table 11. Economic variables when corn price decreases 5 percent

Variable	FEEDLOT	JI	JNI	OI	ONI	SI	SNI	P<
Feeder price, \$/cwt	94.58	94.58	94.58	94.58	94.58	84.30	84.30	-
Purchase price, \$/head	367.05 ^a	366.77 ^a	367.42 ^a	367.73 ^a	366.51 ^a	418.97 ^b	418.39 ^b	0.0001
Hot carcass weight, lb	720.96 ^{ab}	723.05 ^{ab}	731.97 ^a	711.17 ^{ab}	701.17 ^b	715.57 ^{ab}	717.24 ^{ab}	0.03
Carcass price, \$/cwt	100.42 ^a	105.26 ^b	104.91 ^b	104.07 ^{bc}	103.30 ^c	104.83 ^b	104.74 ^b	0.02
Total revenue, \$/head	715.89 ^a	753.48 ^{bc}	760.36 ^b	732.65 ^{ac}	718.41 ^{ad}	742.92 ^{bcd}	744.09 ^{bcd}	0.06
Total feed cost, \$/head	242.14 ^a	222.57 ^b	224.19 ^b	203.61 ^c	203.54 ^c	186.44 ^d	187.89 ^d	0.0001
Corn cost, \$/head	155.69 ^a	132.18 ^b	133.84 ^b	105.72 ^c	105.78 ^c	116.43 ^d	117.79 ^d	0.0005
Interest, \$	39.41 ^a	41.45 ^b	41.56 ^b	43.62 ^c	43.36 ^c	35.89 ^d	35.82 ^d	0.02
Total variable cost, \$/head	733.66 ^a	719.75 ^{ab}	721.22 ^a	704.75 ^b	698.60 ^b	729.12 ^a	729.08 ^a	0.06
Total cost, \$/head	753.78 ^a	734.99 ^{ab}	736.46 ^a	720.12 ^b	713.97 ^b	749.42 ^a	749.37 ^a	0.06
Cost of gain, \$/cwt	48.91 ^a	46.85 ^b	46.80 ^b	45.63 ^b	45.93 ^b	50.32 ^c	50.58 ^c	0.05
Breakeven price, \$/cwt hot carcass	104.63 ^a	101.74 ^b	101.15 ^b	101.54 ^b	102.49 ^{ab}	105.00 ^a	104.85 ^a	0.03
Profit, \$/head	-37.89 ^a	18.49 ^b	23.90 ^b	12.52 ^{bc}	4.44 ^{bc}	-6.49 ^c	-5.28 ^c	0.04

^{abcd} Means with different superscripts in the same row are significantly different with respect to their P-values.

Table 12. Economic variables when feeder price increases 5 percent

Variable	FEEDLOT	JI	JNI	OI	ONI	SI	SNI	P<
Feeder price, \$/cwt	99.31	99.31	99.31	99.31	99.31	88.52	88.52	-
Purchase price, \$/head	385.28 ^a	385.11 ^a	385.79 ^a	386.11 ^a	384.84 ^a	440.33 ^b	439.31 ^b	0.0001
Hot carcass weight, lb	720.96 ^{ab}	723.05 ^{ab}	731.97 ^a	711.17 ^{ab}	701.17 ^b	715.57 ^{ab}	717.24 ^{ab}	0.03
Carcass price, \$/cwt	100.42 ^a	105.26 ^b	104.91 ^b	104.07 ^{bc}	103.30 ^c	104.83 ^b	104.74 ^b	0.02
Total revenue, \$/head	715.89 ^a	753.48 ^{bc}	760.36 ^b	732.65 ^{ac}	718.41 ^{ad}	742.92 ^{bcd}	744.09 ^{bcd}	0.06
Total feed cost, \$/head	250.33 ^a	229.53 ^b	231.23 ^b	209.18 ^c	209.11 ^c	192.57 ^d	194.09 ^d	0.0001
Corn cost, \$/head	163.89 ^a	139.13 ^b	140.89 ^b	111.29 ^c	111.35 ^c	122.56 ^d	123.99 ^d	0.0001
Interest, \$	40.79 ^a	42.96 ^b	43.21 ^b	45.97 ^c	45.19 ^c	37.34 ^d	37.58 ^d	0.03
Total variable cost, \$/head	761.54 ^a	745.26 ^{ab}	748.46 ^{ab}	737.43 ^{bc}	724.10 ^b	758.15 ^{ac}	763.99 ^{ac}	0.03
Total cost, \$/head	781.65 ^a	760.50 ^{bc}	763.71 ^{ab}	752.80 ^b	739.47 ^b	778.44 ^{ac}	784.28 ^{ac}	0.06
Cost of gain, \$/cwt	50.11 ^a	47.81 ^b	47.86 ^b	46.35 ^b	46.99 ^b	51.52 ^a	51.76 ^{ac}	0.04
Breakeven price, \$/cwt hot carcass	108.48 ^a	105.07 ^{bc}	104.99 ^{bc}	104.72 ^{bc}	106.37 ^{ac}	109.01 ^a	108.90 ^a	0.02
Profit, \$/head	-65.76 ^a	-5.89 ^b	-4.07 ^b	-12.07 ^b	-23.33 ^{bc}	-35.06 ^c	-35.51 ^c	0.06

^{abcd} Means with different superscripts in the same row are significantly different with respect to their P-values.

