FEED INTAKE OF FEEDLOT CATTLE:
PREDICTION EQUATIONS AND
EFFECT OF RESTRICTION

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Submitted to the Faculty of the
Graduate College of the
Oklahoma State University
in partial fulfillment of
the requirements for
the Degree of
DOCTOR OF PHILOSOPHY
December, 1988

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ACKNOWLEDGEMENTS

I wish to express sincere appreciation to my major advisers, Dr. Fred Owens and Dr. Don Gill, for their guidance and assistance during the course of this study and in the preparation of this manuscript. I would like to thank Dr. Jim Oltjen for his assistance in analyzing my data and developing intake prediction equations. I also am grateful to the other committee members, Dr. Don Wagner and Dr. Ronald McNew, for their advice during the preparation of this manuscript.

Grateful acknowledgement also is extended to Dr. Bob Lake, Dr. John Thornton and Dr. Bob Hillier with the Hitch Organization for the use of their extensive feedlot records. Their suggestions have helped me to develop prediction equations which should be useful to the commercial feedlot industry.

Special thanks are due to Dr. Chuck Strasia and Dr. Jerry Martin for their assistance in supervising my feeding trials at Goodwell, OK.

I also am grateful to my fellow graduate students for their friendship, assistance and helpful suggestions.

A very special thanks is extended to my parents, Bob and Linda Hicks, for their love and support during the course of this study. I would also like to thank my mother-in-law, Hollis Burgess, for her love and encouragement.

My deepest appreciation is extended to my wife, Mona, and my daughter, Cortney, for their help, understanding, patience, and love during the course of this study.

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CHAPTER I

INTRODUCTION

The amount of feed consumed by animals must be predicted to properly formulate mixed diets. For most nutrients, animals require specified amounts per day, not dietary percentages. Hence, if feed intake is greater or less than a specified amount, formulation of diet on a percentage basis can never be accurate. Feed intake information also is essential to predict performance of animals and economics of production. For feedlot cattle, once the net energy content of the diet and feed intake are known, gains and feed efficiency can be predicted quite accurately using the California Net Energy system (NRC, 1984). Net energy values for feedstuffs are reasonably constant and can be calculated either from tables or from previous records of animal performance. Feed intake, in contrast, cannot be predicted very accurately. In addition, feedlots at times have problems with cattle that either consume too little or too much feed. Cattle subjected to mud or cold stress in winter often have greatly reduced feed intakes and fail to gain at expected rates. A small percentage of cattle consume more feed than they can efficiently utilize and, presumably, have rapid rates of passage and reduced digestibility. Most problems of overconsumption are associated with poorly processed grains. However, some large frame cattle, possibly as a result of selection for high feed intakes, also may consume more feed than can be efficiently utilized.

If feed intake could be predicted or controlled, economics of production would be improved. Potential profit or loss of feedlot cattle could be predicted more precisely if feed intake could be predicted more accurately.

Feed intake equations for cattle have been proposed in publications by Gill (1979), the Agricultural Research Council (1980), Goodrich and Meiske (1981), Owens and Gill (1982), the National Research Council (1984), Fox and Black (1984), Plegge et al. (1984) and Thornton et al. (1985). Most of these predictions have been based on mean feeding weights and mean feed intakes for pens of cattle and relate feed intake to metabolic body size (weight to the 3/4 power). According to most of these equations, feed intake of finishing cattle should increase continually as cattle gain weight. Field experience of cattleman and certain feedlot records refute this suggestion (Thornton et al., 1985). Instead, records prove that feed intake during a feeding period increases rapidly to a plateau and only declines later as cattle reach finished weights. Only four of the above prediction equations (Gill, 1979; Owens and Gill, 1982; Plegge et al., 1984; Thornton et al., 1985) predict this decline in feed intake and only one predicts a relatively flat intake plateau (Thornton et al., 1985). Further study is needed to determine the shape of the feed intake curve for various types and classes of feedlot cattle.

Weekly dry matter intake records were obtained for the years 1983-1985 from a large feedlot in Western Oklahoma. Accordingly, one major objective of this study was to develop a feed dry matter intake prediction equation based on feedlot records from this large feedlot. Factors considered in analysis were initial weight, sex, breed type, season of the year and days on feed. Another objective was to determine the predictability of future feed intake from observed feed intake early in the feeding period (first 28 to 56 days of a feeding period).

Several recent studies indicate that feed efficiency of feedlot cattle can be improved by controlling or limiting feed intake. Several methods to control feed intake have been tested. These include limiting time of access to feed (Garrett, 1979), pair feeding pens at a given percentage of feed intake of pens with ad libitum access to feed (Lofgreen, 1969; Davis et al., 1973; Lofgreen et al., 1983; Plegge et al., 1985, 1986; Hanke et al., 1987) or programming feed intake to obtain specific weight gains (Zinn, 1986). Within these methods, different time periods of restriction (early vs. late in the finishing period) have been investigated (Lofgreen et al., 1987; Wagner, 1987).

Reducing feed intake should not improve efficiency according to the net energy equations and these equations predict feedlot results of cattle with ad libitum access to feed quite precisely. However, the above studies indicate that controlled feeding can improve efficiency (gain/feed). Hence, the net energy equations must be inaccurate. Suggested reasons for improved feed efficiency with controlled feeding include reduced feed wastage, increased diet digestibility, reduced animal activity, and reduced gut and liver size which in turn reduce the maintenance requirement.

In addition to the observed improvement in feed efficiency with controlled feeding, Lake (1987) listed several potential management related advantages which could help to remove some of the variability and risk associated with cattle feeding. Under the proper management conditions, controlled feed intake for feedlot beef cattle could prove economically feasible for production of leaner beef. Thus, the final objective of this study was to determine how and why limiting feed intake effects performance and efficiency. Three different methods of controlling feed intake were tested and effects of controlled intake on digestibility, rate of passage, feed waste, animal behavior and liver size were measured.

CHAPTER II

REVIEW OF LITERATURE

Factors Influencing DMI of Feedlot Cattle

Feed intake has been the subject of several books and symposia recently (Forbes, 1986; Mertens, 1985, 1987; NRC, 1987; Feed Intake Symposium - Oklahoma, 1987). Grovum (1987) recently reviewed the physiological factors controlling feed intake of ruminants. My review will emphasize studies with feedlot cattle fed high energy diets. The NRC (1987) divides the factors influencing feed intake of beef cattle into animal, dietary and environmental components. Additional factors which need to be considered are the use of feed additives and anabolic implants (Potter and Wagner, 1987).

Animal Factors

Body Size. Energy requirements of beef cattle for maintenance and production are related to metabolic body size (body weight $kg^{.75}$) by NRC (1984). Based on this assumption, dry matter intake (DMI) also has been thought to be related to metabolic size (Van Soest, 1982). However, Van Soest questions the use of metabolic size as a base noting that gastrointestinal capacity and rumination are related to the 1.0 power of body weight whereas metabolic requirements may be related to power .75 or less. He concluded that if intake is dependent upon gastrointestinal fill and metabolic requirements, the best power fit would vary depending on the character of animals and feeds. Colburn and Evans (1968) examined the best fit of forage intake with body weight in growing Jersey steers. They noted that as a reference base for DMI of mature animals a power of .54 was a more effective than was the power of .75. Owens and Gill (1982a) in a review of 15 Oklahoma feeding trials (1500 cattle) found that feed intake was related to the .47 power of shrunk body weight. Thornton et al. (1985) reported that mean DMI of yearling beef steers fed a high energy ration in a large commercial feedlot was related to mean body weight during the feeding period raised to the .656 power. However, these workers noted that this relationship changed with time on feed (a power of 1.02 during the first 14 days on feed declining to a power of .47 after 56 days). Preston (1972) concluded that mean DMI of beef cattle was 95 $g/kg^{.75}$, with a 95% confidence interval of 87 to 103. Several beef DMI equations have based DMI calculations on the .75 power of body weight (Gill, 1979; ARC, 1980; Goodrich and Meiske, 1981; NRC, 1984; Fox and Black, 1984).

Body Composition. The lipostatic theory of intake regulation suggests that animals regulate their energy intake to maintain a certain body composition or total body fat content (Kennedy, 1953). Mechanisms responsible for regulation of body fat are not understood (NRC, 1987). Taylor (1969) observed that herbage intake of grazing cattle declined as the weight of internal fat increased due to competition for abdominal space. The NRC (1987) proposed that increased body fat more likely reduces appetite as a result of a feedback from adipose tissue on the appetite control center in the central nervous system. Studies by Forbes (1968) have shown that in pregnant ewes, rumen volume is decreased markedly by the developing fetus(es).

Feed intake equations proposed by Owens and Gill (1982a), Fox and Black (1984) and Plegge et al. (1984) all suggest that intake per unit of metabolic weight begins to decline at about 350 kg average-frame-size steer equivalent weight (NRC, 1987). The "equivalent weight" concept is the basis for predicting DMI in the system developed by Fox and Black (1984). According to this system, a decline in DMI of average frame size steers is predicted to begin at 350 kg and is associated with a body fat composition of 22%. Hyer et al. (1986, 1987) in an investigation of DMI patterns of commercial feedlot cattle described by Thornton et al. (1985) observed that when medium frame steers reach a level of empty body fat of about 32%, DMI begins to decrease markedly.

<u>Mature Size</u>. Cattle varying in mature size or frame size differ in the weights at which they reach a given chemical composition or degree of fatness (Koch et al., 1976; Smith et al., 1976; Harpster et al., 1978; Crickenberger et al., 1978; Fortin et al., 1980). Fox and Black (1984) reviewed these data and concluded that body composition at a given weight varies with frame size; larger frame cattle have heavier weights at the same composition. Thus, cattle varying in mature size or frame size would be expected to differ in the weights at which DMI begins to decline. However, only three DMI prediction equations (Gill, 1979; Fox and Black, 1984; NRC, 1984) include adjustments for frame size.

<u>Gender</u>. Studies have shown that gender (steer, heifer or bull) causes cattle to differ in the weights at which they reach a given degree of fatness (Harpster et al., 1978; Fortin et al., 1980). Thus, depending on gender, weights at which DMI begins to decline would

differ. Harpster et al. (1978) found that DMI of steers was 13% greater than that of heifers but when compared on a relative metabolic size basis (g/weight, $kg^{.75}$) DMI was only 3% higher for heifers. Owens et al. (1985) observed that DMI of beef steers and heifers in a large commercial feedlot were similar when compared at the same liveweights. However, these workers noted that DMI tended to peak earlier in the feeding period for heifers (28 days) than that for steers (70 days) and the decline occurred earlier for heifers. Owens and Gill (1982a) reported that bulls consume about 2% more feed than steers of similar weight in most trials. The NRC (1987) concluded that most of the differences in voluntary intake between sexes can be attributed to differences in weight at a given body fat. Four DMI prediction equations include adjustments for sex (Fox and Black, 1984; NRC, 1984; Plegge et al., 1984; Thornton et al., 1985).

Age. The NRC (1984) concluded that in predicting DMI for growing cattle started on feed as yearlings that body weight should be increased by 10% as compared to calves with similar weights and frame sizes. Goodrich and Meiske (1981) and Fox and Black (1984) indicated that DMI was 10% greater for yearlings than calves. In contrast, Plegge et al. (1984), concluded that mean DMI over a feeding period was only 5.2% greater for yearlings than for calves. Commercial feedlot data from the Imperial Valley in California (Zinn, 1987) indicated that intake was consistently higher (about 15%) and reached a plateau earlier for yearling cattle than for calves. The NRC (1987) concluded that the yearling effect on intake may be the same as that obtained during compensatory growth. If cattle are light for their age growth must have been retarded during a previous period.

The initial weight at which cattle are placed on a high energy diet has a major effect on DMI (NRC, 1987) that to some degree may be related to age of cattle. Owens and Gill (1982a) found that daily DMI increased .20 kg for each 50 kg above 277 kg initial weight, and that it decreased by a similar amount for initial weights under 277 kg. Plegge et al. (1984) noted similar trends in DMI with increasing initial weight. Other workers have noted much greater effects of initial weight on intake. Gill et al. (1981a) in a study with 126 steers observed that feed intake increased by 1.2 kg/d for each 50 kg increase in initial weight. Owens and Gill (1982b) in two trials reported that DMI was increased by .45 kg/d and .6 kg/d for each 50 kg increase in initial weight. In a large commercial feedlot, Thornton et al. (1985) noted an increase of .75 kg/d in DMI for each 50 kg increase in initial weight.

Four DMI prediction equations include adjustments for age (Goodrich and Meiske, 1981; Fox and Black, 1984; NRC, 1984; Plegge et al., 1984) and four have incorporated initial weight as a factor (Gill, 1979; Owens and Gill, 1982a; Plegge et al. 1984; Thornton et al., 1985).

Breed Type. Most of the differences in DMI among beef cattle breeds and their crosses can be accounted for by differences in mature size or by variation in weight at a given body fat (Fox, 1987; NRC, 1987). Owens and Gill (1982a) noted that beef steers of European breeding generally consume feed in amounts equal to steers of British breeding. Smith et al. (1976) reported that crossbreeds averaged 2% greater intake than straightbreds fed to the same stage of growth. Harpster et al. (1978) noted that Angus X Hereford X Charolais crossbred steers consumed about 10% more dry matter per day than straightbred Herefords. However, no differences among breed type were noted in DMI expressed on a metabolic size basis (g/body weight$^{.75}$). Similarly, Lomas et al. (1982) reported that DMI was 19% greater for Charolais steers than Hereford steers but DMI was not different when expressed on a metabolic size basis. Coleman and Evans (1986) noted that Charolais steers consumed 13% more feed per day but 12% less per unit of metabolic body size than did Angus steers. These data tend to indicate that there is little difference among beef breeds in DMI expressed on a equal weight or a metabolic size basis.

Several studies have shown that Holstein steers consume considerably more feed than do beef steers. Garrett (1971) indicated that Holstein steers consumed 3.6 to 8.4% more dry matter per kg metabolic body size. Dean et al. (1976) noted that daily DMI increased by 4 and 11% as the percentage of Holstein breeding in calves increased from 0 to 25% and to 50%. Wyatt et al. (1977) found similar increases (3% and 18%) in daily DMI as the percentage of Holstein breeding in calves increased from 0 to 25% and to 50%. Harpster et al. (1978) noted that 50% Holstein steers consumed 2.3% more feed per kg metabolic body size than did steers without Holstein breeding. Crickenberger et al. (1978) showed the daily metabolizable energy intake by Holstein steers was 14 to 26% greater than by beef steers in two trials. Data of Thonney et al. (1981) showed that Holstein steers consumed about 12% more dry matter each day than Angus steers at comparable weights. The equations of Plegge et al. (1984) indicated that Holstein cattle eat about 8% more than beef breeds, whereas the equation of Fox and Black (1984) shows that Holstein crosses consume 9% more feed than beef breeds whereas straight Holsteins consume 17% more feed. Commercial feedlot data from Kansas (Owens et al., 1985) indicated that DMI of Holstein steers was 9% greater than that of beef steers of equal feeding weight. Data from California feedlots showed that intake of Holsteins was 13% greater than that of beef breeds (Zinn, 1987).

These data indicate that DMI of 50% Holstein crossbred or straightbred Holstein cattle is typically 10.3% (st. dev.= 5.7) greater than that of beef breeds of similar weight. Higher DMI may be due to a higher maintenance demand. Holsteins appear to have a higher proportion of organ and gut tissue (Jones, 1985). The higher DMI of Holstein cattle also might be ascribed to their larger mature size and(or) to genetic selection of Holstein cattle for high milk production and, thereby, high DMI (Owens et al., 1985).

Dietary Factors

Energy Concentration. When high fiber, low energy diets (<65% TDN) are fed, intake generally is considered to be limited by the physical capacity of the animal. With such diets, the quantity of feed consumed is a function primarily of dietary characteristics (Conrad et al., 1964; Montgomery and Baumgardt, 1965b). However, when net energy concentration in the diet is high and NDF content of the diet is low, as in finishing feedlot diets, metabolic controls are the dominant factors limiting DMI (Conrad et al., 1964; Montgomery and Baumgardt, 1965a; Mertens, 1987; NRC, 1987). Hence, depending on the dietary energy concentration or energy density, effects on rate of digestion/passage and on metabolic/physiological controls within the animal will dictate its relationship to DMI (NRC, 1987).

Baumgardt (1970) and Baumgardt et al. (1976) suggested that DMI of cattle was maximum when the diet contained 2.5 Mcal of digestible energy

(DE)/kg DM. This is equivalent to a metabolizable energy (ME) concentration of 2.05 Mcal/kg assuming that ME = 0.82*DE (NRC, 1984). Gill et al. (1981b) fed feedlot steers diets containing from 3.0 to 3.6 Mcal ME/kg of DM (8 to 24% roughage) and observed that for each 10% increase in dietary ME, DMI decreased by 8.8%. This decrease in DMI is somewhat greater than estimates from the ARC (1980) and Goodrich and Meiske (1981) of 4.4 and 3% for each 10% increase in ME. Based on a quadratic regression of feed intake across a number of studies with variable energy levels, Plegge et al. (1984) concluded that DMI of cattle was maximum at a ME content of 2.47 Mcal/kg DM. However, because ME intake is the multiple of ME content and feed intake, ME intake increased beyond the point of maximum intake. ME content of the diet at maximum intake was 3.2 Mcal/kg DM. In a review of a number of feeding trials, Fox and Black (1984) showed that DMI decreased 2g/kg of metabolic body size for each .02 Mcal/kg increase in net energy available for gain (NEg) when NEg exceeded 1.27 Mcal/kg DM. This is equivalent to 2.85 Mcal ME/kg DM. Several intake prediction equations include adjustments for energy concentration of the diet (Garrett, 1973; Song and Dinkel, 1978; ARC, 1980; Goodrich and Meiske, 1981; Fox and Black, 1984; NRC, 1984; Plegge et al. 1984). To illustrate the effect of ME density of the diet on DMI in these equations, predicted DMI for 300 kg medium-frame yearling steers was plotted against ME density (Figures 1 and 2). Five of the equations predict DMI to decrease linearly as ME increases (Figure 1). The other three equations show a quadratic relationship between DMI and ME (Figure 2). The points (ME density) of maximum ME intake and thereby the points of maximum gain from these equations would be: 2.65 (Garrett, 1973), 2.0 (Fox and

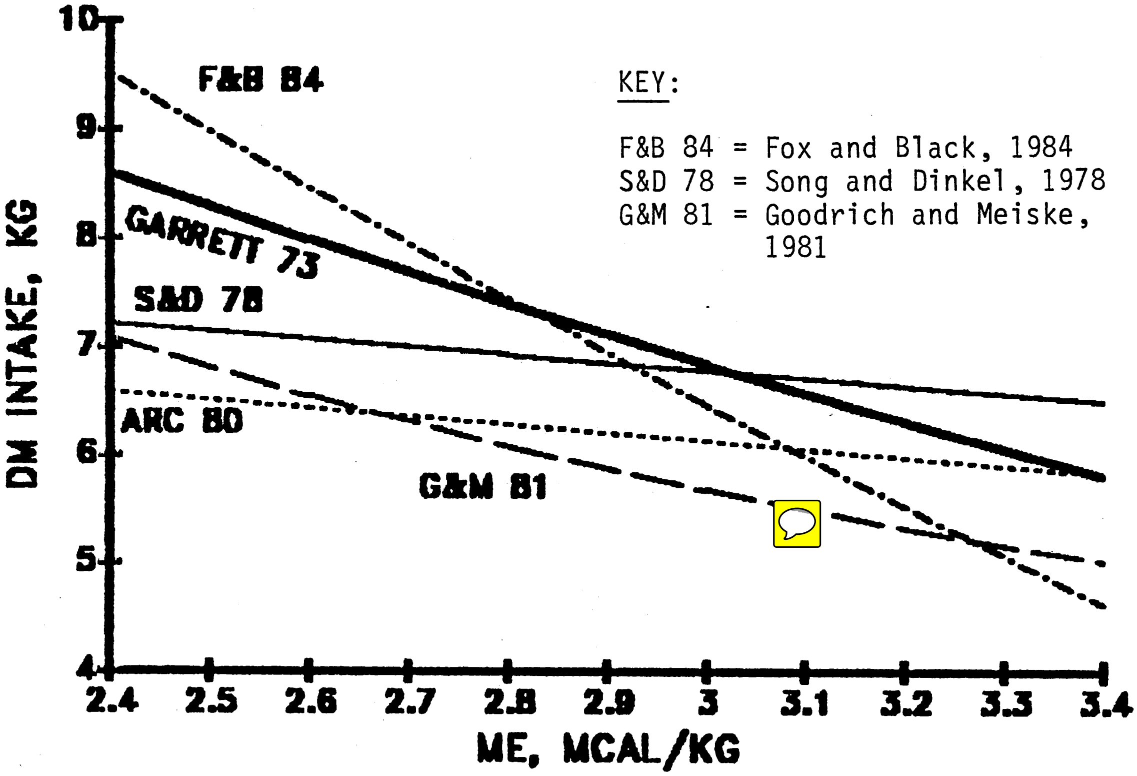

Figure 1. Effect of ME Density on Dry Matter Intake (Linear)

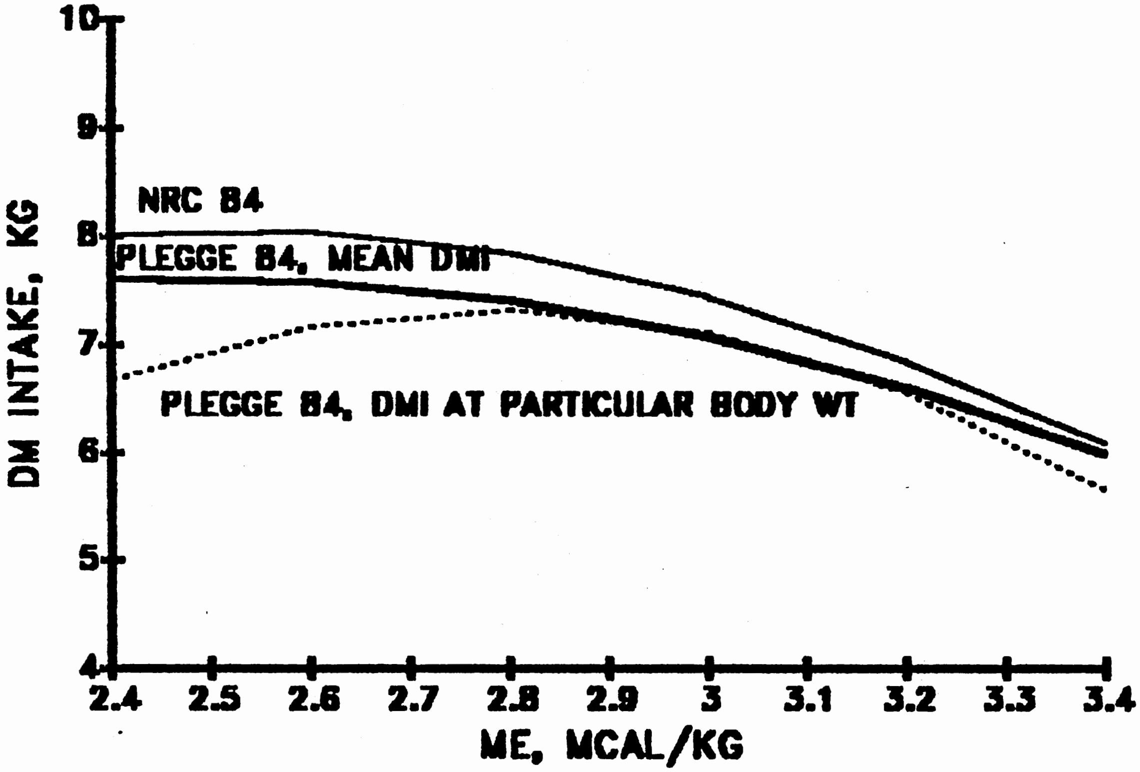

Figure 2. Effect of ME Density on Dry Matter Intake (Quadratic)

Black, 1984), 3.0 (NRC, 1984) and 3.20 (Plegge et al., 1984). The equations of the ARC (1980) and Goodrich and Meiske (1981) show ME intake to continue to increase as ME density increases. Song and Dinkel (1978) predict a constant ME intake, regardless of ME density. Whether a linear, quadratic or other function is most appropriate is not certain though results of Gill et al. (1981b) suggests that ME intake is reasonably constant over a broad range in ME (3.0 to 3.5 Mcal ME/kg DM). Hence, the curve may be forced by depressed intakes at low and at very high ME concentrations.

Feed Processing. The NRC (1984) summarized the influence of processing feedstuffs on intake and utilization and concluded that intake is increased by processing when roughage is the major constituent of the diet; intake generally is reduced by processing of grains if processing increases digestibility. The ARC (1980) summarized data from six journals to separate the interaction of diet energy concentration and degree of processing. They concluded that the change in intake varied with energy content of the diet: fine processing increased intake by 47.2% at .92 Mcal/kg of net energy available for maintenance (NEm), 20.8% at 1.33 NEm, 0% at 1.73 NEm and -17.2% at 2.10 NEm.

Owens and Hicks (1987) reviewed feeding trials (190 grain comparisons) conducted from 1975 to 1986 that examined the value of grain processing for feedlot cattle. With corn grain, they found that DMI was decreased by 6.9%, 1.2% and .9% by steam flaking, dry rolling and high moisture storage of corn, respectively, as compared to whole shelled corn. With milo grain, DMI decreased by 10.4% and 8.4% by steam flaking and reconstituting milo as compared to dry rolled or high moisture milo. With both grains, daily gains were similar regardless of type of processing suggesting that changes in DMI could be attributed primarily to increases in availability of energy from the grain. Other factors such as changes in the end products of digestion (Theurer et al., 1967; Trei et al., 1970), incidence of acidosis and bunk management (Owens and Hicks, 1987) may be involved as well.

Environmental Factors

Temperature and Weather. The NRC (1981) summarized the effects of environment on DMI. They concluded that voluntary DMI of beef cattle is increased by temperatures less than 15°C but decreased by exposure to wind, storms, and mud or by temperatures greater than 25°C (Table 1). They also concluded that adjustment for these effects is more accurate based on the average environmental state for a week or month than on daily fluctuations.

Young (1981, 1983) reviewed the effects of cold stress on beef cattle production and concluded that cold stress elevates resting heat production, energy requirements for maintenance and appetite drive and it decreases digestibility. The stimulation of appetite may partially counteract the increased energy requirements but it cannot alleviate the reduced efficiency of utilization of dietary energy. Elam (1971) reported that feed efficiencies by feedlot cattle were 14 to 20% poorer during winter than during summer in large commercial feedyards in southern California and in the Midwest (Kansas, Nebraska and Texas). Similar, data from the University of Saskatchewan (Milligan and Christison, 1974), from northern Colorado feedlots (Knox and Handley, 1973; Johnson, 1986) and from an Oklahoma panhandle feedlot (Paine et al., 1977) showed marked seasonal fluctuations in performance of cattle

TABLE 1. EFFECTS OF ENVIRONMENT ON FEED INTAKE OF BEEF CATTLE[a]

Temperature, °C or Lot Condition	Intake Change, %
> 35 with no night cooling	-35
> 35 with night cooling	-10
25 to 35	-3 to -10
15 to 25	None
5 to 15	2 to 5
-5 to 5	3 to 8
-15 to -5	5 to 10
< -15	8 to 25[b]
Rain	Temporary decrease of 10 to 30
Mild mud, 10 to 20 cm deep	-5 to -15
Severe mud, 30 to 60 cm deep	-15 to -30

[a] Modified from NRC (1981) and Fox and Black (1984).

[b] Intakes during extreme cold (< -25°C) or during blizzards and storms may be temporarily depressed.

that was attributed to changes in the environment. In contrast to these studies which have shown that performance was depressed during winter months, recent Arizona data (Ray, 1987) noted that gains and feed intake were 20 and 7% greater, respectively, during the winter than the summer. This difference could be attributed to heat stress during summer in Arizona which was not apparent in cooler climates above.. Plegge et al. (1984) reviewed a number of Minnesota feedlot studies and noted that DMI was 12% greater in winter than summer. Regression equations relating mean air temperatures or thermal stress indices to performance of cattle in feedlots indicate that much of the variation in performance could be attributed to climatic variables (Knox and Handley, 1973; Milligan and Christison, 1974; Johnson and Crownover, 1975; Paine et al., 1977).

Johnson (1986) in a review of the effects of climatic stress on beef cattle concluded that the effect of climate on DMI is difficult to predict except when animals are above the threshold of heat stress. At that time, DMI declines at a rapid and accelerating rate as temperature increases. From a review of Colorado, Iowa, Minnesota and Canadian feedlot data, Johnson further concluded that in feedlot cattle in the mid to northern United States and in Canada, climate causes short-term erratic changes in intake, but has little long term effect. Colorado studies indicate that the primary effect of cold stress on feedlot cattle is to increase maintenance energy requirements by 1.0 to 1.5% per effective ambient temperature unit below 20°C (Johnson and Crownover, 1975; Bourdon et al., 1984; Johnson, 1986; Birkelo et al., 1987).

Reviews on the effect of heat stress on animal production have been compiled by Fuquay (1981), Morrison (1983) and Minton (1987). These reviews all illustrate that heat stress reduces DMI by beef cattle. As shown in Table 1, intakes were depressed by 3 to 10% when the temperature was between 25 to 35°C and by as much as 35% when temperatures exceeded 35°C.

The NRC (1981) concluded that even though temperature is the environmental variable most frequently associated with feed intake, certain other factors including lot surface, space per animal and their interaction effects also can alter DMI (Hoffman and Self, 1970; Elam, 1971; Leu at al., 1977). Hahn (1981) has reviewed the effects of housing and management on livestock production; that topic will not be discussed here.

Photoperiod. The NRC (1987) and Young (1987) have reviewed the effects of photoperiod on DMI by beef cattle. Such information is limited because photoperiod typically is confounded with temperature on a seasonal basis. Experiments from environmental chambers provide some insight into the effects of photoperiod. DMI was 6 to 13% lower for sheep (Forbes et al., 1975, 1979; Schanbacker and Crouse, 1980; Tucker et al., 1984) exposed to a constant daily photoperiod of 8 hours light and 16 hours dark (8L:16D) than for sheep kept under 16L:8D photoperiod. Similarly, DMI of Holstein cows (Peters et al., 1981) and Holstein heifers (Peters et al., 1980) exposed to natural daily light periods (9-12 h light) were 5 to 8% lower than for animals exposed to 16L:8D photoperiod. Many commercial feedlots illuminate their lots at night with the assumption that it stimulates eating activity (Tucker et al., 1984; NRC, 1987). Presumably, light intensity has to be much higher than that used by feedlots to have physiological effects, but as an aid in locating feed, water and predators, night lighting should prove useful when moonlight is limited. Peters et al. (1980) observed a 6.5%

decrease in DMI in Holstein heifers exposed to continuous lighting as compared to 16L:8D photoperiod. Young (1987) in overview concluded that shorter photoperiods reduce DMI. This may relate to behavior patterns, as the evening grazing bout of ruminants begins as temperature declines but ceases shortly after sunset. Similar eating bouts are retained in feedlot cattle (Stricklin, 1987). In contrast to these findings from environmental chambers, several feedlot studies have shown intakes to be greater in winter than summer (Plegge et al., 1984; Ray, 1987). These differences illustrate the confounding between temperature and photoperiod on DMI.

Feed Additives

The primary non-nutrient feed additives used in the beef industry are ionophores. Currently only two ionophores, monensin and lasalocid, are approved by the Food and Drug Administration for commercial use in feedlot cattle. Potter and Wagner (1987) recently reviewed the effects of these two ionophores on DMI by beef cattle. They concluded that ionophores usually decrease DMI, increase daily gain and improve feed efficiency.

Goodrich et al. (1984) summarized the results of 228 trials that involved 11,274 head of cattle. Monensin decreased DMI by 6.4% while improving feed efficiency by 7.5%. These workers also summarized 29 trials and showed that DMI of cattle fed monensin decreased more as monensin dosage was increased. At levels typically fed to feedlot cattle, 27.5 and 33 g/ton, monensin depressed DMI by 6.9% and 8.1%. Witt et al. (1980) in a summary of six Oklahoma trials reported that monensin decreased DMI by 5.2%. Wagner (1982) in a summary of 45 trials noted that monensin decreased DMI by 6.1%. In a review of several trials, Plegge et al. (1984) concluded that monensin decreased DMI by 4.3%. Potter et al. (1985) reviewed 14 feedlot trials noting that monensin decreased DMI by 8.1% when fed at a level of 33 mg/kg. The equation of Fox and Black (1984) proposes that monensin reduces DMI by 10%.

Studies indicate that monensin reduces palatability of a diet, particularly during the first 28 days on feed (Elanco, 1975; Baile et al. 1979, 1982; Potter et al., 1984). These studies also show that the palatability of a diet with monensin is dependent upon concentration of the ionophore, how feed is offered to cattle and the type of ration which cattle are receiving.

Wagner (1982) in a summary of 17 feedlot trials reported that lasalocid decreased DMI by a mean of 4.6%. Hoffmann-La Roche (1982) summarized 15 feedlot trials noting that lasalocid fed at levels of 20 and 30 g/ton decreased DMI by 2.2 and 2.5%. The equation of Fox and Black (1984) proposed a 2% reduction in DMI with lasalocid use. Decreases in DMI generally are less with added lasalocid than with added monensin.

Other feed additives often fed to feedlot cattle at low levels include the antibiotics, tylosin and chlortetracycline (Potter and Wagner, 1987). These workers reported that the literature suggest that a temporary anorexia is associated with the high level feeding of antibiotics. Depressed DMI may last up to three weeks; it is thought to be the result of inhibition of rumen bacterial function (Bell et al., 1951). Brown et al. (1975) reported the results of four feedlot trials (1829 cattle) evaluating low level feeding of chlortetracycline (70 mg/hd/d) and tylosin (75 mg/hd/d). They noted slight increases in DMI (2.4 and 1.4%) with feeding of these antibiotics.

Tylosin is cleared for feeding with monensin at a level of 10 g/ton of feed to reduce the incidence of liver abscesses. Potter et al. (1985) summarized 14 feedlot trials which examined at the effect of feeding monensin and tylosin separately or in combination on performance of feedlot cattle. These workers observed no effect of tylosin on DMI when fed at 11 mg/kg diet DM. The combination of tylosin (11 mg/kg) and monensin (33 mg/kg) decreased DMI by 7.7% compared with a decrease of 8.1% from monensin only.

These data indicate that monensin decreases DMI by about 6.5% while lasalocid decreases intake by about 3%. Low level antibiotics such as tylosin have little effect on DMI.

Anabolic Implants

Almost all feedlot cattle and the majority of stocker cattle receive growth-stimulating implants. Four ear implants currently are approved for cattle: Synovex, Steer-oid, Ralgro and Compudose. Gill (1984) reported that implanting steers fed finishing rations increased rate of gain by 8 to 12% and improved feed efficiency by 5 to 8%. By difference, this means that energy intake and DMI were increased by 0 to 7%. Similarly, gains of feedlot heifers were increased by 6 to 10% and feed conversion by 4 to 7% with the use of implants. Potter and Wagner (1987) recently reviewed the effect of anabolic implants on feed intake of beef cattle and concluded that the implants stimulate protein deposition, thereby causing a "pulling" effect on DMI.

Compudose data from three finishing trials (Elanco, 1982) showed that this implant increased DMI by about 9% regardless of dosage level. Feedlot data from International Minerals and Chemical Corporation (no year given) indicates that implanting with Ralgro increased DMI by 8.2%. A review of feedlot implant trials by Syntex (1985) showed that Synovex increased DMI by 5.1% in 33 trials, Ralgro increased DMI by only 1.4% in 24 trials and Compudose increased DMI by 2.8% in eight trials. Owens and Gill (1982) concluded that growth stimulating implants usually increase DMI by 3 to 10% in feedlot cattle. A summary of Minnesota feedlot trials showed that implants increased DMI by about 8% (Plegge et al., 1984).

These data indicate that the use of anabolic implants in feedlot cattle generally increases DMI. However, in developing an intake prediction equation specifically for feedlot cattle, an adjustment factor for the use of implants is not necessary because equations generally are based on data of implanted cattle; very few feedlot cattle are not implanted. Similar to NRC (1984) energy equations, adjustments for disuse rather than utilization of implants is more logical and may be warranted.

Equations for Predicting DMI of Feedlot Cattle

Preston (1972)

Preston (1972) presented a simple equation to predict DMI of growing-finishing beef cattle as follows:

$$\text{DMI (kg/d)} = .095W^{.75} - .221$$

where DMI = daily dry matter intake
W = body weight in kg

This relationship indicates DMI for beef cattle will increase by 95 g per unit of metabolic weight. The 95% confidence interval was from 87 to 103g.

Garrett (1973)

Garrett (1973) developed a DMI prediction equation based on 10 years of feedlot research data collected at Davis and El Centro, California. His equation was:

$$\text{DMI (kg/d)} = 10.5 + .0144\text{MW} - 4.58\text{NEm} + .32\text{NEm}^2$$

where MW = mean weight of animal for feeding period in kg
NEm = Mcal NEm/kg DM

Other factors which were related to DMI in developing this equation, besides body size and energy concentration of the ration were temperature during the feeding period and days on feed. Average temperature during the feeding period did not influence DMI of the cattle in this data set and the number of days on feed had a significant negative influence on DMI. However, for feeding periods of average length (140 ± 20 days) Garrett found that precision of estimating DMI was increased little by including days on feed in his prediction of mean DMI.

Song and Dinkel (1978)

Song and Dinkel (1978) developed a prediction equation to estimate DMI regulated by physiological demand for energy (VFIp) where VFIp was varied with degree of maturity of cattle and energy density of diets. These workers observed that intake per unit of metabolic weight declined as degree of maturity increased. They concluded that this decrease was due to a decrease in physiological demand for energy with aging. Their equation was:

$$\text{DMI (g/kg } W^{.73}) = \text{Energy}_{PD} / \text{Energy}_{DM}$$

where Energy_{PD} = physiological demand for energy per kg of metabolic weight = 424.1 - 265.6DOM
DOM = degree of maturity = current live weight/ expected live weight
Energy_{DM} = Mcal ME/kg DM

This equation was developed using data from 1,105 steers of 14 different breeds of cattle born at the U.S. Meat Animal Research Center at Clay Center, Nebraska between 1970 and 1972 (Smith et al., 1976). All calves were weaned at about 215 days of age. Only postweaning data (excluding the first 28 days) on these steers was included in the regression analysis. All steers received three 12 mg diethylstibestrol implants and had ad libitum access to feed in outside pens. Cattle were weighed at 28-day intervals. The energy concentration of the corn silage-based rations fed to these steers ranged from 2.60 to 2.87 Mcal/kg DM. In each year, steers were divided into three slaughter groups (1970 - 190, 218 and 246; 1971 - 169, 211 and 254; 1972 - 194, 226 and 253 days on feed).

Gill (1979)

Gill (1979) developed a prediction equation based on weekly DMI data obtained from a large commercial feedyard:

$$\text{DMI (kg/d)} = W^{.75} (.0736362 + .0000899IW + .004089FG) - (.0070318 * (W-227.27))^2$$

Where W = body weight in kg
IW = starting shrunk weight in kg
FG = feeder grade, between 1 and 10

The most powerful single factor in this equation is initial weight. As initial weight increases, DMI increases. Feeder grade is used to adjust for DMI differences due to body type, previous nutritional history, age and type of ration fed (Gill and Burditt, 1986). Each unit change in feeder grade will change DMI by about .454 kg/day. For the types of cattle fed in High Plains feedyards, Gill and Burditt (1986) suggested the following feeder grades as starting points for various initial weights:

Initial Weight	Feeder Grade
159	2.8
182	3.2
204	3.6
227	3.8
250	4.0
273	4.2
295	4.8
318	5.3
341	5.8

Gill further suggested that DMI for the first 10 days of a feeding period should be reduced by 25%.

Loch and Pfander (1979)

Loch and Pfander (1979) developed a prediction equation based on the relationship of average body weight to DMI in data obtained from four commercial cattle feedlots at Calexico, California; Hays, Dodge City and Garden City, Kansas. The diets fed at these feedlots were approximately 86% concentrate. Research data from the literature and results of lamb feeding trials conducted at the University of Missouri-Columbia also were used in developing the equation. Their equation is:

$$DMI = 34.26568 - .01844W - .066611CONC$$

where DMI = daily DMI in g/kg of body weight
W = body weight in kg
CONC = percent concentrate in diet

ARC (1980)

The ARC (1980) developed a DMI equation for growing cattle on a fine diet based on a summary of data reported in six journals. They defined a fine diet as one consisting of concentrates and milled and/or pelleted or wafered roughages, alone or in combination. In their summary, mean DMI was 89.8 g per kg of metabolic body size and the mean animal weight was 219 kg. In the 159 diets reviewed, the average percent concentrate was 70. Their equation is:

$$\text{DMI (kg/d)} = W^{.75}\,(.1168 - .01059\text{ME})$$

where W = body weight in Kg
ME = Mcal ME/kg DM

Goodrich and Meiske (1981)

Goodrich and Meiske (1981) developed the following DMI equation based on data from 7,040 steer calves that were fed in 347 pens at the University of Minnesota:

$$\text{DMI (kg/d)} = 1.54 + .1025W^{.75} - .7143\text{ME}$$

where W = (initial weight + final weight)/2 in kg
ME = Mcal ME/kg DM

These workers noted that the correlation between predicted and actual DMI was .833. Thus, 69.4% of the variation in DMI was accounted for by the equation. It was suggested that for yearling steers or large-frame steer calves (including Holstein steers) that DMI should be increased by 8 to 10%.

Owens and Gill (1982)

Owens and Gill (1982) developed an equation based on a summary of 15 feeding trials (about 1,500 cattle) conducted at Oklahoma State University. In these trials, DMI and body weight were recorded in pens of 7 to 25 head each at intervals of 28 to 56 days. The trials lasted 96 to 196 days and cattle, medium or large frame size, were fed diets containing less than 16% roughage with corn or milo grain in the dry or high moisture form. In five of these trials, steers were subdivided by initial weight into groups of at least 32 head. The proposed equation was:

$$\text{DMI (kg/d)} = -5.08 + .0636W - .000072W^2 + .0039\ (IW - 276.7)$$

where W = body weight in kg
IW = initial shrunk body weight in kg

Owens and Gill noted that two-thirds of the observed intakes fell within 8% of the value predicted by this equation.

Fox and Black (1984)

Fox and Black (1984) developed a system for predicting DMI of cattle differing in frame size and sex. They used information from feeding trials reported in various sources, primarily experiment station bulletins and research reports. In their system, DMI for various frame sizes and sexes was based on that used for an average-frame size steer of equivalent body composition. Their basic equation relates DMI to metabolic body size as follows:

$$\text{DMI (kg/d)} = .09 \text{ to } .1 \text{ (decreasing with W)} * W^{.75}$$

Where W = average-frame size steer equivalent body weight in kg.

The coefficient which is multiplied by metabolic body size decreases by about .02 for each 22 kg increase in equivalent weight above 364 kg (Table 2). This system also included adjustments in DMI for age, breed, use of ionophores, dietary energy concentration and environment. Predicted DMI was increased by 10% for yearlings and Holstein crosses and by 17% for Holsteins. DMI was decreased by 10% with the use of monensin and by 2% with the use of lasalocid. Adjustments for dietary energy concentration and environment are listed in Table 3. Base DMI is decreased by 2 $g/W^{.75}$ for each .02 Mcal/kg increase in NEm concentration above 1.27 Mcal/kg DM.

NRC (1984)

The NRC (1984) developed an intake equation for growing and finishing cattle based on a review of published information from various sources. The equation was:

$$\text{DMI (kg/d)} = W^{.75} (.1493\text{NEm} - .046\text{NEm}^2 - .0196)$$

Where W = body weight in kg
NEm = Mcal NEm/kg DM

This equation also includes adjustments for frame size. No adjustment is necessary for medium-frame steer calves, medium-frame bulls and large-frame heifers. Animal weight (W) is increased by 10% for large-frame steer calves and medium-frame yearling steers and by 5% for large-frame bulls. Animal weight is reduced by 10% for medium-frame heifers.

Plegge et al. (1984)

Plegge et al. (1984) used data from 617 pens of cattle (14,199 head) used in feedlot trials conducted by the University of Minnesota from 1966 to 1984 to develop a DMI equation that described mean DMI for

TABLE 2. EFFECTS OF EQUIVALENT WEIGHT ON DRY MATTER INTAKE FOR FOX AND BLACK (1984)

Equivalent Weight, kg	Coefficient
< 364	0.100
364 - 386	0.099
386 - 409	0.098
409 - 439	0.097
439 - 454	0.095
454 - 477	0.093
477+	0.090

TABLE 3. ADJUSTMENT FACTORS FOR DAILY DRY MATTER INTAKE FOR FOX AND BLACK (1984)

Item	Multiplier
Dietary energy concentration, mcal NEg/kg dry matter	
1.27	.99
1.30	.97
1.32	.95
1.34	.93
1.36	.91
1.38	.89
1.40	.87
1.43	.85
1.45	.82
Temperature,°C	
> 35 with no night cooling	.65
> 35 with night cooling	.90
25 to 35	.90
15 to 25	1.00
5 to 15	1.03
-5 to 5	1.05
-15 to -5	1.07
< -15	1.16
Mud	
mild, 10-20 cm	.85
severe, 30-60 cm	.70

a feeding period. Approximately 90% of the cattle were beef steers. Data from 158 pens of cattle (5,244 head) were used to develop an equation to predict DMI of feedlot cattle at any body weight during a feeding period. Only those trials in which DMI and body weights were available for each 28 or 42-day period of the feeding period were included in the analysis. For both equations, each pen was classified according to sex (heifers or steers), age (calves or yearlings), breed (beef or Holstein), season of the year (winter or summer), use of monensin (with or without) and use of anabolic implants (with or without). Winter was defined as the period from October to March and summer as the period from April to September. The two proposed equations are:

$$\text{Mean DMI (kg/d)} = -7.65 + .0063MW + .0000189MW^2 + 9.4106ME - 1.9011ME^2;$$

$$\text{DMI at particular weight (kg/d)} = -43.18 - .004IW + .00003IW^2 + 36.8326RW - 20.8356RW^2 + 24.5011ME - 4.4019ME^2;$$

where MW = mean weight for feeding period in kg
ME = Mcal ME/kg DM
IW = initial shrunk weight in kg
RW = relative body weight = current shrunk body weight/shrunk slaughter weight

Adjustment factors for each of these equations for sex, age, breed, season, use of monensin and use of anabolic implants are shown in Table 4. These two equations accounted for 77.9 and 79.9% of the variation in DMI when adjustments for the mentioned factors were included.

TABLE 4. ADJUSTMENTS FOR SEX, AGE, BREED, SEASON, MONENSIN AND ANABOLIC IMPLANTS FOR PLEGGE ET AL. EQUATIONS[a]

Item	Adjustments, kg/day	
	Mean DMI	Particular DMI
Sex		
Steers	-0.185	0.255
Heifers	0.185	-0.255
Age		
Calves	-0.205	-0.055
Yearlings	0.205	0.055
Breed		
Beef	-0.265	-0.310
Holstein	0.265	0.310
Season		
Summer	-0.145	-0.450
Winter	0.145	0.450
Use of monensin		
With	-0.185	-0.165
Without	0.185	0.165
Use of anabolic implants		
With	0.295	0.300
Without	-0.295	-0.300

[a] Modified from Plegge et al. (1984).

Thornton et al. (1985)

Thornton et al. (1985) developed DMI prediction equations based on daily pen records of 675 pens (119,482 head) of yearling steers (primarily of British breeding) fed in a large feedlot in Western Kansas during 1982. Mean DMI for sequential 14 day intervals were obtained from these feeding records. Most cattle were fed for 98 to 168 days. The mean number of animals per pen was 175 and a mean of 18 observations were available per pen for a total of 3,897 period pen observations. All cattle were implanted with growth stimulants at the start of a feeding period. During the first 28 days on feed, the level of roughage in the diet was decreased stepwise from about 40% to the 14% of the finishing diet. The high concentrate diet consisted primarily of high moisture corn and was supplemented with monensin at levels of 22 to 27 ppm. The diet contained 3.18 Mcal ME/kg DM or 2.18 Mcal NEm/kg DM.

Intake equations were developed that used initial (arrival) feedlot weight and days on feed as input variables. It was noted that feed intake curves for these feedlot cattle appeared to consist of the three segments: adaptation phase (first 14 days), plateau phase (next 84 to 140 days) and a retard phase (after 84 days for heavier cattle or after 140 days for lighter starting weight cattle). Based on these curves, it was observed that the best fit of the data was obtained by using a distinct equation for the adaptation period. This avoided underestimation of DMI early in the feeding period which was apparent from equations designed to fit the total feeding period. Proposed equations were:

DMI, first 14 days (kg/d) = $.0217W^{1.02}$; $R^2 = .54$

DMI, after 14 days (kg/d) = $6.94 + .019DOF - .000127DOF^2 + .0000248IW^2$; $R^2 = .38$

DMI, total feeding period (kg/d) = $1.78 + .118\ DOF - .00123DOF^2 + .0162IW + .00000377DOF^3$; $R^2 = .50$

Mean DMI over 112 days on feed (kg/d) = $.197W^{.656}$; $r^2 = .54$

Where W = shrunk body weight in kg
IW = shrunk initial weight in kg
DOF = days on feed

Based on intake records on 48 pens of beef heifers (5,012 head) and 22 pens of Holstein steers (2,056 head) obtained from the same data base as the beef steers, Owens et al. (1985) noted that steers and heifers consumed similar amounts of feed at similar live weights but that Holsteins consumed about 9% more DM than beef steers of equal feeding weight. Thus, DMI predicted by the proposed equations should be increased by 9% for Holstein steers.