Table 13. Economic variables when feeder price decreases 5 percent

Variable	FEEDLOT	JI	JNI	OI	ONI	SI	SNI	P<
Feeder price, \$/cwt	89.85	89.85	89.85	89.85	89.85	80.09	80.09	-
Purchase price, \$/head	348.59 ^a	348.44 ^a	349.05 ^a	349.34 ^a	348.19 ^a	398.39 ^b	397.47 ^b	0.0001
Hot carcass weight, lb	720.96 ^{ab}	723.05 ^{ab}	731.97 ^a	711.17 ^{ab}	701.17 ^b	715.57 ^{ab}	717.24 ^{ab}	0.03
Carcass price, \$/cwt	100.42 ^a	105.26 ^b	104.91 ^b	104.07 ^{bc}	103.30 ^c	104.83 ^b	104.74 ^b	0.02
Total revenue, \$/head	715.89 ^a	753.48 ^{bc}	760.36 ^b	732.65 ^{ac}	718.41 ^{ad}	742.92 ^{bcd}	744.09 ^{bcd}	0.06
Total feed cost, \$/head	250.33 ^a	229.53 ^b	231.23 ^b	209.18 ^c	209.11 ^c	192.57 ^d	194.09 ^d	0.0001
Corn cost, \$/head	163.89 ^a	139.13 ^b	140.89 ^b	111.29 ^c	111.35 ^c	122.56 ^d	123.99 ^d	0.0001
Interest, \$	38.03 ^a	39.68 ^b	39.97 ^b	42.08 ^c	41.93 ^c	34.52 ^d	34.47 ^d	0.01
Total variable cost, \$/head	722.18 ^a	704.59 ^{ab}	708.33 ^{ab}	693.95 ^{bc}	688.18 ^b	713.35 ^{ac}	714.32 ^{ac}	0.04
Total cost, \$/head	742.30 ^a	719.84 ^{bc}	723.58 ^{ab}	709.32 ^b	703.56 ^b	733.64 ^{ac}	734.61 ^{ac}	0.04
Cost of gain, \$/cwt	49.76 ^a	47.34 ^b	47.45 ^b	46.01 ^b	46.50 ^b	51.10 ^{ac}	51.16 ^c	0.06
Breakeven price, \$/cwt hot carcass	103.06 ^a	99.70 ^b	99.34 ^b	99.24 ^b	100.39 ^{bc}	102.74 ^{ac}	102.46 ^{ac}	0.04
Profit, \$/head	-26.41 ^a	33.31 ^b	36.55 ^b	28.28 ^{bc}	20.20 ^{bc}	9.74 ^c	11.14 ^c	0.04

^{abcd} Means with different superscripts in the same row are significantly different with respect to their P-values.

Feeder cattle price also fluctuates with supply of calves coming to the market. As was the case in this study, spring-born cattle had lower feeder cattle prices but were heavier. Thus in the Midwest it might be more beneficial to buy lighter fall-born calves in spring and backgrounding them on pasture at a low cost during summer and fall. In the South where winter pasture is available to cattle, buying spring-born calves at a cheaper price in fall and backgrounding them on pasture before finishing could be more profitable.

CHAPTER 5. GENERAL CONCLUSIONS

On pasture cattle receiving an ionophore tended to gain faster than those not receiving an ionophore ($P>0.1$) however this trend was reversed when cattle were moved to the feedlot ($P>0.1$). Cattle, which spent more time on pasture, gained faster while on pasture than those that spent less time. When cattle were moved to the feedlot, the trend seen on pasture was reversed and cattle that spent less time on pasture gained faster than those that spent more time on pasture ($P<0.05$). In terms of gain throughout the experiment, FEEDLOT cattle had the highest gain ($P<0.001$).

FEEDLOT, SI and SNI cattle had lower dry matter intake than JI, JNI, OI and ONI ($P<0.01$) in the feedlot. OI and ONI cattle were less efficient than other cattle in the feedlot ($P<0.02$).