Comparison of DMI Equations

Predicted DMI for medium-frame yearling steers started on a high concentrate diet at 275 kg, as calculated from these equations, are presented in Table 5. Specific additional assumptions for each of the equations also are presented. Intake was predicted at 14-day intervals with the Thornton et al. (1985) equations (equations for first 14 days and after 14 days). Using the predicted DMI, live gains were estimated with equations from the NRC (1984) and intakes were matched with the specific body weights in Table 5. As the equations developed by various workers were based on data from different types of cattle and diets, some variation would be expected. At all body weights, the equation of Song and Dinkel (1978) predicted the lowest intakes, possibly because

TABLE 5. PREDICTED INTAKE OF FEEDLOT CATTLE BY PUBLISHED EQUATIONS

Source: Steer Wt	Preston 1972	Garrett 1973	Song & Dinkel 1978	Gill 1979	Loch & Pfander 1979	ARC 1980	Goodrich & Meiske 1981	Owens & Gill 1982	Fox & Black 1984	NRC 1984	Plegge et al. 1984	Plegge et al. 1984	Thornton et al. 1985	Mean
kg	- - - - - - - - - -	- - -	- - -	- - -	- - -	- - -	kg/day - - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -
275	6.19	6.48	5.59	7.91	7.46	5.74	6.32	6.96	6.08	6.98	6.36	5.83	6.67	6.52
300	6.63	6.84	5.68	8.30	8.00	6.13	6.79	7.51	6.49	7.45	6.79	6.47	9.25	7.12
325	7.05	7.20	5.72	8.62	8.52	6.51	7.24	7.98	6.89	7.91	7.24	7.01	9.39	7.50
350	7.47	7.56	5.71	8.87	9.01	6.88	7.69	8.35	7.28	8.36	7.72	7.45	9.48	7.85
375	7.87	7.92	5.67	9.04	9.48	7.25	8.13	8.64	7.59	8.80	8.22	7.78	9.52	8.17
400	8.28	8.28	5.60	9.15	9.93	7.61	8.56	8.83	7.89	9.24	8.74	8.01	9.52	8.45
425	8.67	8.64	5.48	9.19	10.36	7.96	8.99	8.94	8.17	9.67	9.29	8.13	9.46	8.71
450	9.06	9.00	5.33	9.15	10.76	8.31	9.41	8.95	8.35	10.09	9.86	8.15	9.35	8.93
475	9.44	9.36	5.15	9.05	11.14	8.65	9.83	8.88	8.52	10.51	10.46	8.06	9.09	9.11
500	9.82	9.72	4.93	8.88	11.49	8.99	10.24	8.71	8.56	10.92	11.07	7.87	8.73	9.25
Additional Assumptions:														
Initial Wt, kg		-	-	275	-	-	-	275	-	-	-	275	275	
Slaughter Wt, kg		-	500	-	-	-	-	-	-	-	-	500	-	
Feeder Grade		-	-	5	-	-	-	-	-	-	-	-	-	
ME, mcal/kg		-	3.00	-	-	3.00	3.00	-	-	-	3.00	3.00	-	
NEm, mcal/kg		2.03	-	-	-	-	-	-	-	2.03	-	-	-	
NEg, mcal/kg		-	-	-	-	-	-	-	1.37	-	-	-	-	
% Concentrate		-	-	-	90	-	-	-	-	-	-	-	-	

this equation was generated with calf data (steers started on feed at about 8 months of age). Predicted intakes generally were highest with the Loch and Pfander (1979) equations. Excluding the predicted intakes from these two equations, values were least variable for cattle weighing about 400 kg whereas values for lighter or heavier cattle were quite divergent.

To illustrate trends in feed intake with these differences in body weight, these predicted values are presented graphically in Figures 3 and 4. Figure 3 illustrates that many of the equations predict that DMI should increase continually in a manner roughly proportional to body weight. In contrast, four of the equations (Gill, 1979; Owens and Gill, 1982a; Fox and Black, 1984; Plegge et al., 1984) project the relationship between feed intake and body weight to be curved (Figure 4). The equation of Thornton et al. (1985) shows intake to increase in direct proportion to body weight until about 300 kg, then to plateau and begin to decline gradually as animals reach about 400 kg.

The reason for two different types of feed intake patterns is that the linear equations were developed largely from average DMI for feeding trials and average feeding weights; these typically relate intake to metabolic body size and indicate that DMI increases continually as animals gain weight. Such is not the case for intake during a feeding period for feedlot cattle based on field experience of cattlemen and researchers and actual feedlot records (Owens and Gill, 1982a; Thornton et al., 1985). Instead, feed intake during a feeding period generally increases rapidly for the first month and later declines with time on feed (Thornton et al. 1985).

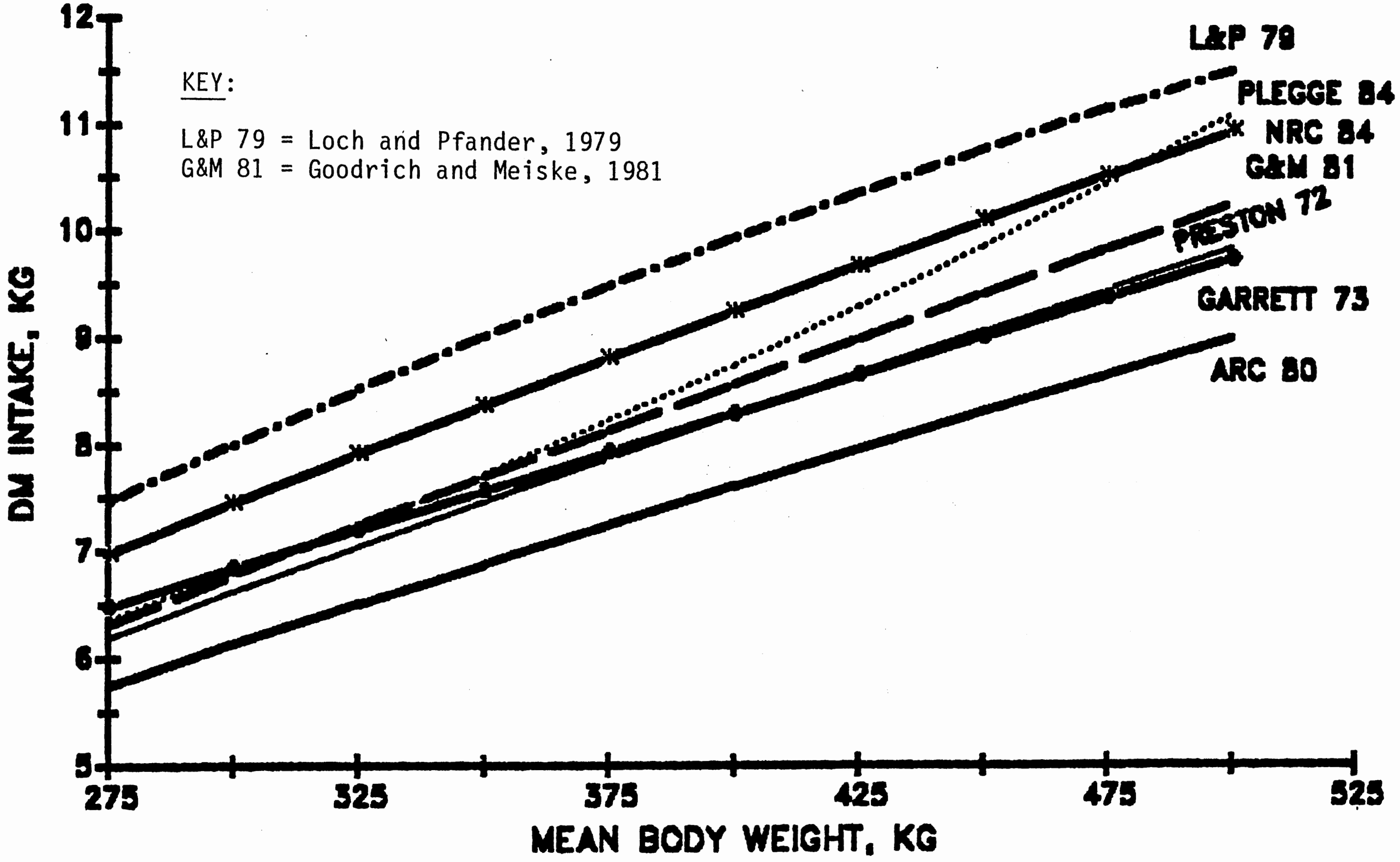

Figure 3. Predicted Feed Dry Matter Intakes of Feedlot Steers Using Equations Based on Average Intakes

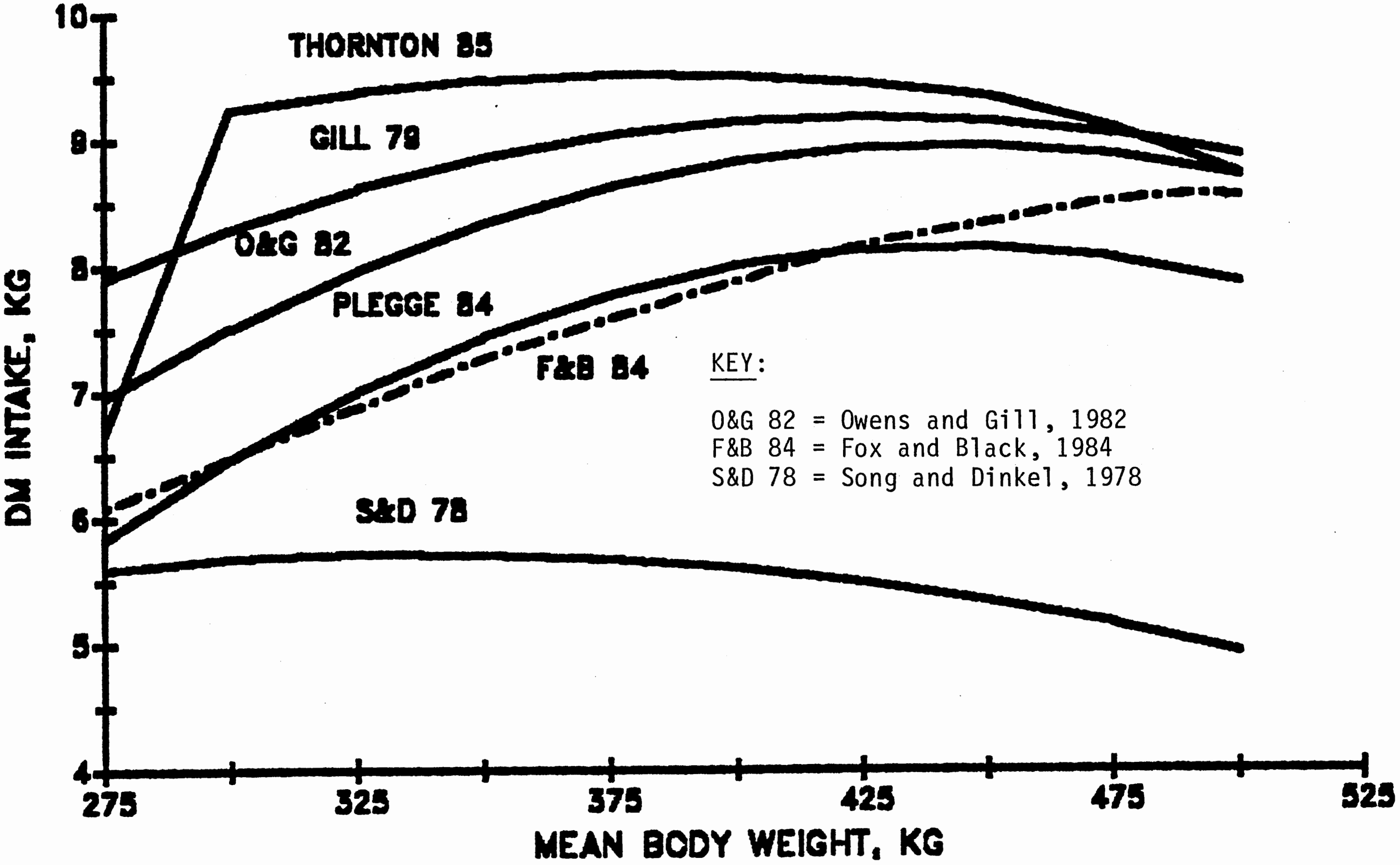

Figure 4. Predicted Feed Dry Matter Intakes of Feedlot Steers Using Equations Based on Interval Intakes

The four equations which predict this rise and decline of DMI were derived primarily from data within feeding trials instead of across overall means of feeding trials. Of these equations, those of Owens and Gill (1982a) and Plegge et al. (1984) predict a gradual rise and fall while the equation of Gill (1979) predicts a relatively flat plateau during the feeding period. Values from these three equations differ dramatically from those of Thornton et al. (1985). DMI predicted by the equation of Gill (1979) would more closely match those predicted by Thornton et al. (1985) if intakes during the first 10 days of the feeding period were reduced by 25% to allow for diet adaptation as suggested by Gill and Burditt (1986).

Controlled DMI for Cattle

Net energy equations (NRC, 1976, 1984) indicate that efficiency of feed utilization should be greatest when DMI is highest. This is because at higher feed intakes, maintenance is automatically diluted. However, results of some recent feeding trials indicate that efficiency of feed use can be increased by restricting intake. Several researchers have tested restricting feed intake of feedlot cattle in either the growing phase or the finishing phase of feedlot trials.

Growing Phase

Many commercial feedyards feed low energy diets to grow light cattle (200-250 kg) before feeding them the finishing ration. High roughage, low energy rations typically are fed for several months to increase their skeletal size and market weight (Lake, 1987). Whether carcass composition is greatly changed by a growing program is a matter of debate. Although a number of workers (Long, 1988) have found no carcass compositional differences between limit and full fed cattle slaughtered at a constant carcass time, other workers and producers report that cattle which are grown before being finished will weigh more when they reach slaughter weight. Rompala and Byers (1978) proposed that almost all weight gained above about 1 kg/d will be fat which implies that fat deposition is increased by higher energy diets. However, recent estimates of cutability (% lean cuts) of carcasses of about 2700 slaughter cattle (Owens et al., 1988) detected only minor effects of daily live weight gains (.8 to 2.5 kg/d) of individual cattle (not adjusted to equal initial weights) on their cutability.

For growing cattle, bulky diets traditionally have been full fed. With bulky diets, rate of gain is limited because cattle cannot consume as much energy as they desire due to the low energy density or bulkiness of the diet and limited gut capacity. Another method of growing cattle is by limiting access to a high-concentrate ration. Mader and Wagner (1987) compared full feeding of a high roughage ration with limit feeding of a high energy ration to growing feedlot cattle in two trials. In trial 1, during a 77 day growing period, steers fed the high energy ration (1.28 Mcal NEg/kg) were fed at 80% of the dry matter intake of the roughage fed steers (1.02 Mcal NEg/kg). During this growing period, limit feeding reduced gains by 8.1% while improving feed efficiency by 9.6%. In trial 2, during a 96 day growing period, steers fed the high energy ration (1.30 Mcal NEg/kg) were fed 75% of the dry matter intake of steers fed the roughage diet (1.12 Mcal NEg/kg). During this growing period, daily gains were reduced by 8.1% while efficiency of feed use was improved by 18%. These efficiency improvements would be expected because the limit fed diet contained less roughage. Subsequent gains of these steers during a finishing period (trial 1- 72 d, trial 2 - 117 d) were not altered by limit feeding. Over the finishing periods, feed efficiency was improved by growing cattle with the higher concentrate ration by 14.9% in trial 1 and by 8.3% in trial 2. Because cost per unit of energy was less from concentrate than from forage, limit feeding proved economically advantageous.

Peter (1987) compared programmed feeding (fed for specific weight gains) of a 62% concentrate ration with full feeding of an 87% roughage ration for feedlot steers and heifers during a 92 d growing period. Programmed feeding improved feed efficiency by 33.8% and by 27.8%, and reduced cost of gain by 17.2% and by 9.4%, respectively, for steers and heifers. In an 84 day trial, Peter (1987) compared full feeding of a 90% silage diet to programmed feeding of an 80% concentrate ration. Programmed feeding improved feed efficiency by 23.3% and reduced cost of gain by 6.7%. Again, feed efficiency improvements presumably were due primarily to diet composition differences. The relative price of NE from forage versus concentrate will dictate the relative economics of programmed concentrate versus roughage feeding.

Lake (1987) listed several advantages of a limit-fed high energy program as compared to the traditional high roughage grower program for feedlots in the Southern Great Plains. These included: 1) grain, usually being cheaper per unit of energy than roughage, reduces cost of gain; 2) limit feeding minimizes negative associative effects between grain and roughage; 3) limit feeding permits the cattle feeder to prescribe a gain to match frame and condition of cattle being fed; 4) reduced bunk cleaning; 5) reduced feed waste; 6) cattle adapt faster to their finishing ration; 7) reduced feed hauling; 8) roughage inventory is reduced; and 9) less manure needs to be handled. One additional advantage of limit feeding high energy rations is that feedlot performance is more predictable because grains are less variable in nutrient composition than are roughages and negative associative effects are reduced (Peter, 1987).

Finishing Phase

Several recent studies have reported that feed efficiency of finishing feedlot cattle can be improved by controlling or limiting feed intake. Results of controlled or restricted feeding studies with finishing steers are summarized in Table 6. Limit or controlled feeding of finishing cattle has improved efficiency of energy use in a number of trials. Most of these trials were day constant, not weight constant. Hence, limit fed cattle often were not as fat at slaughter as control cattle. This has resulted in decreased marbling and lower carcass quality according to the U.S. quality grade standards. In nine of these 17 comparisons efficiency of energy use was improved by controlling feed intakes, and in 13 of the comparisons estimated metabolizable energy of the diet was increased. These ME values were not determined directly, but instead were calculated based on equations described by Hays et al. (1987) using mean weight, mean DMI and rate of gain. These calculated energy values are apparent net or metabolizable energy contents of the diet. Thus this difference could be interpreted as a true increase in energetic efficiency or simply as failure of the Net Energy equations to correctly predict energy needs or deposition by limit fed cattle. These data indicate that the optimum level of restriction probably is in the

TABLE 6. SUMMARY OF RESTRICTED (>85% OF AD LIBITUM) FEEDING RESEARCH

Reference	Sex, Calves or Yearlings	N	Intake	Gain	Feed/Gain	Dietary ME
			% Change			
Lofgreen 1969	SC	12	-13.6	-9.0	-5.1	0.7
Garrett 1979	SC	43	-6.7	-7.6	1.3	3.7
Davis 1973	SY	12	-9.9	-15.7	6.9	-1.2
Davis 1973	SY	12	-5.4	-4.7	0.7	1.2
Lofgreen 1983	SC	88	-10.4	-11.4	1.0	1.0
Plegge 1985	SY	24	-7.3	-5.0	-2.5	1.6
Plegge 1985	SY	24	-4.5	-1.6	-3.2	1.6
Plegge 1986	SY	16	-8.0	-3.6	-4.7	4.3
Plegge 1986	SY	26	-4.6	-2.9	-2.2	3.0
Zinn 1986	SC	90	-5.8	0.0	-4.3	3.6
Hanke 1987	SY	80	-12.8	-13.1	-0.9	-1.1
Lofgreen 1987	SC	24	-10.0[a]	-7.0	-5.4	3.3
Lofgreen 1987	SC	24	-20.0[b]	-3.0	-4.7	3.3
Wagner 1987	SY	32	-16.9	-19.4	0.9	2.8
Wagner 1987	SY	32	-5.8	-11.5	5.6	-1.7
Wagner 1987	SY	32	-9.7	-12.9	3.0	1.0
Wagner 1987	SY	32	-12.6[c]	-14.3	7.6	-2.0

[a] Restricted only during first 59 days (time required to reach 318 kg). Overall intake 101.5% of ad lib.

[b] Restricted only during first 68 days (time required to reach 318 kg). Overall intake 98.4% of ad lib.

[c] Restricted only during first 56 days. Overall intake 92.8% of ad lib.

range of 90 to 95% of ad libitum intake. Higher levels of restriction may improve feed efficiency and apparent ME but can decrease weight gains drastically leading to the need to feed for increased lengths of time in order for cattle to reach similar quality grades. Although limit feeding is not always energetically advantageous, certain management benefits from limit feeding make limit feeding a popular concept.

Methods of Limit Feeding

As noted in Table 6, slight restrictions in feed intake appear to increase efficiency of feed use whereas severely limiting intake will depress both gain and efficiency of feed use. Thus, the ideal method for limit feeding must not severely retard performance. Several methods to control feed intake have been tested. These include 1) limiting time of access to feed or water, 2) pair feeding pens at a given percentage of feed intake of pens with ad libitum access to feed and 3) programming feed intake to obtain specific weight gains. Within these methods, different time periods of restriction (early vs late in the finishing period) and order of restriction within a feeding period have been investigated. Use of feed additives (e.g., salt, trace minerals) to control feed intake has not been tested for feedlot cattle. Timed access to feed and limiting the water supply have been tested, but results remain sketchy.

Limiting Time of Access to Feed. Garrett (1979) limited daily time of access to feed for feedlot steers to a 16 hour period (1600 to 0800). Limiting time of access to feed reduced feed intake by 6.7%, daily gains by 7.6% and efficiency of feed use by 1.3% as compared to ad libitum access time to feed. In addition, steers with limited time of access to feed had less fat and had lower grading carcasses than steers with ad libitum access to feed. However, animals with limited access to feed deposited as much protein per day as those animals with ad libitum access to feed. Garrett concluded that much of the additional energy consumed by ad libitum cattle was converted to fat. In recent unpublished Oklahoma trials, restricting time of access to an unlimited amount of feed to only 2 h each day with individually fed steers reduced feed intakes by 10.2% and gain by 9% but improved efficiency of feed use by 1.3%.

Pair Feeding. Pair feeding pens at a given percentage of the intake of cattle with ad libitum access to feed is the method of controlled feeding that has been tested most extensively. Lofgreen (1969) reported that feeding steers at 86.4% of ad libitum reduced daily gains by 9% while improving feed efficiency by 5.1%. However, with limit feeding the percentage of carcasses grading choice was reduced from 92% to 67%. Lofgreen et al. (1983) observed that feeding feedlot steers at 90% of the consumption of their pair mates on a metabolic body size basis reduced gains by 11.4% and efficiency of feed use by 1%. Even though the limit fed steers were fed two weeks longer than the ad libitum fed steers, their carcasses still had lower marbling scores and quality grades. Kansas work reported by Davis et al. (1973) showed that feeding steers 95% of free-choice intake reduced daily gains by 4.7% while having no effect on feed efficiency. Further restriction, at 90% of free-choice intake, reduced gains by 15.7% and efficiency of feed use by 11.4%.

Minnesota workers have conducted a number of studies on restricted feed intake. Limiting intake to 92% and 96% of ad libitum improved feed efficiency by 2.5% and 3.2% while reducing daily gains by 5% and 1.6%, respectively (Plegge et al., 1985). In a second trial with intakes restricted to these same levels, Plegge et al. (1986) noted improvements of 4.7% and 2.2% in feed conversion with restricted feeding while gains were reduced by 3.6% and 2.9%. In both Minnesota studies, amounts of feed offered to the restricted cattle were calculated from amounts fed to the ad libitum cattle the previous day, so intakes fluctuated daily. Further analysis of these data (Peters et al., 1987; Plegge, 1987) revealed that dietary metabolizable energy values tended to increase as feed intake decreased. In a pooled analysis of these two studies, Plegge (1987) observed that restricting intake to 92% and 96% of ad libitum improved feed efficiency by 2.8% and 2.6%.

Wagner (1987) fed yearling steers at 83% of ad libitum and noted that daily gains were reduced by 19% while efficiency was not altered. In an additional trial, Wagner fed yearling steers either 94 or 90% of ad libitum and observed that gains were reduced by 11.5 and 12.9% while efficiency of feed use was reduced by 5.6 and 3.0%, respectively. In both trials, Wagner fed all cattle to a common slaughter weight and detected no difference in the percentage of carcasses grading choice.

Rust et al. (1986) fed Holstein yearling steers at 70% and 85% of free choice and observed that cattle fed free choice gained 40.5% faster than limit fed cattle. However, feed efficiency was similar for all intake levels. Similarly, Hanke et al. (1987) noted that feeding crossbred yearling steers 87% of ad libitum reduced gain by 13% without significantly altering feed efficiency (+.9%). O'Connor et al. (1987)

fed 12 Angus steers and 12 Simmental steers at a high (9.7 kg/d), a medium (7.2 kg/d) or a low (6.7 kg/d) level of dry matter intake for an 87 d trial. Efficiency of feed use was reduced by 31.5% and 50% at the medium and low levels of intake. If one assumes the high intake level was equivalent to ad libitum feeding, then the medium and low intakes were 74% and 69% of ad libitum. Such extreme restriction is very detrimental to performance and efficiency.

Israeli workers have tested limit feeding of Israeli-Friesian bull calves. Levy et al. (1974) fed a 70% concentrate ration to calves (240 kg initial weight) at either ad libitum or 85% of ad libitum intake. The limit fed cattle gained 7.8% slower but were 11.8% more efficient in converting metabolizable energy to gain. Even though the limit fed bulls were on feed 15 days longer, they were (P<.05) less fat than the ad libitum cattle. Drori et al. (1974) in a similar experiment fed bull calves 1.5 kg hay/d plus free choice or 85% of free choice of a pelleted concentrate. Limit fed bulls gained only 3% slower but were 16% more efficient (concentrate/gain) and had less fat trim (3.3% vs. 3.7%).

In Denmark, Andersen (1975) fed Red Danish bulls either ad libitum, 85%, 70% or 55% of ad libitum. By reducing feed intake, gain was reduced more for fat than lean and bone. The most efficient conversion of feed to weight gain was noted at 85% of ad libitum intake. With reduced fat deposition, increases in feed efficiency would be expected. With less fat deposition by bulls than steers and less by steers than heifers, one might expect the least benefit from limit feeding with bulls and the greatest benefit with heifers if reduced fat deposition is desired.

In addition to trials with cattle, several trials have been conducted with lambs. Limiting intake of lambs of a 90% concentrate diet to 88% and 84% of ad libitum intake (S. Hart, personal communication) reduced daily gains 0% or 14% but improved efficiency of feed utilization by 20% and 6%. Differences in carcass traits, though small, consistently reflected a decreased carcass fat content.

<u>Phase Restriction</u>. This approach to limit feeding was tested recently by Lofgreen et al. (1987). Three groups of steers had access to feed either ad libitum or at 90% or 80% of ad libitum amounts until the steers reached a weight of 318 kg. Thereafter, all steers had ad libitum access to feed until slaughter. Over the 193 d feeding trial, there was a trend towards increased feedlot performance with restricted feeding; efficiency of feed use was improved by 5.4% and 4.7% with intakes at 90% and 80% of ad libitum during the early portion of the finishing period (at lighter weights). Feed intakes per unit of weight during finishing were greatest for steers with restricted intakes earlier. In a similar study, Wagner (1987) fed yearling steers (376 kg) 87% of ad libitum for the first 56 days of the feeding period and noted a 14% reduction in gain and a 7.6% reduction in feed efficiency over the entire feeding period. He fed restricted steers an additional 13 days to reach a similar slaughter weight.

A similar study with sheep was reported by South African workers (Greeff et al., 1986a, 1986b) in which Merino lambs had access to feed ad libitum or at 82%, 72%, 65%, 55% or 45% of ad libitum amounts from 25 to 33 kg live weight. Later (from 33 to 45 kg live weight), all sheep had ad libitum access to feed. During the restriction phase, digestibility of the diet increased whereas growth rate and efficiency of feed use decreased progressively with increasing restriction. During the realimentation phase, there were progressive increases in feed intake, growth rate and feed efficiency at restriction levels up to the 65% restriction level though more severe restrictions resulted in decreased feed intake, growth rate and feed efficiency. Over the entire feeding period, the 82% and 72% groups tended to convert feed to weight more efficiently even though they were fed 10 days longer than the ad libitum group. These workers concluded that sheep subjected to a feed restriction at levels up to 65% of ad libitum during th first 25% of the normal finishing weight gain will still recover completely after the restriction is removed.

Programmed Feeding. Another approach to limit feeding is to limit the amount of feed provided so that cattle will achieve a prescribed daily weight gain. With such a program, feed supply is reduced most drastically early in the feeding period. With ad libitum access to feed, feed intakes by feedlot cattle peak and plateau between 60 and 100 days on feed to decline later as cattle deposit fat and approach slaughter weight (Thornton et al., 1985). Thus, feedlot cattle with ad libitum access to feed have a discontinuous growth pattern, making rapid gains initially and slower gains later in the finishing phase (Zinn, 1986). Programming feed intake to a specific daily weight gain alters both intake and growth patterns more drastically than do other methods of limit feeding.

Zinn (1986) divided 180 steer calves into ad libitum and restricted treatment groups. Steers in the ad libitum group received feed at 110% of appetite whereas feed intake of steers in the programmed group was adjusted weekly to maintain a daily gain of 1.27 kg. This was equal to the anticipated average weight gain of the ad libitum group. In this experiment, daily gains were similar for ad libitum (1.25 kg) and programmed (1.24 kg) groups. However, feed intake of the programmed steers was 5.8% lower, so efficiency of feed use was improved by 4.3% by programming. In contrast to results from most other limit feeding studies (Drori et al., 1974; Garrett, 1979; Levy et al., 1974; Lofgreen, 1969 and Lofgreen et al., 1983), Zinn found no differences in carcass composition (estimated from specific gravity) due to intake level. Zinn also noted that steers in the programmed group rapidly developed into "meal eaters" usually consuming their allotment within 30 minutes after each feeding. This approach to limit feeding would be the simplest method to apply under feedlot conditions. However, under-estimating gain of a set of cattle probably would be a costly mistake. With typical feed and yardage costs, it is difficult for improved efficiency to fully compensate economically for lost time.

A final approach to limit feeding is to program feed intake of cattle to specific weight gains for variable lengths of time and/or alternating periods over a total feeding period as has been tested by Canadian workers (Hironaka and Kozub, 1973; Hironaka et al., 1979, 1984). Hironaka and Kozub (1973) divided 90 Hereford steer calves (212 kg) into six groups and fed an all concentrate diet until marketing (489 kg). One group had ad libitum access to feed while the other groups were programmed to specific daily weight gains for 12 or 24 weeks at a low (.45 kg gain/d) or medium (.9 kg gain/d) level and then placed on full feed. Although the restricted steers gained faster than the full fed steers after the period of restriction, compensation was not sufficient to allow these steers to catch up to the others in weight.

Thus, they took 19 to 68 days longer to reach market weight so that the amount of feed eaten during the entire feeding period was similar by all groups. Nevertheless, feed efficiency tended to be improved with restricted feeding (.2% to 4.6%). The most efficient group was fed to maintain daily gains of .9 kg for 24 weeks, but these cattle required 29 more days to reach market weight. Restricted steers tended to have less backfat and carcass grades differed markedly.

In a similar study, Hironaka et al. (1979) fed 76 Hereford steers an all concentrate diet to gain at low (L, .5 kg/d), medium (M, .8 kg/d) or high (H, ad libitum) rates during two 12 week periods followed by a third period which lasted until the steers reached slaughter weight (480 kg). Five feeding sequences were tested: LMH, HML, MMM, HHH and LLH. Steers fed ad libitum over the total feeding period gained fastest (P<.01, 1.15 kg/d). Feed efficiency was similar among all treatment groups, but restricted groups required 43 to 66 more days to reach market weight. Steers that were most severely restricted in the early or later stages or to a moderate degree throughout the entire feeding period had leaner carcasses than those with ad libitum access to feed for the entire period.

Hironaka et al. (1984) fed 80 Charolais X Hereford steer calves an all concentrate diet in amounts to allow gains of about .7 kg/d (L) or .9 kg/d (M), or were fed ad libitum (H). Using the same feeding programs tested above (LMH, HML, MMM, HHH, and LLH) intakes were controlled during two periods of 12 week duration with steers being fed to 420 kg. The steers with ad libitum access to feed for the total feeding period consumed the most feed per day, gained the fastest (1.10 kg/d) and required the least time to reach market weight. But feed efficiency was improved by 6% to 7.2% with the restricted feeding programs, except for the LLH program, even though 27 to 42 additional days were required for steers to reach market weight. Similar to the previous study, steers that had DMI restricted during part or all of the experiment had leaner carcasses than those fed ad libitum over the entire period. Economics of these feeding programs were evaluated under four different market situations; economic returns favored the LMH program in all four cases. Economics will depend on the marketing system. If excessive fat thickness is discounted, limit feeding has greater potential then when lack of intramuscular fat is discounted.

The results of these Canadian studies (Hironaka and Kozub, 1973; Hironaka et al., 1979, 1984), in which feed intake was programmed to a specific weight gain, differ from those reported by Zinn (1986) in that fat deposition was decreased in all three Canadian trials with some level of restricted feeding while the time required to reach market weight was increased. These differences may be due to the fact that under Zinn's continuous restriction program, restricted steers gained constantly but at the average rate of the ad libitum fed steers, whereas in the Canadian studies, gain of restricted steers was considerably less (78% to 92% of ad libitum) than for ad libitum fed steers.

<u>Method Comparisons</u>. The most commonly tested method of controlled feeding is pair feeding pens at a given percentage of the intake of pens with ad libitum access to feed. Under research conditions, pair feeding is feasible. But in a large commercial feedyard, pair feeding would be difficult to implement. Limiting the amount of feed provided so that cattle will achieve a prescribed daily gain as tested by Zinn (1986) appears more feasible on a large scale and currently is being used by

some feedyards in California (Zinn, 1987). However, with this method of controlled feeding under-programming the gain of a set cattle probably is a costly mistake as it would be difficult for improved efficiency to fully compensate for lost time. Whether restriction should be imposed throughout the finishing period or just during the first half, as tested by Lofgreen et al. (1987) and Wagner (1987), remains to be determined.

Potential Pitfalls. With limit feeding animal management problems are of concern. Bunk space, feeding frequency and behavior topics have been addressed previously by Lake (1987) and Zinn (1987). With limit feeding, it presumably is important that cattle be fed at least twice daily. Peter (1987) indicated that bunk space must be sufficient so all cattle can eat simultaneously. Lake (1987) reported that with nine inches of bunk space per head, 55% of growing cattle in a pen can eat at one time, whereas with twelve inches per head, 75% can eat simultaneously. Lake further reported that when heifer calves were allotted to pens with either nine or twelve inches of bunk space per head, no differences in performance were detected during the growing phase. He fed the two daily meals with only a 2 hr interval so that timid cattle would have more chance to eat. Zinn (1987) recently assessed the importance of bunk space for limit-fed steers. In his study, 64 steers were sorted into light (200 kg) and heavy (228 kg) groups and assigned bunk space allotments of 6, 12, 18 and 24 inches per head. Weight gain and feed efficiency improved linearly with increasing bunk space for pens of steers from the lighter group while the opposite was observed for pens of cattle from the heavy group. Thus, within a group of cattle, the lighter cattle may benefit from additional space while the heavier cattle may benefit from the increased competition associated with restricted space.

Another potential problem with limit feeding is lactic acidosis. Lactic acidosis is noted most frequently when animals consume large meals infrequently. Incidence of acidosis could increase with controlled feeding because cattle consume their feed during a short period of time (Plegge, 1986). When the amount of feed is restricted and meals are frequent, the incidence of acidosis should be reduced. Yet, changes in the amount of feed supplied occur quite often, due either to errors in feed calling and feed delivery to a pen of cattle or the need to compensate for changes in weather or diet moisture content. With such changes, the potential for acidosis presumably could be greater for limit fed than for unrestricted cattle. Errors in feed delivery to limit fed pens of cattle can be catastrophic. A higher quality of cattle management is needed when intake is controlled. Including antibiotics and ionophores in limit fed diets to increase rumen stability and reduce lactic acidosis and liver abscesses would be recommended.

In summary, the potential advantages for controlling feed intake of finishing cattle, in addition to frequently improving feed efficiency include: 1) simplified and improved bunk management, 2) reduced labor for calling feed, 3) greater control over feed inventories, 4) reduced sorting of feed and bunk cleaning, 5) reduced feed weathering and waste, 6) reduced feed hauling, 7) less manure to be handled and 8) controlled performance to meet slaughter dates of futures contracts (Lake, 1987; Zinn, 1987).

Possible Reasons for Improved Feed Efficiency

Reducing feed intake should not improve efficiency according to the net energy equations (NRC, 1976, 1984). Those equations precisely match feedlot performance of cattle provided ad libitum access to feed. However, results of the above studies indicate that slight intake restriction can improve efficiency, if not on a feed efficiency basis, at least on a metabolizable energy basis. Several reasons for this improvement in efficiency of feed use include: 1) reduced feed waste from spillage, spoilage, wind and weather loss, 2) increased diet digestibility, 3) reduced size of the gut and liver, 4) reduced animal activity, 5) reduced dressing percent or fat deposition and 6) reduced variation in animal-to-animal and day-to-day intakes. Few studies have been conducted in an effort to determine which of these factors are important.

Feed Waste. One proposed reason for the improvement in feed efficiency with limit feeding is reduced feed waste from spillage, spoilage, wind and weather losses. As waste with pigs and chickens usually exceeds 5% of feed, one could expect similar values for cattle. Gill and Oldfield (1965) reported that feed waste of group-fed pigs varied from 3 to 25% and of individually-fed pigs from 7 to 36% indicating that waste varies greatly from one pig to another. Similarly, commercial cattle feeders have observed that in some pens certain cattle will dig feed out of the bunk. Gill and Egan (1957) found that if the level of feed in feeders was kept very low, necessitating frequent feeding, loss of feed by White Leghorn chickens could be cut from 33% to 2% percent using the same feeders. Presumably, feed wastage of cattle could similarly be reduced. In an outside commercial feedyard, the potential benefits from reduced sorting and weather losses and to maintain feed freshness would be greater than in a confinement test feeding facility.

Digestibility. Another proposed reason for the improvement in feed efficiency with limit feeding is increased diet digestibility. Under most conditions, intake and digestibility are inversely related (NRC, 1978: ARC, 1980). As feed intake increases, rate of passage may be accelerated which may cause digestibility to decrease (Owens et al., 1986a). Faster movement through the gastrointestinal tract exposes feed to digestive processes for a shorter time. The committee for dairy cattle (NRC, 1978) estimated that digestibility of organic matter declined by an average of 4 percent for each multiple of maintenance increase in intake. At twice maintenance intake, an 80% TDN diet would drop to 76.8%. The ARC (1980) concluded that the depression in metabolizable energy increases at an increasing rate with feed intake. They suggested the equation: Change in digestibility per multiple of maintenance = .107 - (.113 X digestibility at maintenance). At twice maintenance intake, digestibility would drop from 80% to 76.5%. Rust and Owens (1982) reported a larger depression (8.7%) in organic matter digestibility per multiple of maintenance intake for a high concentrate ration fed to steers. Van Soest et al. (1984) developed discount factors to adjust for the effect of intake level on digestion for specific feeds. As intake increased above maintenance, the discount increased up to about three times maintenance, at which point the effect plateaued (Fox, 1987). One would expect greater depressions with less thoroughly processed grains and higher digestible neutral detergent fiber (NDF) concentration in the diet. Discounts by the Van Soest system are based on total NDF, not digested NDF. Owens et al. (1986a,b) observed that total tract starch digestion tended to decrease as feed intake was increased from 1% of body weight to 2.2% of body weight in steers, possibly due to an increased rate of passage through the intestines.

Several sheep studies have shown that organic matter digestibility increased with feed restriction. Leaver et al. (1969) reported that feeding sheep increasing amounts of an 80% concentrate ration (600 g to 1400 g) resulted in a curvilinear drop in organic matter digestibility from 83 to 75.9%. Graham and Searle (1972, 1975) in two different studies observed higher organic matter digestibilities with sheep fed at maintenance than with ad libitum access to feed. Graham and Searle (1975) also noted that digestibility decreased as ad libitum intake of sheep increased from 800 g/d to 1300 g/d. In contrast to these studies, Rompala and Byers (1978) reported that feeding beef steers at 70% of ad libitum had no effect on diet digestibility. Although, these data generally indicate that restricting intake to levels near maintenance will increases diet digestibility, effects of slight restrictions (<15%) in feed intake of feedlot cattle remain largely unknown (Plegge, 1987).

<u>Changes in Size of Organs</u>. Another reason proposed to explain the improved feed efficiency with limit feeding is reduced size of gut and liver which in turn could lead to reduced maintenance energy requirements. As proportional sizes of the gut and liver increase, maintenance energy expenditures increase (Farrell et al., 1986). Rust et al. (1986) noted that liver weight in Holstein steers increased as feed intake increased from 70% of ad libitum to ad libitum. Lunt et al.

(1986) reported that in beef steers liver mass increased at the rate of 0.52 kg per kg of daily gain. With limit feeding, weight gains generally decrease so liver weight might be expected to decrease slightly. A more regular supply of energy and nutrients also could reduce liver size as changes in metabolic flux would be reduced. Reynolds and Tyrrell (1987) noted that whole body oxygen consumption was greater by heifers fed 130 g per kg of metabolic body size than by heifers fed at 70 g. Burrin et al. (1987b) observed similar reductions in partial, hepatic and splanchnic oxygen consumption in limit fed ram lambs. In an additional study, Burrin et al. (1987a) noted that total visceral organ mass represented less of empty body weight in maintenance fed wethers than in sheep fed ad libitum. As increased digesta passage through the gut elevates the rate of turnover and erosion of the mucosa, slight restriction and regular meal size potentially could reduce protein and energy needs for replacing these tissues. No information on the effect of slightly restricted intake on gut size or turnover rate has been located.

Animal Activity. Whether limit fed cattle are more or less active than cattle with ad libitum access to feed is debatable. For the first several days of restriction, limit fed cattle appear restless, but following an adjustment period, they settle into a routine and appear calmer than cattle with ad libitum access to feed (Lake, 1987). If limit fed cattle are more lethargic, perhaps reduced movement and activity would reduce maintenance energy requirements.

Fat Deposition. Reduced fat deposition with limit feeding has been reported by several workers (Andersen, 1975; Garrett, 1979; Hironka and Kozub, 1973; Hironka et al., 1979, 1984; Levy et al., 1974; Lofgreen, 1969; Lofgreen et al., 1983). This could contribute to an improvement in feed efficiency because on a wet tissue weight basis, more energy is needed to deposit fat than to deposit lean (Hironka and Kozub, 1973; Webster, 1980).

Animal Variation. Zinn (1987) proposed that limit feeding minimizes day-to-day variation in feed intake. Animals with ad libitum access to feed exhibit wide inter- and intra- day fluctuations in feed intake. These fluctuations may cause digestive disturbance and decrease feed utilization. Stroup et al. (1987) reported that feed intake of a single animal over time exhibited cyclic variation in intake with 12-h, 24-h, 14-d and 28-d frequencies. Reducing day-to-day variation in intake conceivably could reduce the incidence of lactic acidosis and poor performing cattle. When averaged over a pen, this would lead to improved efficiency of feed use.

In summary, the increase in feed efficiency often observed with restricted intake in research trials could be attributable partially to differences in feed waste, digestibility, gut or liver size, animal activity, fat deposition or feeding regularity. Through proper management, slight restrictions in feed intake should prove useful under commercial feedlot conditions due to large pen size and animal variation and concerns about bunk management, feed waste and sorting and cost of hauling feed. Many of the benefits of limit feeding might be obtained by permitting bunks to remain slick for a short period of time each day. Data indicate that it is not necessary to provide animals with free choice access to feed at all times to maximize gain and efficiency of feed use by feedlot cattle. Indeed, slight restriction may stimulate cattle to eat more feed.

CHAPTER III

PREDICTING DRY MATTER INTAKE OF FEEDLOT BEEF STEERS: INFLUENCE OF INITIAL WEIGHT, TIME ON FEED AND SEASON OF YEAR RECEIVED IN YARD

Summary

Feed intake records from a large commercial feedlot were analyzed to determine the relationship of dry matter intake by beef steers to initial weight, time on feed and season of the year in which the cattle were received in the yard. Information was available for dry matter intake of a high concentrate feedlot diet at 7-day intervals from 2,051 pens of cattle over a three year period (1983-1985). Pens held a mean of 145 beef steers per pen for a total of 296,367 cattle. For analysis, the data were divided into groups of cattle entering the feedlot in the following four seasons: January 29 - April 30 (winter wheat pasture cattle), May 1 - July 30 (graze-out wheat pasture and early intensive gazing program cattle), July 31 - October 29 (grass pasture cattle) and October 30 - January 28 (grass pasture cattle). The number of pens received in each of these seasons were 604 (90,972 hd), 416 (56,543 hd), 585 (84,855 hd) and 445 (63,997 hd). This approach to the data accounted for much of the seasonal patterns in feed intake attributable to the inseparable factors of environment (temperature and day-length) and animal background and origin. Dry matter intake prediction equations were developed for each season which included initial weight, days on feed and 8 to 28 day mean intake as input variables. By including 8 to 28 day intake as an input variable, which in total could explain 64 to 76% of the variation in weekly intake, accuracy of prediction was increased (R^2 increases by .10 to .19 units). Including such data allows feed intake predictions to be customized for a pen which leads to more accurate gain projections. By detecting low intake pens early in the feeding period, appropriate corrective measures can be taken.

(Key Words: Feed Intake, Initial Weight, Days on Feed, Feedlot Steers)

Introduction

Because DMI (dry matter intake) is the basis on which nutrient requirements, gain and profit are all calculated, DMI must be predicted accurately. Performance of feedlot steers (thereby gain and profit) can be predicted quite accurately based on the California Net Energy Equations (NRC, 1976, 1984) when net energy content of the diet and DMI are known. In turn, net energy content of a diet can be estimated with a reasonably high degree of accuracy from tables of feed composition or from a history of animal performance of cattle fed a similar diet (Hays et al., 1987; Zinn, 1987). The primary factor limiting the precision of predicting performance is our ability to predict DMI.

Equations to predict DMI have been proposed by several workers (Table 1). Predicted feed intakes for medium-frame yearling steers started on a high concentrate diet at 275 kg, as calculated from these equations were presented earlier in this publication (Table 5 and Figures 3 and 4 of Chapter II). As the equations developed by various workers were based on data from different types of cattle and diets, some variation would be expected. Among the equations, predicted values were most similar for cattle weighing about 400 kg; estimates of DMI for lighter or heavier cattle were quite divergent.

Most of the equations predict that DMI will increase continually in a linear fashion as body weight increases (Figure 3). In contrast, four of the equations (Gill, 1979; Owens and Gill, 1982a; Fox and Black, 1984; Plegge et al., 1984) indicate that the relationship between DMI and body weight is curvilinear (Figure 4). The equation of Thornton et al. (1985) predicts that DMI is in direct proportion to body weight until steers reached about 300 kg (30 d) at which time it would plateau and gradually begin to decline as animals reach about 400 kg. These different patterns have been derived from two different types of data. The linear equations were developed from mean feed intakes for feeding trials and mean feeding weights; these typically relate intake to metabolic body size. Such equations indicate that DMI increases in rough proportionality to weight. These are based on means similar to the net energy equations. Continually increasing intakes of individual animals or pens are not commonly observed in feedlot cattle based on field experience of cattle producers and researchers and on actual feedlot records (Owens and Gill, 1982; Thornton et al., 1985). Instead, DMI for a set of animals during a feeding period generally increases rapidly for the first month and declines only later with time on feed (Thornton et al. 1985).

The four equations which predict such a rise and decline of DMI were derived from data within feeding trials instead of across means of weight and intake of many individual feeding trials. Of these equations, those of Owens and Gill (1982) and Plegge et al. (1984)

predict a gradual rise and fall while the equation of Gill (1979) predicts a relatively flat plateau during the feeding period. The values predicted by these three equations differ dramatically from those of Thornton et al. (1985). Intakes predicted by the equation of Gill (1979) would more closely match those predicted by Thornton et al. (1985) if DMI during the first 10 days of the feeding period were reduced by 25% to allow for diet adaptation as suggested by Gill and Burditt (1986).

One objective of this study was to more precisely define the relationship between DMI and various factors which are measurable initially or at intervals early during a feeding period (initial weight, days on feed, current weight) of commercially fed beef steers fed a high energy feedlot diet. All of the previously proposed prediction equations except for that of Thornton et al. (1985) utilize current weight as an input variable. Yet, in a typical commercial setting, current weight is not known or measured during a feeding period. The equation of Thornton et al. (1985) also does not account for environmental or seasonal effects which could alter intake patterns. Accordingly, another objective was to employ prediction equations utilizing initial weight and days on feed as input variables to detect and account for any seasonal differences in DMI.

Materials and Methods

Weekly dry matter intake records were obtained from a large feedlot in Western Oklahoma (Hitch I Feeders, Hooker, OK) for all pens of cattle marketed between January 1983 and December 1985. This represented 2,051 pens of non-dairy steers. These were primarily steers of British breeding, usually crossbred and a small number of steers with Brahman breeding (238 pens). Most cattle had been purchased from Western Oklahoma and the Texas Panhandle. Most were yearlings when started on feed and were fed for 114 to 165 days. Intakes for this three year period are based on a total of 296,367 cattle or a mean of 145 steers per pen.

Data available for each set of cattle included feedlot purchase weight, initial feedlot arrival weight, final weight, sex, cattle type (breed), flesh condition (thin, medium, fleshy), origin of cattle (region of US), number of cattle in the pen, head-days in hospital pens for all reasons, deaths per pen for all reasons and head-days removed due to riding by other animals (bullers). Projected current weights were calculated from net energy equations and past feed intakes to estimate weight (when needed for graphs) during the feeding trial. This was necessary in order to calculate DMI versus current weight and DMI as a percentage of body weight. Diets were similar in energy content throughout this 36 month period. Net energy values for maintenance (NEm) and energy (NEg) were calculated based on equations described by Hays et al. (1987) using initial arrival weight, mean DMI and final slaughter weight. Weights at intervals during the feeding period then could be calculated based on feed intakes, NEm and NEg values for the feed and initial weights. No information on backgrounding or history of cattle was available. All cattle were run through a dipping vat at the start, received routine medical attention and growth-stimulating ear implants. During the first three to four weeks on feed, cattle typically were fed a 35% roughage diet (NEm=1.88; NEg=1.16 Mcal/kg DM) for 14 days, a 20% roughage diet (NEm=1.98; NEg=1.25 Mcal/kg DM) for 10 days and a 10% roughage diet (NEm=2.09; NEg=1.34 Mcal/kg DM) thereafter. The highest energy diet consisted primarily of steam flaked corn grain, corn silage, chopped alfalfa hay and a soybean meal, urea supplement. Monensin was included in all diets at concentrations between 22 and 30 ppm.