Cattle receiving an ionophore on pasture had lower KPH fat than those that did not receive an ionophore ($P<0.01$) and tended to have more backfat ($P=.09$). All treatments were YG 2 and all treatment groups graded 75 % Choice or higher.

When using actual prices, FEEDLOT cattle were less profitable than other cattle ($P<0.001$) and the reason for this was the lower carcass prices they received. However when 10 years average prices were used for feeder and fed cattle prices and feed components, SI and SNI cattle were the least profitable cattle ($P<0.001$).

These results show that cattle grazed on pasture for various time periods had acceptable and comparable carcass grades. The price received for carcasses was influenced by the time of year the cattle were marketed and this was an important factor affecting profitability.

APPENDIX. ECONOMIC ANALYSES WORKSHEETS

Example 1. Base example for FEEDLOT cattle**Revenue**

Sales income (lbs @ \$ _____)
 Death loss (1 % of sales) _____

Gross income = Sales income – death loss _____

Variable Costs

Feeder cost (lbs @\$ _____)
 Interest @ 10 % _____

Feed Costs

- | | |
|--|-----------------|
| 1) Corn | (bu @\$ _____) |
| 2) Supplement and Minerals (natural based) | (lbs @\$ _____) |
| 3) Supplement and Minerals (urera based) | (lbs @\$ _____) |
| 4) Alfalfa hay (mid-bloom) | (ton @\$ _____) |
| 5) Molasses | (ton @\$ _____) |
| 6) Soybean meal | (lbs @\$ _____) |

Total feed costs = (1+2+3+4+5+6)

- 7) Veterinary and health
- 8) Machinery and equipment
- 9) Marketing and miscellaneous
- 10) Interest on feed & other costs @ 10 %
- 11) Labor, 2 hours per head @7.50 per hour
- 12) Trucking
- 13) Implants and others

Total variable costs = (Feeder cost + interest on feeder cost + total feed costs + items 7 through 13)

Income over variable costs = (Gross income – total variable costs)

Fixed costs

Machinery, equipment, housing \$21

Total all costs = Total variable costs + fixed costs

Income over all costs = (Gross income – total all costs)

Example 2. Base example for SI and SNI cattle**Revenue**

Sales income (lbs @ \$____)
 Death loss (1 % of sales) _____

Gross income = Sales income – death loss _____

Variable Costs

Feeder cost (lbs @\$____)
 Interest @ 10 % _____

Feed Costs

- 1) Corn (bu @\$____)
- 2) Supplement and Minerals (natural based) (lbs @\$____)
- 3) Supplement and Minerals (urera based) (lbs @\$____)
- 4) Alfalfa hay (mid-bloom) (ton @\$____)
- 5) Molasses (ton @\$____)
- 6) Soybean meal (lbs @\$____)
- 7) Improved pasture cost

Total feed costs = (1+2+3+4+5+6+7)

- 8) Veterinary and health
- 9) Machinery and equipment
- 10) Marketing and miscellaneous
- 11) Interest on feed & other costs @ 10 %
- 12) Labor, 2 hours per head @7.50 per hour
- 13) Trucking
- 14) Implants and others

Total variable costs = (Feeder cost + interest on feeder cost + total feed costs + items 8 through 14)

Income over variable costs = (Gross income – total variable costs)

Fixed costs

Machinery, equipment, housing \$21

Total all costs = Total variable costs + fixed costs

Income over all costs = (Gross income – total all costs)

Example 3. Base example for JI, JNI, OI and ONI cattle**Revenue**

Sales income (lbs @ \$____)
 Death loss (1 % of sales) _____

Gross income = Sales income – death loss _____

Variable Costs

Feeder cost (lbs @\$____)
 Interest @ 10 % _____

Feed Costs

- 1) Corn (bu @\$____)
- 2) Supplement and Minerals (natural based) (lbs @\$____)
- 3) Supplement and Minerals (urera based) (lbs @\$____)
- 4) Alfalfa hay (mid-bloom) (ton @\$____)
- 5) Molasses (ton @\$____)
- 6) Soybean meal (lbs @\$____)
- 7) Improved pasture cost

Total feed costs = (1+2+3+4+5+6+7)

- 8) Veterinary and health
- 9) Machinery and equipment
- 10) Marketing and miscellaneous
- 11) Interest on feed & other costs @ 10 %
- 12) Labor, 2 hours per head @7.50 per hour
- 13) Trucking
- 14) Implants and others

Total variable costs = (Feeder cost + interest on feeder cost + total feed costs + items 8 through 14)

Income over variable costs = (Gross income – total variable costs)

Fixed costs

Machinery, equipment, housing \$16

Total all costs = Total variable costs + fixed costs

Income over all costs = (Gross income – total all costs)

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