For this report, only the information on beef steers was used for statistical analysis. Data for heifers and for dairy steers were removed prior to data analysis based on previous suggestions (Plegge et al., 1984; Thornton et al., 1985) that sex and breed will alter DMI. Those data are in Chapter IV of this manuscript. For statistical analysis and comparisons, components included initial shrunk weight, days on feed and season of the year in which cattle were placed on feed. In developing intake equations, models for each receiving season included initial shrunk weight up to the fourth power, days on feed up to the sixth power, all two- and three-way interactions plus intake from 8 to 28 days. These models were simplified by using the backward elimination regression technique of the statistical analysis system (SAS, 1987). In this technique, variables were deleted from a model one by one not allowing R^2 to drop by more than .005.

Results and Discussion

Effect of Season on Intake Patterns

Seasonal factors such as temperature and photoperiod have been suggested to influence DMI of beef cattle (Fox and Black, 1984; Plegge et al., 1984; Johnson, 1986; NRC, 1981, 1987; Ray, 1987; Young, 1987). In general, heat stress (temperature greater than 25°C) decreases intake (NRC, 1981, 1987). Cold stress increases maintenance energy requirements by 1.0 to 1.5% per effective ambient temperature unit below 20°C (Johnson and Crownover, 1975; Bourdon et al., 1984; Johnson, 1986; Birkelo et al., 1987) and thereby, supposedly, causes DMI to increase. However, based on a review of feedlot data from Colorado, Iowa, Minnesota and Canada, Johnson (1986) concluded that climate causes short-term erratic changes in DMI but has little long term effect on DMI by feedlot cattle in the mid to Northern United States and in Canada.

In an attempt to examine the influence of month on DMI, feed intakes of cattle with mean initial weights of 273, 318 and 364 kg (600, 700 and 800 lb) for the months of October 1982 until January 1986 were plotted (Figure 1). Intakes for the first 30 days on feed were deleted from this analysis to reduce variation. This left about 27,000 observations to generate means for this plot. Parallel intakes of cattle of the three initial weight groups indicate that DMI was being altered by some external factor(s). From this figure, it appears that DMI usually peaked in the late fall (October and November) after which DMI decreased to a low point in February. Subsequently, DMI increased to a peak in May and June followed by a decline in July and August. This summer decline may be due to heat stress during these months. This decline may be less or more apparent in cattle fed in cooler or warmer regions of the U.S. Plegge et al. (1984) indicated that DMI was 12% greater for cattle fed in winter than summer. Data in Figure 1 indicate that intakes usually were about 10% greater for the highest than the lowest month during each year.

Monthly weather data including average high and average low temperature and total precipitation were obtained from the weather station at Hooker, OK to correlate with these intake patterns. Average monthly temperature over this three year period is plotted in Figure 2. Correlations between the mean monthly feed intakes and the nine different components of the weather data generally were quite low (Table 2). However, multiple coefficients of determination (R^2) indicated that month explained from 36 to 42% of the variation in mean monthly DMI in the three weight groups studied. But few environmental factors were correlated with DMI. For heavier cattle, certain indicators of heat stress were negatively related to DMI suggesting that a given temperature causes greater heat stress in heavier cattle than lighter cattle. Conversely, indicators of cold stress tended to depress DMI more for cattle with lighter than with heavier initial weights suggesting that cold is more stressful for lighter cattle. These data suggest that factors related to month other than these measured environmental factors must influence these seasonal shifts in feed intakes. Such factors could include animal background, origin and age (cattle are often imported from Northern states for winter feeding and imported from the South or Southwest for summer feeding).

Distribution plots of the percentage of pens of cattle placed on feed during different months of the year are shown in Figures 3 and 4. For this particular feedyard, the peak receiving season for cattle was February, March and April. Most cattle received during this period have grazed winter wheat pasture. Cattle received in the next three month period (May, June and July) presumably consisted primarily of animals which have come off of graze-out wheat pasture and early intensive grazing programs. Cattle received in the remaining six months (August to January) will have grazed grass pasture. Another peak receiving season is August, September and October. Based on these presumed differences in cattle background over these different months, the year was divided into four seasons based on the month cattle were placed on feed; separate DMI prediction equations were developed for each season. These subdivisions should account for seasonal patterns in feed intake due both to environmental factors (temperature and day-length) and to animal background, origin and age.

The year was divided into the following four receiving seasons such that each season would have an equal number of days: January 29 - April 30 (92 days), May 1 - July 30 (91 days), July 31 - October 29 (91 days) and October 30 - January 28 (91 days). The number of pens received in each of these seasons were 604 (90,972 hd), 416 (56,543 hd), 585 (84,855 hd) and 445 (63,997 hd). Data for cattle groups classified by season received in the yard are presented in Table 3. Data for cattle groups classified by season received in the yard and initial shrunk weight groups are presented in Tables 4-12. For presentation, cattle were divided into the following weight groups: 205, 227, 250, 273, 295, 318, 341, 364, 386 and 409 kg which correspond to 450 (425-474), 500 (475-524), 550 (525-574), 600 (575-624), 650 (625-674), 700 (675-724), 750 (725-774), 800 (775-824), 850 (825-874) and 900 (875-924) lb, respectively.

DMI curves at various days on feed for each of the four receiving seasons further classified by starting weight (approximately 23 kg increments) are illustrated in Figures 5-8. Little crossover in feed intake curves between these different cattle weight groups within a season is apparent. DMI consistently peaked and plateaued higher for cattle entering the feedlot at heavier weights. Despite differences in curves with season, the overall shape of the intake curve for each weight group within a season proved surprisingly similar. Daily DMI increased by about .35, .34, .46 and .44 kg for each 25 kg increase in initial weight, respectively, for the four seasons (Figures 9-12). An A on these plots designates one pen of cattle at a point, a B designates two pens and so on. In earlier Oklahoma research trials in which cattle were grouped by initial weight for feeding, feed intake increased by .1 to .6 kg for each 25 kg increase in initial weight (Gill et al., 1981a; Owens and Gill, 1982a, 1982b; Thornton et al., 1985).

Shape of the curve was similar to patterns observed previously in a Western Kansas feedlot (Thornton et al., 1985). These workers noted that DMI plateaued at about 28 days and declined as cattle reached slaughter weights. The peak occurred with fewer days on feed for cattle at heavier than at lighter initial weights. The point at which DMI declines for a pen of cattle can be used in feedlots as a signal that cattle have reached slaughter weight and that continued feeding may be uneconomical. Hyer et al. (1986) examined the intake patterns of the feedlot cattle described by Thornton et al. (1985) and concluded that when medium frame steers reach a level of empty body fat of about 32%, DMI begins to decline. Thus, body composition may inhibit intake of finished cattle.

In an effort to obtain a broader perspective on seasonal DMI patterns, intakes by day of the year for 273, 318 and 364 kg steers within each season were plotted across seasons on a single plot (Figure 13). For this plot, it was assumed that cattle were placed on feed at the mid-point of each of the four seasons. This plot illustrates that seasonal DMI patterns differ. Peak feed intakes generally were greatest for cattle fed in the fall and lowest for cattle fed in the summer

(Table 13). These differences when summed yield the seasonal intake patterns previously discussed (Figure 1). Whereas mean intakes over the entire feeding period generally were quite similar for cattle fed in the winter, spring or summer, cattle fed in the fall consumed an average of .1 kg more DM per day. Based on initial and slaughter weights, daily gains were greatest (P<.05) for cattle fed during the spring (presumably coming off winter wheat pasture) in all initial weight groups. These cattle also were the most efficient at converting feed to gain (P<.05) while cattle fed in the fall were the least efficient (P<.05).

In all seasons, DMI increased linearly for the first 21 to 28 days. This period can be considered to be an adaptation as cattle adjust to their new environment and pen mates and gradually adapt to their high concentrate finishing diet. During this period, the roughage content of the diet is being decreased sequentially and DMI remains roughly proportional to body weight (Thornton et al., 1985). During this period, cattle must switch from bulk fill to chemostatic regulation of DMI. At about 21 to 28 days, DMI often plateaus or decreases slightly for about 14 days after which DMI increases again, particularly for those cattle placed on feed in the winter (Figures 5 and 8). This irregularity probably is associated with adaptation of the cattle to their top (finishing) ration.

DMI curves for cattle received during January 29 - April 30 and July 31 - October 29 were quite similar in shape (Figure 13) exhibiting a gradual but continual increase in DMI for the first 60 to 70 days followed by a slow but steady decline in DMI. Intakes by cattle with lighter initial weights climbed for a longer period of time. During spring and fall ambient temperatures typically are mild. The climbing intakes for the first 60 days probably were associated with the mild temperatures. Peak daily intakes for cattle fed in the fall were .25 to .30 kg greater than peak intakes of cattle fed in the spring (Table 13). Yet, mean daily intakes were only about .1 kg greater. The greater peak intakes of cattle started on feed in the fall could be associated with declining temperatures. In addition, these cattle probably grazed dry grass pasture prior to being placed in the feedlot, whereas many of the cattle fed in the spring grazed lush wheat pasture. Steeper DMI declines of longer fed cattle fed in the fall may be due to photoperiod or shortened daylength.

DMI curves for cattle started on feed during May 1 - July 30 and October 30 - January 28 had similar patterns (Figure 13). Cattle started on feed in these two seasons exhibited little decline in DMI as they approach slaughter weight as compared to cattle received in the other two seasons. Cattle fed during the summer exhibited a distinct plateau in DMI after 28 days. This probably was associated with high temperatures which occur in July and August and reduced DMI during midday. Furthermore, a high percentage of these cattle probably had grazed wheat pasture from October through May and would be fatter than cattle which were removed from wheat pasture in February or March and placed in the feedyard. DMI of winter fed cattle tended to increase (slightly) for a longer period, 50 to 60 days, at which point intake plateaued. This continual increase could be associated with lengthing days during this season. The DMI pattern for winter fed cattle also was more erratic than that for cattle fed in other seasons, possibly due to cold stress.

Development of Prediction Equations

Many feedlot nutritionists believe that cattle which eat below (or above) "average" for the first month of a feeding period continue to eat below (or above) "average" for the remainder of the feeding period (R.P. Lake, Hitch I Feeders, personal communication, 1988). This idea is supported by the commercial feedlot data of Thornton et al. (1985) which detected a correlation between DMI from day 14 to day 28 and DMI at subsequent periods (R^2=.53 to .73). In their data, DMI at an earlier time (the first 14 days) was not as closely related to DMI at day 56 or thereafter (R^2=.37 to .47). A plot of the correlation between DMI during sequential 7d periods versus mean DMI for the entire feeding period for individual pens within each of the four seasons is plotted in Figure 14. This figure suggests that feed intake during days 21 to 35 should be quite useful to predict subsequent feed intake (r^2=.43 to .77). Mean feed intake was less accurately predicted for cattle placed on feed from July 31 to October 29 than during other seasons.

To examine further the predictability of intake based on preliminary data, the relationship of early DMI data to subsequent DMI was tested for each of the seasons using intake data from seven different periods (none, 0-7, 0-14, 0-21, 0-28, 0-56 and 0-84 days). The full models included, in addition to these respective previously observed intakes, initial shrunk weight up to the 4th power, days on feed up to the 6th power and all two- and three-way interactions. The root mean square errors (MSE) and R^2's for each of these models are reported in Tables 14 and 15. These data illustrate that by including early DMI in the prediction equation, R^2 was increased dramatically. By including only the first week's intake in the equations, R^2's were increased by .06 to .10 units. The accuracy of the prediction equations continued to increase as more early DMI data was included in the models. Early DMI data was least effective in increasing the accuracy of intake prediction for those cattle received from July 31 to October 29. This probably is a reflection of the fact that the model for this season was reasonably accurate (R^2=.67) even before the DMI information was added. Based on these data, we decided to test further models which included mean DMI observed during additional periods (8-28, 15-28, 22-28, 29-56, 29-84 and 57-84 days). The most accurate equations were those which included the mean DMI from 29 to 84 days in the model (R^2=.72 to .84). Of the periods up to day 28, the 8 to 28 day information proved most useful (R^2=.64 to .77). The R^2's for the models including the mean DMI over 0 to 28 days were similar. However, during the first week on feed, cattle are typically fed some hay which is not included in DMI records. Thus, 8 to 28 day DMI should generally be more accurate and useful. Fit was improved further using subsequent periods, but in a commercial feedyard, updating DMI projections after cattle have been on feed 28 days would be more practical and more easily implemented than using subsequent periods. Updating projections of gain based on previous DMI should increase the accuracy of gain projections and have economic implications. If low DMI pens could be detected early in the feeding period appropriate corrective measures (altered pen size, diet, management, culling) could be taken.

The final models (prediction equations) for each of the four receiving seasons are presented in Tables 16-19. Plots of observed DMI are compared to predicted DMI for cattle consuming the mean (center line) and one standard deviation above or below the mean daily DMI during days 8 to 28 for each of the receiving seasons and each of three initial weights (273, 318 and 364 kg) in Figures 15 to 26.

A total of 11,377 weekly pen DMI observations were used in developing the prediction equation (Table 16) for cattle received between January 29 and April 30. These 21 factors including initial weight, observed DMI from 8 to 28 days, days on feed and interactions explained about 65% of the observed variation in DMI (R^2=.6515). Plots of observed (symbols) and predicted (lines) intakes (Figures 15-17) illustrate that this equation does a reasonably good job of predicting DMI. It is interesting to note that cattle with an initial weight of 273 kg eating above average for days 8 to 28 ate below average after about day 110 and vice versa. This could be attributed to the fact that the cattle initially eating above average would approach slaughter weight sooner, thus their DMI would decline sooner. DMI of 318 kg steers (below average, average and above average) tended to merge at about day 110 as they approached slaughter weight (Figure 16). For cattle averaging 364 kg initially (Figure 17), DMI curves tended to remain separate over the entire 120 day feeding period regardless of initial intake.

A total of 7,755 weekly pen DMI observations were used in developing the prediction equation (Table 17) for cattle received between May 1 and July 30. These 34 factors explained about 64% of the observed variation in DMI (R^2=.6356). Predicted DMI curves for 273 kg cattle (Figure 18) eating below average, average or above average merged at about day 80. Observed DMI data did not match curves well; lack of accuracy with the equation may be attributed to a low number of pens eating below (8 pens) or above average (4 pens) in this particular initial weight group. DMI curves (Figures 18-20) indicate that steers that ate average amounts of feed during days 8 to 28 reached an intake plateau at about day 28, as has been discussed previously. In contrast, DMI of cattle eating below average initially tended to increase as the feeding period progressed whereas DMI of cattle eating above average initially tended to decline, particularly for cattle initially weighing 318 kg. Again, DMI of cattle eating above average decline presumably because these cattle fatten sooner and are more sensitive to heat stress.

A total of 10,748 weekly pen DMI observations were used in developing the prediction equation (Table 18) for cattle received between July 31 and October 29. These 26 factors explained about 76% of the observed variation in DMI (R^2=.7620). Intakes of cattle received in this season were much more accurately predicted than those of cattle received in the other three seasons (R^2 was .1 to .12 greater). DMI curves for cattle eating below average, average and above average again tended to merge at 120, 110 and 100 days for cattle initially weighing 273, 318 and 364 kg, respectively (Figures 21-23).

A total of 8,423 weekly pen DMI observations were used in developing the prediction equation (Table 19) for cattle received between October 30 and January 28. These 25 factors explained about 66% of the observed variation in DMI (R^2=.6643). As was noted in the other three seasons, predicted DMI curves of 273 kg cattle eating below average, average and above average merged as slaughter weight was approached (Figure 24). In contrast to curves from other seasons, DMI curves for the three consumption groups for 318 and 364 kg cattle tended to remain parallel over the entire feeding period (Figures 25 and 26).

In an effort to obtain a wider perspective on seasonal DMI patterns of cattle eating below average, average and above average from day 8 to 28, predicted DMI by day of the year for 318 kg steers within each season were plotted across seasons on a single plot (Figure 27). This plot clearly illustrates that seasonal DMI patterns differed. Though this presents curves for pens grouped by initial intake levels, the predicted DMI for these 318 kg steers compare well with observed curves for 318 kg steers (Figure 13).

DMI equations utilizing the mean intake from days 15 to 28 (instead of 8 to 28 day) also were developed for each of the seasons (Tables 20-23). Because all of these equations were developed empirically, extrapolation beyond observed input values can be erroneous and misleading. Suggested limitations for maximum days on feed, 8 to 28 day and 15 to 28 day intakes are presented for the various initial weight groups within each season in Tables 24-27. When these prediction equations are applied outside this data range, results are erratic. It is important to respect these input limitations if one expects output to be reasonable. Applicability of these curves in different environments with different cattle types or ages or feed types needs to be tested. Should intake information from day 8 to 28 not be available, expected intake during this period can be estimated from the equation: DMI (8 to 28d) = 2.77 + .0195*initial weight (R^2=.47; MSE=1.20).

Effect of Age on Intake Patterns

Within this data set, most of the cattle being fed presumably were over 1 year of age. Data from Southern California feedlots accumulated by Zinn (1987) suggest that the pattern and level of DMI throughout the feeding period differs between calves and yearlings. DMI was consistently higher and achieved a plateau earlier for yearling cattle than for calves for both crossbred (Figure 28) and Brahman cattle (Figure 29). Data for 25 pens of calves and 25 pens of yearlings provided by a feedlot in Western Kansas also exhibited dramatic differences in DMI patterns (Figure 30). Yearlings had an DMI curve with three distinct segments (adaptation, plateau and retard phases); DMI increased linearly for the first 40 to 50 days, plateaued for about 40 days and then declined for the final 40 days. In contrast, DMI of calves increased for about 70 days and plateaued for the remaining 100 days. Part of these differences could be attributed to differences in season and initial weight. The yearlings (348 kg), received primarily from Kansas, were started on feed in August and September. The calves (270 kg), received from North and South Dakota and Nebraska, were placed on feed in February. Based on these DMI patterns from cattle of known age, it would appear that cattle having initial weights less than about 261 kg in the large data set probably are calves (Figures 5-8). DMI patterns for our light initial weight cattle were quite similar to curves for calves described by Zinn. Hence, empirical derivation of the model has already incorporated some but not all of the animal age effect. Initial weight and early feed intake are probably accounting for a portion of the age effect (Figures 31-34).

Effect of Current Weight on Feed Intake

DMI for cattle classified by starting weight at various current weights are presented in Figures 35-38 for each of the four receiving seasons. These DMI curves illustrate that DMI does not increase linearly as body weight increased during a feeding period; this confirms the need for curvilinearity over time of DMI prediction equations. DMI increased linearly with weight for about the first 25 kg of gain or 30 days on feed. Thereafter, DMI plateaued and later declined as slaughter weight was approached. The overall pattern, though consisting of a series of plateaus which vary with starting weight, when combined yields a curve of DMI versus current weight. At lighter weights, lower mean DMI can be attributed to the low DMI of cattle started at light weights. DMI increases as current body weight increases both because DMI increases with time on feed and because cattle of heavier starting weights are included only at the higher weight portion of the curve.

To adjust for changes in body weight, many researchers have developed thumb rules to relate daily DMI to body weight. For younger cattle, daily DMI are generally expected to exceed 3% of body weight . In contrast, as cattle reach heavier weights, values of near 2% are anticipated. DMI as a percentage of body weight for cattle with different weights on delivery to the feedlot for each of the four seasons is plotted against body weight in Figures 39-42. Consistent peaks and parallel declines were noted for cattle started at various weights. Peaks (% of body weight value) generally were higher for cattle started at lighter weights. However, for cattle received during May through July and November through January, the peaks for 250 kg (calves) were lower than for 295 kg (presumably yearlings) cattle. Similarly, in the small data set (50 pens) from the Kansas feedyard peak intakes expressed as a percentage of body weight were greater for yearlings than calves (Figure 43). This suggests that age as well may alter height of the peak in DMI. Similarly, limit feeding to grow cattle prior to placing them on a finishing ration resulted in increased DMI per unit of body weight late in the feeding period (Lofgreen et al., 1987). No specific advantage of expressing daily DMI on the basis of a percentage of body weight versus absolute amounts is apparent. DMI has been proposed by some workers as a fraction of metabolic body size (body weight$^{.75}$).

DMI as calculated by the various proposed equations are projected against observed intakes for steers initially weighing 273 kg received between July 31 and October 29 in Figures 44 and 45. In these two plots, observed intakes fall within the region between the two parallel dotted lines (mean DMI$\pm$1 st. dev.). Figure 44 illustrates predicted values with those equations developed from mean feed intakes for feeding trials and mean feeding weights. Figure 45 illustrates predicted values with those equations derived from data within feeding trials. Values proposed by the equations derived from mean DMI data were generally low for lighter weights (<400 kg) but excessive for heavier weights (>450 kg). These equations do an adequate job of predicting mean DMI but in the commercial feedlot industry they are of limited usefulness since they fail to predict intake patterns that occur during a feeding period. Predicted DMI values with the equations of Plegge et al. (1984) and Fox and Black (1984) were low at weights below 425 kg but were fairly accurate at weights greater than 425 kg (Figure 45). The equation of Song and Dinkel (1978) consistently under-predicted DMI, possibly, because this equation was generated with calf data (steers started on feed at about 8 months of age). Predicted DMI values with the equations of Gill (1979), Owens and Gill (1982) and Thornton et al. (1985) fell within the observed DMI range at weights below 425 kg but were high as steers approached slaughter weight (Figure 45). The equation of Gill (1979) came closest to predicting the observed DMI pattern. Unfortunately, most of these equations are iterative over weight (time) and thereby are more complex to use for prediction than our multifactor equations which use only data available at the start of a feeding period. The predicted DMI (line) for 273 kg steers with our equation is illustrated in Figure 46 as compared to the observed intake range (area between dotted lines) and observed mean DMI (symbols).

TABLE 1. DRY MATTER INTAKE EQUATIONS FOR FEEDLOT CATTLE

Source	Equation[a]
Preston (1972)	$DMI = .095W^{.75} - .221$
Garrett (1973)	$DMI = 10.5 + .0144MW - 4.58NEm + .32NEm^2$
Gill (1979)	$DMI = W^{.75} (.0736362 + .0000899IW + .004089FG) - (.0070318 * (W-227.27))^2$
Loch & Pfander (1979)	$DMI = (34.26568 - .01844W - .066611CONC) * .001W$
ARC (1980)	$DMI = W^{.75} (.1168 - 0.01059ME)$
Goodrich & Meiske (1981)	$DMI = 1.54 + .1025W^{.75} - .7143ME$
Owens & Gill (1982)	$DMI = -5.08 + .0636W - .000072W^2 + .0039 (IW - 276.7)$
Fox & Black (1984)	$DMI = .09$ to $.1$ (decreasing with W) $* W^{.75}$
NRC (1984)	$DMI = W^{.75} (.1493NEm - .046NEm^2 - .0196)$
Plegge et al. (1984)	
For mean intake:	$DMI = -7.65 + .0063MW + .0000189MW^2 + 9.4106ME - 1.9011ME^2$
For intake during feeding trial:	$DMI = -43.18 - 0.004IW + .00003IW^2 + 36.8326RW - 20.8356RW^2 + 24.5011ME - 4.4019ME^2$
Thornton et al. (1985)	
First 14 days:	$DMI = .0217W^{1.02}$
After 14 days:	$DMI = 6.94 + .019DOF - .000127DOF^2 + .0000248IW^2$

[a] Terms include DMI, daily dry matter intake, kg; W, shrunk weight in kg; IW, starting shrunk weight in kg; MW, mean shrunk weight for the feeding trial in kg; ME, metabolizable energy in Mcal/kg of feed dry matter; NEm, net energy for maintenance in Mcal/kg of feed dry matter; FG, feeder grade between 1 and 10; CONC, percent concentrate in diet; RW, current shrunk as a fraction of shrunk slaughter weight; DOF, days on feed.

TABLE 2. CORRELATIONS BETWEEN MONTHLY MEAN DRY MATTER INTAKE AND ENVIRONMENTAL FACTORS

	Initial Weight Group (kg)[a]			
Factor	273	318	364	Mean of Groups
Simple Correlations:				
Average High	.107	-.083	-.227	-.140
Average Low	.123	-.059	-.215	-.128
Total Precipitation	.177	.055	-.002	.025
No. days high≥ 32°C	-.072	-.189	-.358*	-.210
No. days high≤ 0°C	-.170	-.024	.070	.043
No. days low≤ 0°C	-.200	-.023	.094	.062
No. days low≤ -18°C	-.122	-.067	.022	.009
Heating Degree Days[b]	-.174	.024	.150	.094
Cooling Degree Days[b]	-.080	-.178	-.347*	-.185
Multiple Coefficients of Determination (R^2):				
Month	.372	.420	.362	.082

[a] Cattle with mean initial weights of 273 (250-294), 318 (295-340) and 364 (341-385) kg.

[b] One heating (cooling) degree day is accumulated for each degree that daily mean temperature is < (>) 18°C.

*(P<.05)

TABLE 3. SUMMARY BY SEASON RECEIVED FOR BEEF STEERS

Item	Jan 29-April 30	May 1-July 30	July 31-Oct 29	Oct 30-Jan 28
Pens	604	416	585	445
No. Head/pen	151±56	136±58	145±68	144±60
Total Head	90972	56543	84855	63997
Weights, kg				
Purchase	326±33.2	333±39.0	329±36.0	326±33.6
Initial	315±33.4	321±39.3	317±36.4	315±33.4
Finished	526±27.3	523±31.7	510±28.5	517±26.1
Daily Gain, kg	1.44±.12	1.38±.13	1.34±.18	1.35±.14
Feed/Gain	6.43±.38	6.72±.38	7.05±.65	6.79±.53
Yard Days	139±18	138±20	136±24	140±19
Sick Days	119±147	134±190	191±271	249±326
Buller Days	390±490	602±655	865±849	452±466
Dead, %	0.67	0.57	0.71	0.99
DM Intake, kg				
0-7 days	7.47±1.21	7.63±1.22	6.85±1.41	7.02±1.34
8-14 days	8.64±0.98	8.62±1.10	8.06±1.23	8.41±1.09
15-21 days	9.07±0.99	9.22±1.16	9.10±1.23	9.09±1.14
22-28 days	9.12±0.92	9.46±1.09	9.43±1.12	9.04±1.01
29-35 days	9.11±0.93	9.49±1.01	9.63±1.10	9.05±0.92
36-42 days	9.39±0.94	9.60±0.98	9.90±1.09	9.31±0.91
43-49 days	9.58±0.96	9.66±0.88	10.07±1.04	9.42±0.96
50-56 days	9.70±0.90	9.64±0.87	10.17±0.99	9.55±1.01
57-63 days	9.79±0.85	9.66±0.90	10.19±1.00	9.60±0.98
64-70 days	9.85±0.82	9.66±0.90	10.14±0.98	9.65±1.04
71-77 days	9.84±0.77	9.62±0.92	10.05±0.97	9.58±1.02
78-84 days	9.85±0.78	9.59±0.92	9.91±0.93	9.52±0.99
85-91 days	9.78±0.74	9.54±0.95	9.80±0.90	9.49±0.94
92-98 days	9.71±0.74	9.53±0.93	9.63±0.87	9.52±0.90
99-105 days	9.60±0.69	9.48±0.88	9.44±0.84	9.41±0.84
106-112 days	9.47±0.71	9.39±0.88	9.21±0.85	9.38±0.80
113-119 days	9.27±0.67	9.33±0.83	8.90±0.80	9.22±0.75
120-126 days	9.09±0.66	9.22±0.84	8.65±0.80	9.16±0.77
127-133 days	8.91±0.65	9.02±0.86	8.32±0.71	9.00±0.70
134-140 days	8.75±0.63	8.77±1.00	8.07±0.70	8.93±0.70
141-147 days	8.60±0.64	8.16±0.79	7.86±0.68	8.79±0.68
Mean	9.23±0.68	9.23±0.78	9.35±0.87	9.15±0.77

TABLE 4. SUMMARY BY INITIAL WEIGHT FOR STEERS RECEIVED JANUARY 29 - APRIL 30 (PART 1)

	Initial Weight Grouping (kg)			
Item	250	273	295	318
Pens	18	85	160	145
No. Head/pen	184±63	159±48	157±48	160±59
Total Head	3306	13531	25149	23224
Weights, kg				
Purchase	267±7.3	286±8.8	308±8.6	330±8.3
Initial	255±4.5	273±6.9	295±6.4	318±6.5
Finished	487±15.7	504±16.8	517±24.8	527±18.3
Daily Gain, kg	1.36±.08	1.38±.10	1.42±.09	1.44±.11
Feed/Gain	6.17±.32	6.25±.33	6.39±.37	6.41±.34
Yard Days	160±6	156±11	147±11	136±11
Sick Days	293±345	188±188	120±120	115±136
Buller Days	1142±1054	571±532	438±450	313±351
Dead, %	1.18	1.09	0.70	0.56
DM Intake, kg				
0-7 days	6.05±1.15	6.88±0.99	7.44±1.22	7.39±1.04
8-14 days	7.39±1.06	8.00±0.81	8.60±0.90	8.54±0.71
15-21 days	8.06±0.82	8.45±0.72	8.88±0.80	8.96±0.74
22-28 days	8.33±0.43	8.41±0.67	8.92±0.80	9.06±0.65
29-35 days	8.06±0.55	8.32±0.66	8.86±0.70	9.09±0.69
36-42 days	8.40±0.64	8.58±0.65	9.14±0.72	9.35±0.64
43-49 days	8.30±0.63	8.69±0.69	9.35±0.72	9.59±0.65
50-56 days	8.54±0.43	8.92±0.71	9.48±0.66	9.69±0.67
57-63 days	8.75±0.51	9.05±0.64	9.57±0.60	9.78±0.58
64-70 days	9.02±0.59	9.20±0.68	9.67±0.63	9.88±0.60
71-77 days	8.96±0.47	9.25±0.65	9.72±0.56	9.85±0.58
78-84 days	9.05±0.65	9.35±0.60	9.69±0.59	9.87±0.59
85-91 days	9.03±0.49	9.30±0.60	9.61±0.59	9.85±0.61
92-98 days	9.08±0.53	9.29±0.55	9.56±0.61	9.80±0.70
99-105 days	9.07±0.51	9.27±0.54	9.45±0.60	9.70±0.70
106-112 days	9.11±0.62	9.12±0.57	9.34±0.59	9.58±0.69
113-119 days	8.97±0.60	9.05±0.63	9.14±0.59	9.45±0.70
120-126 days	8.85±0.66	8.92±0.60	9.02±0.62	9.21±0.70
127-133 days	8.52±0.54	8.71±0.58	8.90±0.67	9.10±0.65
134-140 days	8.52±0.64	8.59±0.60	8.84±0.65	8.92±0.65
141-147 days	8.35±0.59	8.38±0.55	8.72±0.60	9.03±0.82
148-154 days	8.21±0.58	8.30±0.53	8.45±0.65	8.84±0.45
155-161 days	8.27±0.68	8.10±0.47	8.23±0.51	
162-168 days		7.75±0.25	8.20±0.67	
Mean	8.39±0.26	8.62±0.41	9.04±0.41	9.23±0.45

TABLE 5. SUMMARY BY INITIAL WEIGHT FOR STEERS RECEIVED JANUARY 29 - APRIL 30 (PART 2)

Item	Initial Weight Grouping (kg) 341	 364	 386	 409
Pens	125	42	17	9
No. Head/pen	143±57	120±50	110±44	74±30
Total Head	17902	5027	1862	663
Weights, kg				
Purchase	350±8.5	374±8.9	394±11.2	421±11.4
Initial	340±6.5	364±7.4	383±6.2	409±7.3
Finished	540±19.9	556±24.9	559±20.8	571±16.8
Daily Gain, kg	1.46±.12	1.53±.14	1.45±.14	1.53±.13
Feed/Gain	6.51±.36	6.64±.33	6.83±.39	6.94±.37
Yard Days	129±12	120±15	112±17	97±9
Sick Days	89±107	58±57	49±59	47±57
Buller Days	322±499	166±202	153±187	75±109
Dead, %	0.44	0.44	0.64	0.60
DM Intake, kg				
0-7 days	7.79±1.06	8.29±1.20	7.97±1.18	8.62±2.08
8-14 days	8.91±0.74	9.56±1.21	9.56±1.10	9.62±1.40
15-21 days	9.41±0.88	10.15±1.10	10.05±1.39	10.21±1.14
22-28 days	9.45±0.75	10.25±1.10	9.96±1.21	10.59±0.97
29-35 days	9.45±0.75	10.28±0.96	9.99±1.09	10.81±1.12
36-42 days	9.79±0.71	10.50±0.98	10.35±1.11	11.04±1.07
43-49 days	10.00±0.76	10.69±0.97	10.34±1.09	11.37±0.96
50-56 days	10.09±0.73	10.72±0.91	10.54±0.88	11.40±0.88
57-63 days	10.12±0.76	10.82±0.85	10.57±0.88	11.44±0.82
64-70 days	10.14±0.68	10.79±0.90	10.29±0.86	11.31±0.86
71-77 days	10.07±0.70	10.64±0.91	10.36±0.67	11.07±1.09
78-84 days	10.05±0.69	10.60±0.98	10.30±0.94	11.35±1.18
85-91 days	10.02±0.69	10.51±0.92	10.40±0.82	10.90±1.03
92-98 days	9.86±0.67	10.47±0.95	10.26±0.86	
99-105 days	9.75±0.65	10.15±0.64	10.10±1.17	
106-112 days	9.69±0.83	9.92±0.72	9.89±1.06	
113-119 days	9.45±0.67	9.70±0.67	9.62±0.82	
120-126 days	9.34±0.67	9.29±0.88		
127-133 days	9.20±0.57			
134-140 days	8.84±0.55			
141-147 days	9.06±0.33			
Mean	9.50±0.54	10.10±0.78	9.91±0.80	10.62±0.97

TABLE 6. SUMMARY BY INITIAL WEIGHT FOR STEERS RECEIVED MAY 1 - JULY 30 (PART 1)

Item	Initial Weight Grouping (kg)			
	205	227	250	273
Pens	6	10	12	31
No. Head/pen	102±15	103±19	126±38	149±55
Total Head	613	1033	1516	4629
Weights, kg				
Purchase	221±13.5	239±9.0	260±6.5	286±8.5
Initial	205±8.3	225±6.4	248±5.1	275±6.6
Finished	453±12.1	461±16.5	475±15.0	483±16.6
Daily Gain, kg	1.05±.04	1.13±.07	1.18±.07	1.32±.09
Feed/Gain	6.95±.36	6.75±.32	6.66±.36	6.46±.28
Yard Days	216±13	194±19	179±10	148±11
Sick Days	673±607	379±234	307±310	234±252
Buller Days	115±98	498±951	622±377	1085±963
Dead, %	2.12	1.36	1.58	0.73
DM Intake, kg				
0-7 days	4.80±0.75	5.54±1.04	5.03±1.50	6.95±0.95
8-14 days	5.23±0.91	6.25±1.40	6.49±1.16	7.93±0.79
15-21 days	5.07±0.57	6.33±1.49	7.04±1.15	8.49±0.73
22-28 days	5.89±0.32	6.94±1.17	7.49±0.67	8.66±0.60
29-35 days	6.71±0.48	7.64±0.86	7.89±0.65	8.66±0.68
36-42 days	7.43±0.54	8.25±0.49	8.28±1.00	8.79±0.65
43-49 days	8.13±0.40	8.65±0.55	8.58±0.88	8.85±0.60
50-56 days	8.86±0.82	9.05±0.93	8.44±0.84	8.88±0.65
57-63 days	9.51±1.22	8.85±0.78	8.26±0.70	8.93±0.67
64-70 days	9.01±0.29	8.47±0.62	8.38±0.74	9.00±0.72
71-77 days	8.95±0.45	8.49±0.53	8.40±0.75	8.90±0.71
78-84 days	8.66±0.45	8.37±0.58	8.45±0.67	8.83±0.69
85-91 days	8.02±0.48	8.44±0.70	8.39±0.52	8.85±0.78
92-98 days	8.08±0.47	8.30±0.64	8.32±0.32	8.81±0.70
99-105 days	8.18±0.52	8.24±0.52	8.30±0.42	8.80±0.74
106-112 days	7.90±0.50	8.08±0.52	8.20±0.51	8.71±0.76
113-119 days	8.27±0.69	7.98±0.50	8.14±0.27	8.83±0.72
120-126 days	7.67±0.45	7.91±0.50	8.24±0.33	8.78±0.85
127-133 days	7.72±0.41	7.88±0.57	8.25±0.39	8.59±0.72
134-140 days	7.35±0.44	7.69±0.33	8.01±0.30	8.40±0.63
141-147 days	7.39±0.48	7.64±0.25	8.09±0.49	8.25±0.69
148-154 days	7.65±0.27	7.65±0.54	8.18±0.79	
155-161 days	7.18±0.53	7.44±0.41	8.07±0.64	
162-168 days	7.23±0.44	7.44±0.42	7.98±0.53	
169-175 days	7.60±0.47	7.32±0.50		
176-182 days	6.91±0.58			
183-189 days	6.82±0.39			
190-196 days	6.34±0.50			
197-203 days	6.31±0.49			
Mean	7.30±0.23	7.64±0.25	7.84±0.21	8.51±0.50

TABLE 7. SUMMARY BY INITIAL WEIGHT FOR STEERS RECEIVED MAY 1 - JULY 30 (PART 2)

	Initial Weight Grouping (kg)			
Item	295	318	341	364
Pens	73	92	115	45
No. Head/pen	137±63	140±55	141±63	130±48
Total Head	9986	12846	16169	5871
Weights, kg				
Purchase	308±8.1	328±8.5	351±7.2	370±7.8
Initial	297±6.0	318±6.7	340±6.3	360±6.1
Finished	505±18.5	5205±21.4	539±16.4	547±19.7
Daily Gain, kg	1.37±.10	1.39±.13	1.42±.10	1.41±.14
Feed/Gain	6.60±.34	6.72±.37	6.71±.32	6.87±.43
Yard Days	143±11	137±11	131±10	125±9
Sick Days	148±160	120±166	85±96	86±106
Buller Days	729±733	633±650	558±557	392±464
Dead, %	0.74	0.52	0.41	0.36
DM Intake, kg				
0-7 days	7.50±0.82	7.72±0.84	7.99±1.01	8.21±0.90
8-14 days	8.50±0.80	8.71±0.57	8.94±0.75	9.15±0.74
15-21 days	9.07±0.58	9.35±0.68	9.63±0.68	9.70±0.94
22-28 days	9.18±0.65	9.67±0.69	9.85±0.69	9.98±0.85
29-35 days	9.15±0.75	9.62±0.76	9.86±0.67	10.01±0.92
36-42 days	9.22±0.77	9.74±0.84	9.91±0.73	10.16±0.99
43-49 days	9.32±0.68	9.76±0.82	9.95±0.64	10.05±0.86
50-56 days	9.27±0.73	9.72±0.79	9.88±0.67	10.07±0.90
57-63 days	9.26±0.71	9.78±0.84	9.89±0.71	10.06±0.85
64-70 days	9.35±0.77	9.70±0.89	9.91±0.72	10.11±0.73
71-77 days	9.26±0.78	9.67±0.90	9.91±0.75	10.10±0.72
78-84 days	9.31±0.75	9.65±0.91	9.84±0.70	9.99±0.83
85-91 days	9.29±0.80	9.54±0.92	9.83±0.78	9.97±0.79
92-98 days	9.36±0.77	9.50±0.97	9.85±0.75	9.85±0.75
99-105 days	9.36±0.67	9.43±0.87	9.79±0.68	9.87±0.79
106-112 days	9.29±0.71	9.40±0.80	9.75±0.70	9.77±0.80
113-119 days	9.32±0.71	9.37±0.77	9.67±0.69	9.69±0.75
120-126 days	9.26±0.65	9.43±0.79	9.61±0.66	9.37±0.73
127-133 days	9.07±0.61	9.33±0.85	9.56±0.65	
134-140 days	9.17±1.05	9.16±0.74	9.57±0.65	
141-147 days	8.93±0.56			
Mean	9.00±0.50	9.30±0.61	9.52±0.52	9.66±0.65

TABLE 8. SUMMARY BY INITIAL WEIGHT FOR STEERS RECEIVED MAY 1 - JULY 30 (PART 3)

	Initial Weight Grouping (kg)	
Item	386	409
Pens	21	9
No. Head/pen	131±67	103±62
Total Head	2744	927
Weights, kg		
Purchase	393±7.1	418±10.8
Initial	383±5.5	405±7.1
Finished	561±12.9	567±24.2
Daily Gain, kg	1.43±.12	1.36±.17
Feed/Gain	6.95±.33	7.35±.46
Yard Days	118±10	110±15
Sick Days	54±52	36±49
Buller Days	340±338	363±429
Dead, %	0.40	0.00
DM Intake, kg		
0-7 days	8.16±1.15	8.85±1.47
8-14 days	9.53±0.90	9.83±1.18
15-21 days	10.15±0.74	10.06±1.34
22-28 days	10.33±0.83	10.35±1.23
29-35 days	10.34±0.75	10.21±1.22
36-42 days	10.30±0.68	10.27±0.87
43-49 days	10.32±0.77	10.44±0.99
50-56 days	10.27±0.82	10.32±0.85
57-63 days	10.30±0.82	10.41±0.93
64-70 days	10.28±1.00	10.31±0.83
71-77 days	10.31±1.06	10.15±0.56
78-84 days	10.40±1.06	10.42±0.81
85-91 days	10.34±1.08	10.23±0.76
92-98 days	10.23±0.96	10.11±0.75
99-105 days	10.19±1.15	10.30±0.73
106-112 days	9.83±1.02	10.02±0.64
Mean	9.91±0.71	9.96±0.75

TABLE 9. SUMMARY BY INITIAL WEIGHT FOR STEERS RECEIVED JULY 31 - OCTOBER 29 (PART 1)

	Initial Weight Grouping (kg)			
Item	227	250	273	295
Pens	16	31	50	106
No. Head/pen	105±23	116±40	151±60	143±59
Total Head	1686	3604	7543	15153
Weights, kg				
Purchase	245±6.0	262±6.7	284±7.3	309±8.9
Initial	231±6.1	249±6.8	274±5.8	296±6.6
Finished	462±15.4	466±12.2	479±17.6	496±18.2
Daily Gain, kg	1.05±.07	1.09±.09	1.21±.12	1.33±.16
Feed/Gain	7.01±.76	7.04±.36	7.00±.48	6.88±.51
Yard Days	200±10	184±14	159±15	140±14
Sick Days	708±461	447±343	358±372	230±346
Buller Days	513±553	441±532	1492±1292	1000±853
Dead, %	2.31	1.61	1.14	0.81
DM Intake, kg				
0-7 days	3.76±1.04	4.15±1.14	5.89±1.10	6.72±1.06
8-14 days	5.11±1.05	5.46±1.04	7.18±0.95	7.90±0.86
15-21 days	6.35±1.07	6.70±0.98	8.10±0.95	8.92±0.87
22-28 days	7.07±1.04	7.64±0.78	8.45±0.87	9.13±0.84
29-35 days	7.48±0.88	8.49±0.99	8.54±0.81	9.32±0.94
36-42 days	7.86±1.07	8.96±1.20	8.83±0.71	9.55±0.93
43-49 days	7.99±1.37	9.11±0.87	9.07±0.76	9.73±0.85
50-56 days	8.64±1.38	9.05±0.63	9.24±0.72	9.87±0.77
57-63 days	8.36±1.10	8.83±0.52	9.31±0.80	9.94±0.82
64-70 days	8.25±0.79	8.69±0.61	9.24±0.72	9.85±0.75
71-77 days	7.97±0.92	8.56±0.59	9.23±0.66	9.79±0.72
78-84 days	7.95±0.83	8.44±0.57	9.09±0.65	9.65±0.67
85-91 days	8.06±0.89	8.38±0.59	8.92±0.62	9.57±0.64
92-98 days	7.92±0.85	8.17±0.51	8.85±0.56	9.40±0.61
99-105 days	7.92±0.90	8.11±0.43	8.75±0.56	9.21±0.60
106-112 days	7.87±0.95	8.06±0.35	8.63±0.68	9.10±0.66
113-119 days	7.85±0.64	7.93±0.42	8.48±0.57	8.95±0.70
120-126 days	7.83±0.72	7.85±0.42	8.29±0.55	8.70±0.65
127-133 days	7.75±0.94	7.82±0.31	8.20±0.59	8.37±0.62
134-140 days	7.60±0.67	7.75±0.42	8.01±0.60	8.29±0.71
141-147 days	7.60±0.58	7.53±0.49	7.82±0.52	8.24±0.88
148-154 days	7.57±0.61	7.33±0.43	7.66±0.52	
155-161 days	7.45±0.82	7.17±0.48	7.66±0.50	
162-168 days	7.22±0.73	7.07±0.47		
169-175 days	7.11±0.66	6.87±0.35		
176-182 days	7.00±0.67	6.76±0.43		
183-189 days	7.08±0.85			
Mean	7.38±0.74	7.68±0.44	8.41±0.48	9.10±0.58

TABLE 10. SUMMARY BY INITIAL WEIGHT FOR STEERS RECEIVED JULY 31 - OCTOBER 29 (PART 2)

	Initial Weight Grouping (kg)			
Item	318	341	364	386
Pens	150	149	56	20
No. Head/pen	146±66	164±84	118±53	142±71
Total Head	21902	24472	6601	2844
Weights, kg				
Purchase	330±8.8	351±8.5	372±7.7	392±9.1
Initial	318±6.5	339±5.5	362±6.6	382±7.0
Finished	513±20.4	525±17.5	538±19.4	585±18.6
Daily Gain, kg	1.40±.16	1.38±.16	1.40±.15	1.32±.17
Feed/Gain	6.88±.55	7.19±.71	7.22±.63	7.78±1.03
Yard Days	130±12	126±12	119±11	111±10
Sick Days	128±139	109±126	89±101	155±198
Buller Days	839±756	879±824	508±548	613±663
Dead, %	0.58	0.46	0.39	0.77
DM Intake, kg				
0-7 days	7.18±0.93	7.40±1.03	7.63±1.08	7.57±0.95
8-14 days	8.35±0.76	8.61±0.71	8.76±0.85	8.78±0.78
15-21 days	9.35±0.83	9.70±0.71	9.83±0.95	9.97±0.87
22-28 days	9.62±0.85	9.99±0.70	10.18±0.83	10.25±0.90
29-35 days	9.80±0.90	10.12±0.76	10.30±0.95	10.25±0.92
36-42 days	10.06±0.94	10.37±0.74	10.57±0.85	10.58±0.85
43-49 days	10.20±0.85	10.55±0.73	10.75±0.83	10.75±0.68
50-56 days	10.28±0.88	10.60±0.71	10.81±0.79	10.95±0.72
57-63 days	10.34±0.85	10.61±0.66	10.79±0.73	10.98±0.78
64-70 days	10.31±0.76	10.61±0.72	10.70±0.75	10.88±0.89
71-77 days	10.23±0.78	10.51±0.70	10.62±0.70	10.75±0.72
78-84 days	10.12±0.72	10.31±0.67	10.50±0.64	10.56±0.63
85-91 days	9.96±0.72	10.21±0.62	10.38±0.66	10.56±0.62
92-98 days	9.87±0.70	10.00±0.62	10.18±0.56	10.34±0.80
99-105 days	9.68±0.60	9.81±0.69	10.00±0.62	10.18±0.84
106-112 days	9.46±0.67	9.57±0.75	9.73±0.69	
113-119 days	9.25±0.68	9.17±0.80	8.98±0.63	
120-126 days	9.06±0.69	8.95±0.88		
127-133 days	8.66±0.63	8.77±0.78		
134-140 days	8.43±0.86			
Mean	9.55±0.58	9.81±0.47	10.00±0.65	10.11±0.55

TABLE 11. SUMMARY BY INITIAL WEIGHT FOR STEERS RECEIVED OCTOBER 30 - JANUARY 28 (PART 1)

	Initial Weight Grouping (kg)			
Item	250	273	295	318
Pens	22	56	111	95
No. Head/pen	132±57	131±60	140±66	150±52
Total Head	2902	7333	15590	14289
Weights, kg				
Purchase	263±10.4	285±7.6	308±8.1	330±9.2
Initial	250±7.8	273±6.8	296±6.4	318±7.0
Finished	488±19.3	500±21.8	507±22.4	517±20.0
Daily Gain, kg	1.22±.14	1.28±.15	1.35±.14	1.37±.11
Feed/Gain	6.48±.46	6.66±.63	6.67±.55	6.74±.41
Yard Days	180±13	163±13	147±9	136±8
Sick Days	848±703	429±409	231±233	190±208
Buller Days	268±326	431±419	501±415	490±530
Dead, %	2.72	2.54	0.92	0.63
DM Intake, kg				
0-7 days	4.86±0.87	6.02±1.30	6.92±1.05	7.20±1.08
8-14 days	6.48±0.96	7.48±1.11	8.26±0.70	8.54±0.76
15-21 days	6.83±1.07	8.20±1.10	8.94±0.66	9.25±0.72
22-28 days	7.40±0.85	8.33±0.96	8.85±0.73	9.06±0.66
29-35 days	7.79±0.78	8.39±0.79	8.78±0.59	9.09±0.69
36-42 days	8.01±0.78	8.56±0.72	8.98±0.58	9.41±0.66
43-49 days	8.21±0.68	8.50±0.77	9.14±0.60	9.49±0.64
50-56 days	8.18±0.80	8.64±0.84	9.27±0.61	9.55±0.70
57-63 days	8.17±0.67	8.73±0.74	9.35±0.67	9.65±0.70
64-70 days	7.80±1.07	8.81±0.83	9.38±0.66	9.75±0.70
71-77 days	7.82±0.95	8.86±0.80	9.33±0.69	9.65±0.70
78-84 days	7.90±0.87	8.78±0.71	9.25±0.70	9.58±0.69
85-91 days	8.07±0.69	8.75±0.73	9.19±0.66	9.62±0.70
92-98 days	8.31±0.61	8.80±0.82	9.21±0.65	9.67±0.66
99-105 days	8.32±0.67	8.75±0.85	9.14±0.59	9.55±0.62
106-112 days	8.40±0.64	8.93±0.96	9.20±0.61	9.57±0.63
113-119 days	8.16±0.77	8.91±0.74	9.15±0.64	9.42±0.59
120-126 days	8.28±0.75	8.92±0.71	9.12±0.65	9.41±0.64
127-133 days	8.30±0.69	8.90±0.63	9.05±0.64	9.27±0.58
134-140 days	8.45±0.74	8.88±0.64	9.00±0.59	9.45±0.78
141-147 days	8.42±0.59	8.78±0.57	8.90±0.64	
148-154 days	8.47±0.60	8.67±0.59	8.62±0.55	
155-161 days	8.40±0.57	8.48±0.61		
162-168 days	8.57±0.53	8.32±0.75		
169-175 days	8.79±0.55			
Mean	7.87±0.54	8.45±0.59	8.90±0.45	9.21±0.49

TABLE 12. SUMMARY BY INITIAL WEIGHT FOR STEERS RECEIVED OCTOBER 30 - JANUARY 28 (PART 2)

	Initial Weight Grouping (kg)		
Item	341	364	386
Pens	91	55	12
No. Head/pen	147±63	158±54	127±53
Total Head	13350	8668	1529
Weights, kg			
Purchase	351±8.7	374±8.0	389±7.5
Initial	339±6.4	361±5.7	380±4.3
Finished	528±20.1	545±18.7	541±13.8
Daily Gain, kg	1.39±.15	1.43±.12	1.36±.12
Feed/Gain	6.92±.48	7.01±.46	7.45±.60
Yard Days	127±9	119±9	112±7
Sick Days	162±160	110±115	71±98
Buller Days	411±497	487±506	301±353
Dead, %	0.55	0.52	0.26
DM Intake, kg			
0-7 days	7.57±1.18	7.70±0.96	8.50±1.18
8-14 days	8.88±0.79	9.23±0.72	9.81±0.96
15-21 days	9.51±0.86	10.01±0.93	10.41±1.01
22-28 days	9.40±0.75	10.04±0.84	9.94±0.67
29-35 days	9.37±0.71	10.03±0.90	9.81±0.69
36-42 days	9.72±0.73	10.23±0.80	10.07±0.46
43-49 days	9.81±0.81	10.50±0.74	10.37±0.68
50-56 days	10.03±0.87	10.61±0.83	10.40±0.83
57-63 days	10.03±0.82	10.64±0.78	10.43±0.80
64-70 days	10.11±0.80	10.71±0.71	10.54±0.76
71-77 days	10.00±0.76	10.61±0.80	10.55±0.80
78-84 days	9.95±0.78	10.54±0.74	10.42±0.74
85-91 days	9.90±0.79	10.40±0.64	10.28±0.80
92-98 days	9.88±0.79	10.39±0.63	10.19±0.64
99-105 days	9.79±0.68	10.25±0.56	10.13±0.70
106-112 days	9.74±0.65	10.07±0.42	
113-119 days	9.58±0.60	9.99±0.59	
120-126 days	9.63±0.62	9.94±0.76	
127-133 days	9.48±0.69		
Mean	9.55±0.59	10.00±0.54	10.06±0.53

TABLE 13. EFFECT OF SEASON RECEIVED IN YARD ON MEAN INTAKE, PEAK INTAKE, DAILY GAIN AND FEED EFFICIENCY FOR DIFFERENT INITIAL WEIGHT GROUPS

Initial Weight Group	Season of Year Received in Yard			
	Jan 29-April 30^{g}	May 1-July 30^{h}	July 31-Oct 29 ^{g}	Oct 30-Jan 28 ^{g}
Mean DM Intake, kg				
250	8.39^{a}	7.84^{b}	7.68^{b}	7.86^{b}
273	8.62^{e}	8.51^{ef}	8.41^{e}	8.45^{e}
295	9.04^{a}	9.00^{ab}	9.10^{a}	8.90^{b}
318	9.23^{b}	9.30^{b}	9.55^{a}	9.21^{b}
341	9.50^{b}	9.52^{b}	9.81^{a}	9.55^{b}
364	10.10	9.66	10.35	10.00
386	9.91	9.91	10.11	10.06
Peak DM Intake, kg				
250	9.02^{a}	8.44^{b}	8.83^{ab}	7.80^{c}
273	9.20^{a}	8.88^{b}	9.31^{a}	8.81^{b}
295	9.67^{b}	9.32^{c}	9.94^{a}	9.38^{c}
318	9.88^{b}	9.76^{b}	10.34^{a}	9.75^{b}
341	10.14^{b}	9.95^{c}	10.61^{a}	10.11^{bc}
364	10.82^{a}	10.05^{b}	10.79^{a}	10.71^{a}
386	10.57^{ab}	10.32^{b}	10.98^{a}	10.54^{ab}
Average Daily Gain, kg				
250	1.36^{a}	1.18^{b}	1.10^{c}	1.22^{b}
273	1.38^{a}	1.32^{b}	1.18^{c}	1.28^{b}
295	1.42^{a}	1.37^{b}	1.33^{c}	1.35^{bc}
318	1.45^{a}	1.39^{b}	1.40^{b}	1.37^{b}
341	1.46^{a}	1.42^{b}	1.38^{c}	1.39^{bc}
364	1.53^{a}	1.41^{b}	1.40^{b}	1.43^{b}
386	1.45^{a}	1.43^{a}	1.32^{b}	1.36^{ab}
Feed/Gain				
250	6.17^{c}	6.66^{b}	7.04^{a}	6.48^{b}
273	6.25^{d}	6.46^{c}	7.00^{a}	6.66^{b}
295	6.39^{ac}	6.60^{b}	6.88^{a}	6.67^{b}
318	6.41^{c}	6.72^{b}	6.88^{a}	6.74^{b}
341	6.51^{d}	6.71^{c}	7.19^{a}	6.92^{b}
364	6.64^{b}	6.87^{b}	7.48^{a}	7.01^{b}
386	6.83^{b}	6.95^{b}	7.78^{a}	7.45^{a}

^{abcd}Means in same row with different superscripts differ (P<.05).
^{ef}Means in same row with different superscripts differ (P<.10).
^{g}Peak intakes occurred from day 57 to 70.
^{h}Peak intakes occurred from day 43 to 56

TABLE 14. EFFECT OF PREVIOUS INTAKE DATA ON ROOT MSE (KG) OF MODEL FOR BEEF STEERS

Intake Data, Days	Season of Year Received in Yard			
	Jan 29- April 30	May 1- July 30	July 31- Oct 29	Oct 30- Jan 28
0	0.755	0.782	0.790	0.775
0-7	0.680	0.726	0.719	0.713
0-14	0.650	0.707	0.701	0.694
0-21	0.625	0.688	0.690	0.675
0-28	0.609	0.674	0.669	0.662
0-56	0.549	0.596	0.576	0.571
0-84	0.536	0.548	0.547	0.539
8-28	0.605	0.666	0.664	0.653
15-28	0.613	0.659	0.658	0.652
22-28	0.646	0.655	0.663	0.677
29-56	0.560	0.570	0.570	0.573
29-84	0.545	0.528	0.546	0.541
57-84	0.563	0.535	0.565	0.555

TABLE 15. EFFECT OF PREVIOUS INTAKE DATA ON R^2 OF MODEL FOR BEEF STEERS

Intake Data, Days	Season of Year Received in Yard			
	Jan 29- April 30	May 1- July 30	July 31- Oct 29	Oct 30- Jan 28
0	.464	.502	.669	.531
0-7	.566	.572	.726	.604
0-14	.604	.594	.740	.625
0-21	.634	.616	.748	.645
0-28	.652	.632	.763	.658
0-56	.717	.711	.824	.746
0-84	.728	.756	.842	.774
8-28	.657	.639	.767	.668
15-28	.647	.647	.771	.668
22-28	.609	.651	.767	.643
29-56	.705	.736	.828	.744
29-84	.719	.774	.842	.772
57-84	.701	.768	.831	.760

TABLE 16. REGRESSION COEFFICIENTS FOR DRY MATTER INTAKE EQUATION USING DAY 8-28 INTAKE FOR BEEF FEEDLOT STEERS RECEIVED JANUARY 29 - APRIL 30 (R^2=0.6515)

Item[a]	b	Standard Error	Sig. Level
Intercept	700.24439	84.13524	.0001
INWT	-8621.70423	1006.69993	.0001
INWT^2	39407.28197	4507.67898	.0001
INWT^3	-79512.50819	8964.74669	.0001
INWT^4	59674.34987	6690.68903	.0001
DMI	-69.96854	10.15971	.0001
INWT*DMI	859.23650	119.68303	.0001
INWT^2*DMI	-3882.27532	525.33427	.0001
INWT^3*DMI	7744.00336	1019.27192	.0001
INWT^4*DMI	-5749.54354	738.59275	.0001
DOF^3*DMI	-1.72609	0.07095	.0001
DOF^4*DMI	0.81484	0.04451	.0001
DOF	28.67407	1.90714	.0001
INWT^2*DOF	66.86216	6.43886	.0001
DOF^2	-116.71740	7.54939	.0001
INWT*DOF^2	43.00824	6.98286	.0001
INWT^2*DOF^2	-152.02399	18.97276	.0001
DOF^3	221.69936	14.68587	.0001
INWT^3*DOF^3*DMI	7.93837	0.95203	.0001
DOF^4	-201.09944	14.54041	.0001
DOF^5	88.81197	7.06823	.0001
DOF^6	-15.79402	1.34128	.0001

[a] Terms include INWT, initial shrunk weight in kg/1000; DMI, mean dry matter intake (kg) observed days 8-28; DOF, days on feed/100.

TABLE 17. REGRESSION COEFFICIENTS FOR DRY MATTER INTAKE EQUATION USING DAY 8-28 INTAKE FOR BEEF FEEDLOT STEERS RECEIVED MAY 1 - JULY 30 (R^2=0.6356)

Item[a]	b	Standard Error	Sig. Level
Intercept	34.31669	4.11554	.0001
INWT^2	-2496.50616	341.13701	.0001
INWT^3	9837.99433	1597.19618	.0001
INWT^4	-10344.12253	2031.88967	.0001
INWT^2*DMI	148.00219	17.66996	.0001
INWT^3*DMI	-678.35287	101.45803	.0001
INWT^4*DMI	783.94939	144.51754	.0001
DOF	-596.71305	60.96836	.0001
INWT*DOF	5169.99622	509.76117	.0001
INWT^2*DOF	-11016.76512	1223.41157	.0001
INWT^4*DOF	12603.25608	2063.55767	.0001
INWT*DOF*DMI	-122.64979	12.94725	.0001
INWT^2*DOF*DMI	463.31317	54.75841	.0001
INWT^4*DOF*DMI	-805.12867	136.74696	.0001
DOF^2	1757.40393	155.08607	.0001
INWT*DOF^2	-13312.51694	1105.61350	.0001
INWT^2*DOF^2	29821.62991	2656.66773	.0001
INWT^3*DOF^2	-24829.61238	2662.16303	.0001
INWT^4*DOF^2	6688.95472	1377.26327	.0001
INWT*DOF^2*DMI	139.32740	16.28125	.0001
INWT^2*DOF^2*DMI	-636.36517	81.78822	.0001
INWT^3*DOF^2*DMI	571.89433	95.05383	.0001
DOF^3	-1905.33991	171.56631	.0001
INWT*DOF^3	10460.77238	882.43756	.0001
INWT^2*DOF^3	-10609.16839	937.88896	.0001
INWT*DOF^3*DMI	-31.64868	3.79009	.0001
INWT^2*DOF^3*DMI	110.15596	13.12604	.0001
DOF^4	972.24924	94.27955	.0001
INWT*DOF^4	-3027.50821	281.21768	.0001
INWT^2*DOF^4	-5555.27495	518.04157	.0001
INWT^3*DOF^4	6922.47739	681.37842	.0001
DOF^5	-225.08690	24.17533	.0001
INWT^2*DOF^5	3738.71930	367.70586	.0001
DOF^6	23.84159	2.83503	.0001
INWT^3*DOF^6	-1618.49443	175.79581	.0001

[a] Terms include INWT, initial shrunk weight in kg/1000; DMI, mean dry matter intake (kg) observed days 8-28; DOF, days on feed/100.

TABLE 18. REGRESSION COEFFICIENTS FOR DRY MATTER INTAKE EQUATION USING DAY 8-28 INTAKE FOR BEEF FEEDLOT STEERS RECEIVED JULY 31 - OCTOBER 29 (R^2=0.7620)

Item[a]	b	Standard Error	Sig. Level
Intercept	-7.84344	0.44473	.0001
INWT^2*DMI	58.59416	4.59190	.0001
INWT^3*DMI	-214.98019	21.69159	.0001
INWT^4*DMI	214.13327	26.93930	.0001
DOF*DMI	10.88529	0.96992	.0001
INWT*DOF	1086.57115	58.43474	.0001
INWT^2*DOF	-4633.89313	298.88524	.0001
INWT^3*DOF	5537.76538	446.09552	.0001
INWT*DOF*DMI	-167.51089	15.59566	.0001
INWT^2*DOF*DMI	632.57312	60.33232	.0001
INWT^3*DOF*DMI	-686.57678	71.17534	.0001
INWT*DOF^2	-1888.71048	104.67837	.0001
INWT^2*DOF^2	6998.16984	420.18518	.0001
INWT^3*DOF^2	-7281.54528	535.40547	.0001
INWT*DOF^2*DMI	99.92224	12.53346	.0001
INWT^2*DOF^2*DMI	-389.97796	40.96050	.0001
INWT^4*DOF^2*DMI	546.06742	57.40482	.0001
INWT*DOF^3	884.06401	56.09499	.0001
INWT^2*DOF^3	-799.33751	99.06229	.0001
INWT*DOF^3*DMI	-56.56016	8.48783	.0001
INWT^2*DOF^3*DMI	199.35098	24.92794	.0001
INWT^2*DOF^4	-1727.92653	154.38081	.0001
INWT*DOF^4*DMI	6.82457	1.32545	.0001
INWT^3*DOF^4*DMI	-87.66574	11.52331	.0001
INWT*DOF^5	-10.39825	1.44341	.0001
INWT^3*DOF^5	2434.40744	253.40639	.0001
INWT^4*DOF^6	-1199.71702	158.08690	.0001

[a] Terms include INWT, initial shrunk weight in kg/1000; DMI, mean dry matter intake (kg) observed days 8-28; DOF, days on feed/100.

TABLE 19. REGRESSION COEFFICIENTS FOR DRY MATTER INTAKE EQUATION USING DAY 8-28 INTAKE FOR BEEF FEEDLOT STEERS RECEIVED OCTOBER 30 - JANUARY 28 (R^2=0.6643)

Item[a]	b	Standard Error	Sig. Level
Intercept	-4.89835	0.40915	.0001
DMI	0.92938	0.04957	.0001
DOF^{2}*DMI	18.18383	2.16319	.0001
DOF^{3}*DMI	-30.03601	3.58476	.0001
DOF^{4}*DMI	25.49784	2.49670	.0001
DOF^{6}*DMI	-0.61926	0.10552	.0001
INWT*DOF	221.36651	12.54387	.0001
INWT^{2}*DOF	-427.77868	27.90449	.0001
INWT*DOF*DMI	8.88346	1.06086	.0001
INWT*DOF^{2}*DMI	-205.02788	14.51880	.0001
INWT^{2}*DOF^{2}*DMI	258.91962	19.00573	.0001
INWT*DOF^{3}	-541.43052	43.22174	.0001
INWT^{3}*DOF^{3}	2956.89653	250.88897	.0001
INWT*DOF^{3}*DMI	294.92725	21.91866	.0001
INWT^{3}*DOF^{3}*DMI	-536.74744	42.84391	.0001
DOF^{4}	-203.15457	20.44485	.0001
INWT*DOF^{4}	2385.59930	224.22765	.0001
INWT^{2}*DOF^{4}	-4343.82273	422.21885	.0001
INWT*DOF^{4}*DMI	-235.77685	18.72887	.0001
DOF^{5}	66.75091	8.71289	.0001
INWT*DOF^{5}	-634.09465	75.21868	.0001
INWT^{3}*DOF^{5}	1914.13825	244.21813	.0001
INWT^{2}*DOF^{5}*DMI	201.81747	18.25818	.0001
INWT^{4}*DOF^{5}*DMI	532.31800	50.39117	.0001
INWT^{2}*DOF^{6}	174.97611	26.96970	.0001
INWT^{4}*DOF^{6}*DMI	-462.73046	45.60747	.0001

[a] Terms include INWT, initial shrunk weight in kg/1000; DMI, mean dry matter intake (kg) observed days 8-28; DOF, days on feed/100.

TABLE 20. REGRESSION COEFFICIENTS FOR DRY MATTER INTAKE EQUATION USING DAY 15-28 INTAKE FOR BEEF FEEDLOT STEERS RECEIVED JANUARY 29 - APRIL 30 (R^2=0.6423)

Item[a]	b	Standard Error	Sig. Level
Intercept	-50.86657	5.93070	.0001
INWT^2	2243.95031	294.00829	.0001
INWT^3	-7916.34171	1130.30693	.0001
INWT^4	7729.40008	1236.95939	.0001
INWT*DM	69.38870	7.78756	.0001
INWT^2*DM	-540.62971	65.55418	.0001
INWT^3*DMI	1437.85143	182.49950	.0001
INWT^4*DMI	-1276.49855	168.89242	.0001
DOF^2*DMI	-25.05938	1.96686	.0001
DOF^5*DMI	6.30753	0.48784	.0001
DOF^6*DMI	-1.66010	0.14102	.0001
DOF	409.02039	29.25059	.0001
INWT*DOF	-4162.27109	313.52311	.0001
INWT^2*DOF	17180.34025	1344.53766	.0001
INWT^3*DOF	-32863.82708	2691.83709	.0001
INWT^4*DOF	24002.09951	2053.46329	.0001
INWT^3*DOF*DMI	49.96960	8.98492	.0001
DOF^2	-82.67759	6.56729	.0001
INWT^3*DOF^2	1283.50951	220.19891	.0001
INWT*DOF^2*DMI	172.87264	14.34762	.0001
INWT^2*DOF^2*DMI	-338.27042	29.95682	.0001
DOF^3	212.05639	16.25116	.0001
INWT*DOF^3	-332.66060	33.50717	.0001
INWT^3*DOF^3	-919.60300	154.05394	.0001
INWT^3*DOF^3*DMI	208.02696	20.14763	.0001
DOF^4	-132.43489	9.83594	.0001
INWT*DOF^4	273.81588	22.62929	.0001
INWT*DOF^4*DMI	-27.99799	2.31532	.0001
DOF^6	4.97864	0.56940	.0001

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[a] Terms include INWT, initial shrunk weight in kg/1000; DMI, mean dry matter intake (kg) observed days 15-28; DOF, days on feed/100.

TABLE 21. REGRESSION COEFFICIENTS FOR DRY MATTER INTAKE EQUATION USING DAY 15-28 INTAKE FOR BEEF FEEDLOT STEERS RECEIVED MAY 1 - JULY 30 (R^2=0.6446)

Item[a]	b	Standard Error	Sig. Level
Intercept	3.71233	0.21266	.0001
DOF*DMI	46.22324	5.70724	.0001
DOF^2*DMI	-184.72879	15.20469	.0001
DOF^3*DMI	255.79701	18.58262	.0001
DOF^4*DMI	-131.99824	10.09871	.0001
DOF^5*DMI	24.07633	2.16015	.0001
DOF	-234.81686	26.15507	.0001
INWT*DOF	1315.85986	175.42357	.0001
INWT^2*DOF	-2988.28208	366.19190	.0001
INWT^4*DOF	6946.70896	652.17524	.0001
INWT*DOF*DMI	-299.64814	42.83503	.0001
INWT^2*DOF*DMI	907.47267	115.20932	.0001
INWT^3*DOF*DMI	-1001.48543	112.98845	.0001
DOF^2	866.86644	57.91263	.0001
INWT*DOF^2	-2147.25955	179.08537	.0001
INWT*DOF^2*DMI	859.21334	82.01868	.0001
INWT^2*DOF^2*DMI	-1600.46745	148.91709	.0001
INWT^3*DOF^2*DMI	1099.50754	101.70475	.0001
DOF^3	-1119.90597	66.73783	.0001
INWT^2*DOF^3	12307.62992	832.88585	.0001
INWT^3*DOF^3	-12615.78776	903.32251	.0001
INWT*DOF^3*DMI	-956.07728	75.86680	.0001
INWT^2*DOF^3*DMI	1082.18126	90.00162	.0001
DOF^4	682.38304	45.72930	.0001
INWT*DOF^4	357.04781	50.67638	.0001
INWT^2*DOF^4	-5569.61429	401.08195	.0001
INWT*DOF^4*DMI	302.35508	24.46854	.0001
INWT^3*DOF^4*DMI	-537.03648	48.62685	.0001
DOF^5	-189.05442	14.80801	.0001
INWT^4*DOF^5	8349.09155	798.71607	.0001
DOF^6	15.32722	1.54348	.0001
INWT^2*DOF^6	227.75080	27.64723	.0001
INWT^4*DOF^6	-1909.38298	255.62340	.0001
INWT*DOF^6*DMI	-13.83614	1.65148	.0001

[a] Terms include INWT, initial shrunk weight in kg/1000; DMI, mean dry matter intake (kg) observed days 15-28; DOF, days on feed/100.

TABLE 22. REGRESSION COEFFICIENTS FOR DRY MATTER INTAKE EQUATION USING DAY 15-28 INTAKE FOR BEEF FEEDLOT STEERS RECEIVED JULY 31 - OCTOBER 29 (R^2=0.7658)

Item[a]	b	Standard Error	Sig. Level
Intercept	-11.90352	0.90327	.0001
$INWT^3$	1412.31690	178.57472	.0001
$INWT^4$	-2903.66792	433.85693	.0001
$INWT^2*DMI$	57.44467	5.17640	.0001
$INWT^3*DMI$	-329.02700	34.64686	.0001
$INWT^4*DMI$	462.47434	58.56198	.0001
DOF*DMI	48.20418	3.86476	.0001
DOF^2*DMI	-61.26305	3.21236	.0001
DOF^3*DMI	26.96992	1.49182	.0001
DOF	-88.36896	22.14588	.0001
INWT*DOF	1446.28695	238.10671	.0001
$INWT^2*DOF$	-6681.70801	938.98888	.0001
$INWT^3*DOF$	8231.13761	1217.84739	.0001
INWT*DOF*DMI	-396.37122	37.41711	.0001
$INWT^2*DOF*DMI$	1277.22602	128.64168	.0001
$INWT^3*DOF*DMI$	-1315.85583	147.12090	.0001
$INWT^2*DOF^2$	1826.69419	198.68180	.0001
$INWT^4*DOF^2$	-4146.08222	729.84279	.0001
$INWT*DOF^2*DMI$	294.91538	19.13126	.0001
$INWT^2*DOF^2*DMI$	-684.77516	51.26504	.0001
$INWT^4*DOF^2*DMI$	837.29682	89.94717	.0001
DOF^3	16.77475	2.67913	.0001
$INWT*DOF^3$	-582.87639	52.03848	.0001
$INWT^2*DOF^3*DMI$	91.22034	7.62614	.0001
$INWT*DOF^4$	265.44076	22.99546	.0001
$INWT*DOF^4*DMI$	-71.62216	4.66220	.0001
$INWT*DOF^5$	-47.05484	4.25888	.0001
$INWT^2*DOF^5*DMI$	66.82675	5.03205	.0001
$INWT^4*DOF^6*DMI$	-72.14052	7.06153	.0001

[a] Terms include INWT, initial shrunk weight in kg/1000; DMI, mean dry matter intake (kg) observed days 15-28; DOF, days on feed/100.

TABLE 23. REGRESSION COEFFICIENTS FOR DRY MATTER INTAKE EQUATION USING DAY 15-28 INTAKE FOR BEEF FEEDLOT STEERS RECEIVED OCTOBER 30 - JANUARY 28 (R^2=0.6634)

Item[a]	b	Standard Error	Sig. Level
Intercept	-7.13638	0.90093	.0001
INWT^2	94.54656	14.18048	.0001
DMI	1.85379	0.16281	.0001
INWT*DMI	-5.39159	0.78843	.0001
DOF^3*DMI	-44.50575	4.33273	.0001
DOF^4*DMI	44.01925	4.61893	.0001
DOF^6*DMI	-1.27337	0.17873	.0001
INWT*DOF	310.99344	69.96147	.0001
INWT^2*DOF	-2854.50238	471.85141	.0001
INWT^3*DOF	7521.02791	1376.48533	.0001
INWT^4*DOF	-8313.76515	1476.35277	.0001
INWT*DOF*DMI	27.91148	4.42506	.0001
INWT*DOF^2	599.25020	138.89384	.0001
INWT*DOF^2*DMI	-136.14285	16.40353	.0001
INWT^4*DOF^2*DMI	430.19271	55.46887	.0001
DOF^3	220.71553	39.98324	.0001
INWT*DOF^3	-2329.13693	371.98040	.0001
INWT^3*DOF^3	4119.31731	502.21326	.0001
INWT*DOF^3*DMI	442.19492	43.38963	.0001
INWT^3*DOF^3*DMI	-688.53168	65.22936	.0001
DOF^4	-397.81763	61.51568	.0001
INWT*DOF^4	3432.38287	488.46689	.0001
INWT^2*DOF^4	-3183.65653	389.92085	.0001
INWT*DOF^4*DMI	-358.23854	36.67770	.0001
DOF^5	108.51328	17.84835	.0001
INWT*DOF^5	-868.29716	133.99646	.0001
INWT^2*DOF^5*DMI	257.57232	27.79686	.0001
INWT^4*DOF^5*DMI	569.38214	60.28106	.0001
INWT^2*DOF^6	280.11791	43.83210	.0001
INWT^4*DOF^6*DMI	-419.20919	46.98104	.0001

[a] Terms include INWT, initial shrunk weight in kg/1000; DMI, mean dry matter intake (kg) observed days 15-28; DOF, days on feed/100.

TABLE 24. SUGGESTED LIMITATIONS FOR INTAKE EQUATIONS FOR BEEF STEERS RECEIVED JANUARY 29 - APRIL 30

Initial Weight Grouping, kg	Maximum Yard Days[a] (DOF)	DMI, kg[b] Days 8-28	DMI, kg[b] Days 15-28
250	160±6	7.92±1.00	8.19±0.84
273	156±11	8.29±0.88	8.43±0.90
295	147±11	8.80±1.04	8.90±1.06
318	136±11	8.85±0.88	9.01±0.91
341	129±12	9.25±1.02	9.43±1.10
364	120±15	9.98±1.58	10.20±1.57
386	112±17	9.85±1.70	10.00±1.83
409	96±9	10.14±1.58	10.40±1.52

[a] Mean DOF ± 1 standard deviation.
[b] Mean Intake ± 1.5 standard deviations.

TABLE 25. SUGGESTED LIMITATIONS FOR INTAKE EQUATIONS FOR BEEF STEERS RECEIVED MAY 1 - JULY 30

Initial Weight Grouping, kg	Maximum Yard Days[a] (DOF)	DMI, kg[b] Days 8-28	DMI, kg[b] Days 15-28
227	194±19	6.50±1.88	6.63±1.94
250	179±10	7.00±1.38	7.26±1.33
273	148±11	8.36±0.93	8.58±0.91
295	143±11	8.92±0.83	9.12±0.82
318	137±11	9.25±0.86	9.51±0.95
341	131±10	9.47±0.94	9.74±0.94
364	125±9	9.60±1.15	9.84±1.29
386	118±10	10.00±1.09	10.25±1.08
409	110±15	10.09±1.79	10.21±1.88

[a] Mean DOF ± 1 standard deviation.
[b] Mean Intake ± 1.5 standard deviations.

TABLE 26. SUGGESTED LIMITATIONS FOR INTAKE EQUATIONS FOR BEEF STEERS RECEIVED JULY 31 - OCTOBER 29

Initial Weight Grouping, kg	Maximum Yard Days[a] (DOF)	DMI, kg[b]	
		Days 8-28	Days 15-28
227	200±10	6.18±1.40	6.71±1.42
250	184±14	6.60±1.32	7.17±1.27
273	159±15	7.91±1.25	8.27±1.26
295	140±15	8.65±1.14	9.03±1.17
318	130±12	9.10±1.06	9.48±1.14
341	126±12	9.43±0.87	9.84±0.91
364	119±11	9.59±1.12	10.00±1.19
386	111±10	9.67±1.06	10.11±1.10

[a] Mean DOF ± 1 standard deviation.
[b] Mean Intake ± 1.5 standard deviations.

TABLE 27. SUGGESTED LIMITATIONS FOR INTAKE EQUATIONS FOR BEEF STEERS RECEIVED OCTOBER 30 - JANUARY 28

Initial Weight Grouping, kg	Maximum Yard Days[a] (DOF)	DMI, kg[b]	
		Days 8-28	Days 15-28
250	180±13	6.90±1.24	7.11±1.33
273	163±13	8.00±1.47	8.27±1.48
295	147±9	8.68±0.87	8.89±0.89
318	136±8	8.95±0.93	9.15±0.93
341	127±9	9.26±1.00	9.46±1.06
364	119±9	9.76±1.08	10.03±1.19
386	112±7	10.05±1.12	10.17±1.07

[a] Mean DOF ± 1 standard deviation.
[b] Mean Intake ± 1.5 standard deviations.

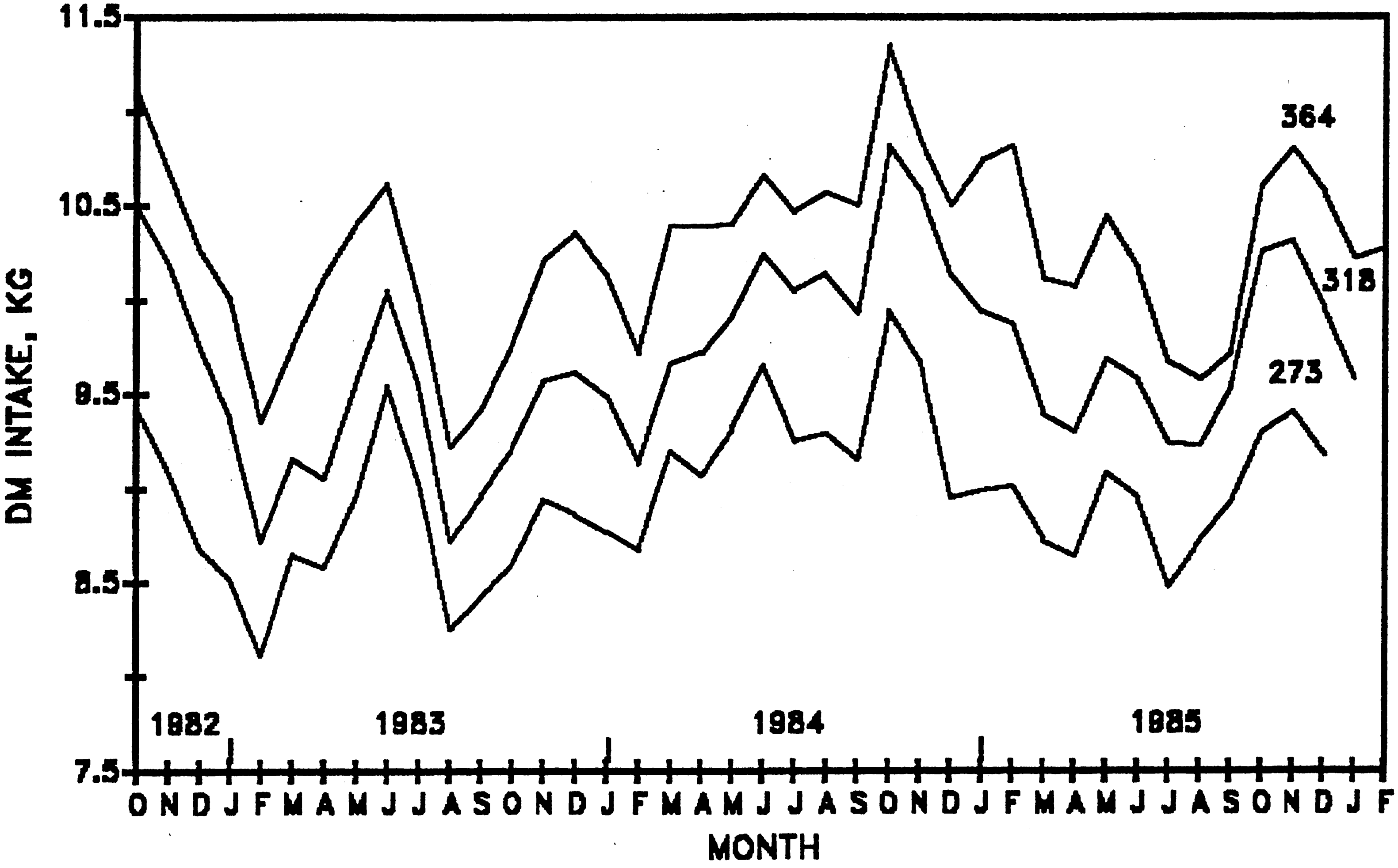

Figure 1. Seasonal Dry Matter Intakes of Cattle with Mean Initial Weights of 273 (250-294), 318 (295-340) and 364 (341-385) Kilograms

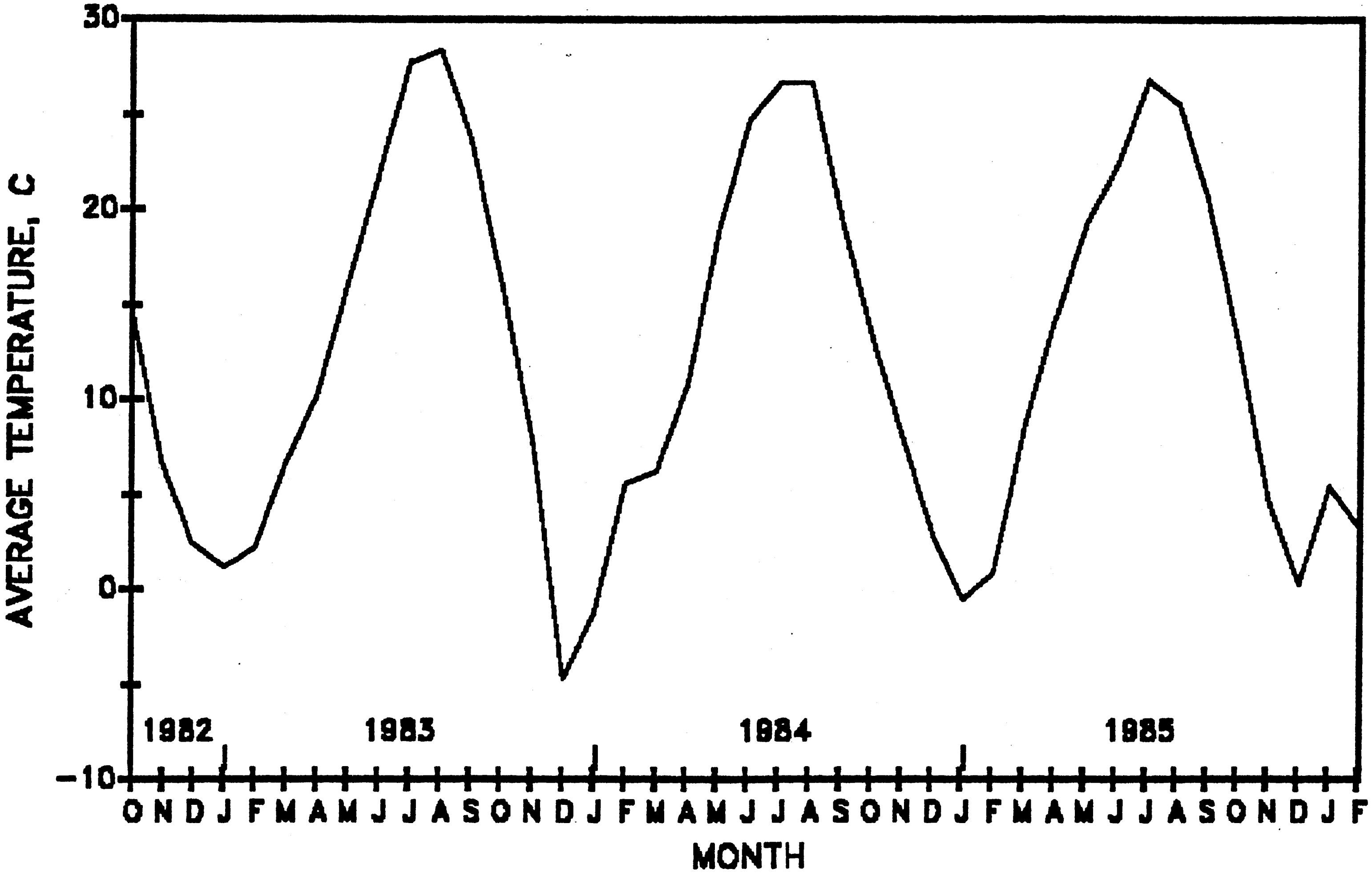

Figure 2. Average Monthly Temperature for the Years 1982-1986

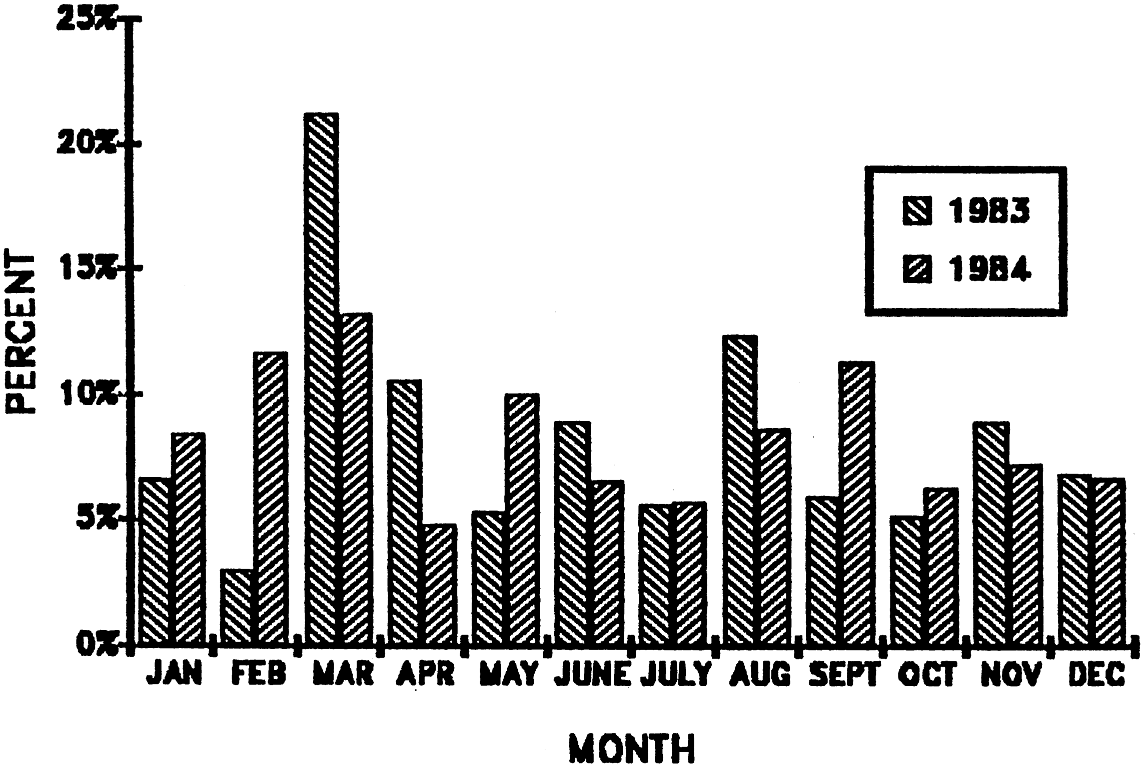

Figure 3. Distribution of Pens of Cattle Received by Month for the Years 1983 and 1984

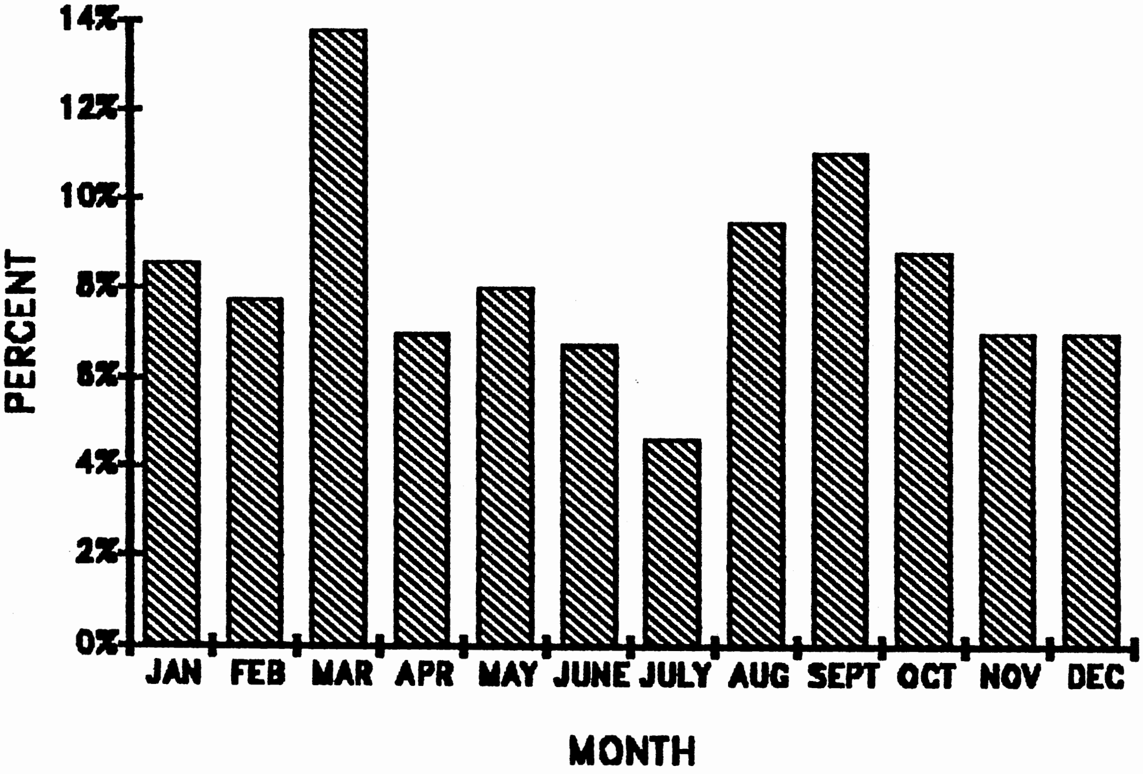

Figure 4. Distribution of Pens of Cattle Received by Month for the Years 1982-1985

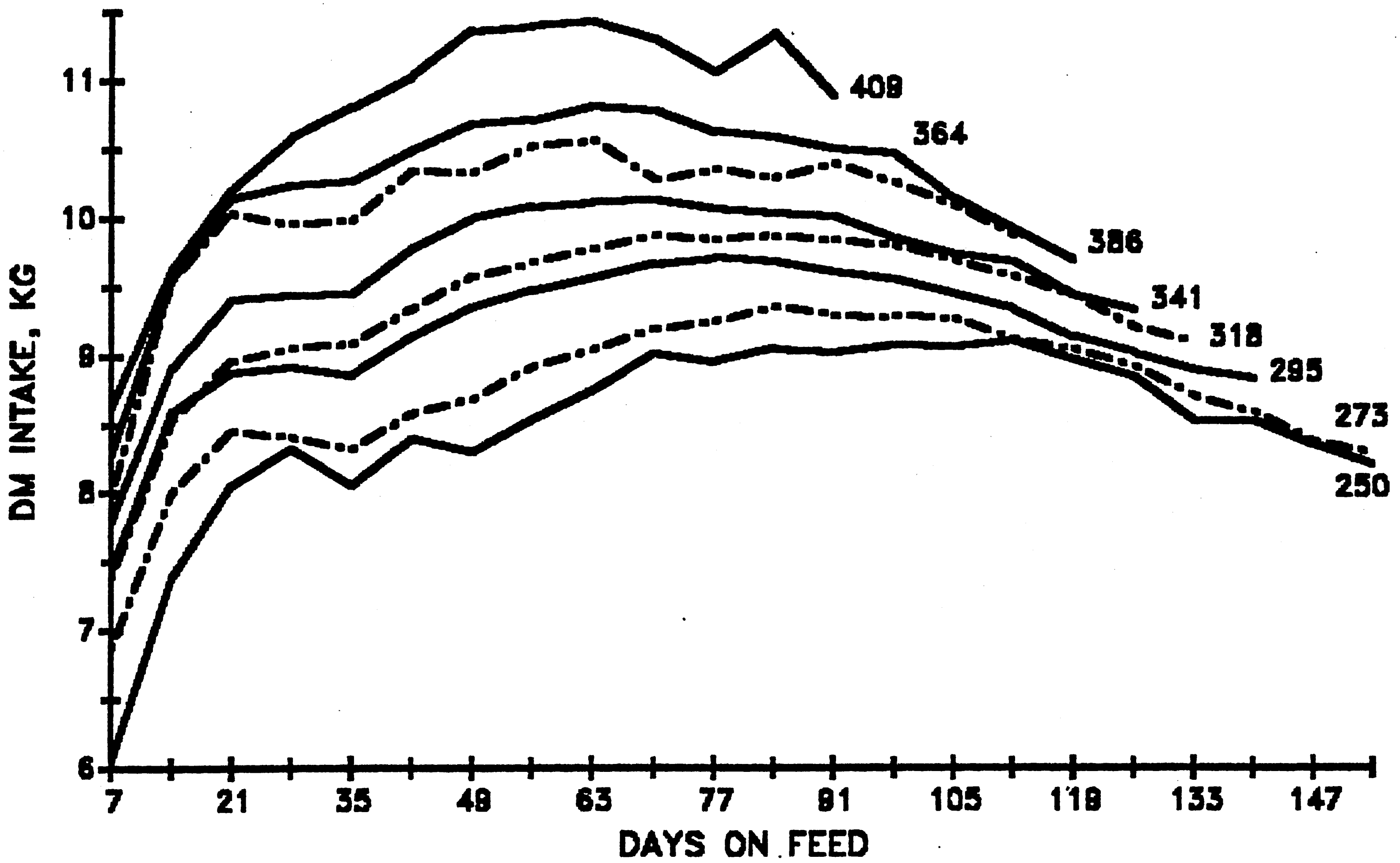

Figure 5. Feed Intake Versus Days on Feed for Steers Received January 29 - April 30 with Different Initial Weights

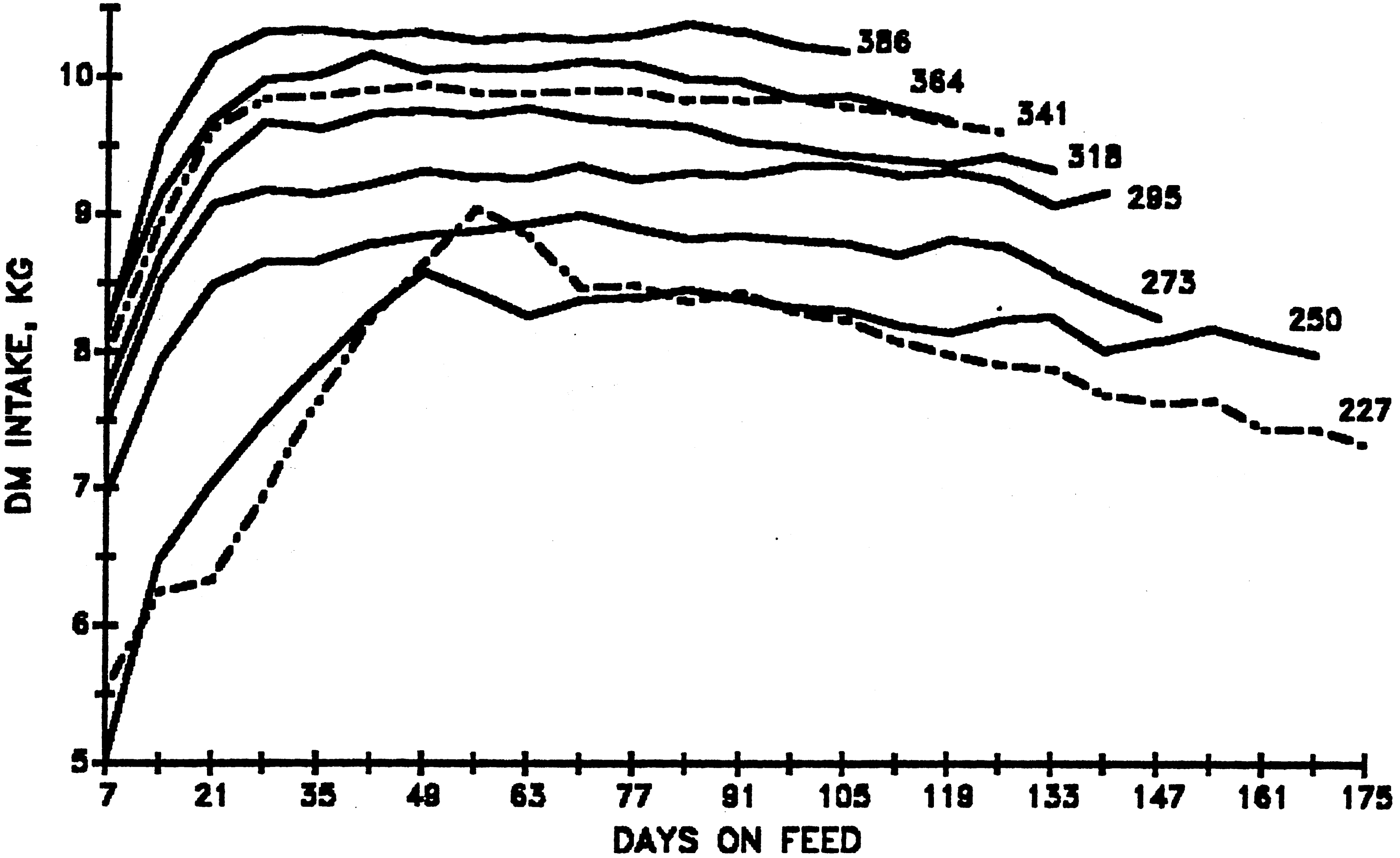

Figure 6. Feed Intake Versus Days on Feed for Steers Received May 1 - July 30 with Different Initial Weights

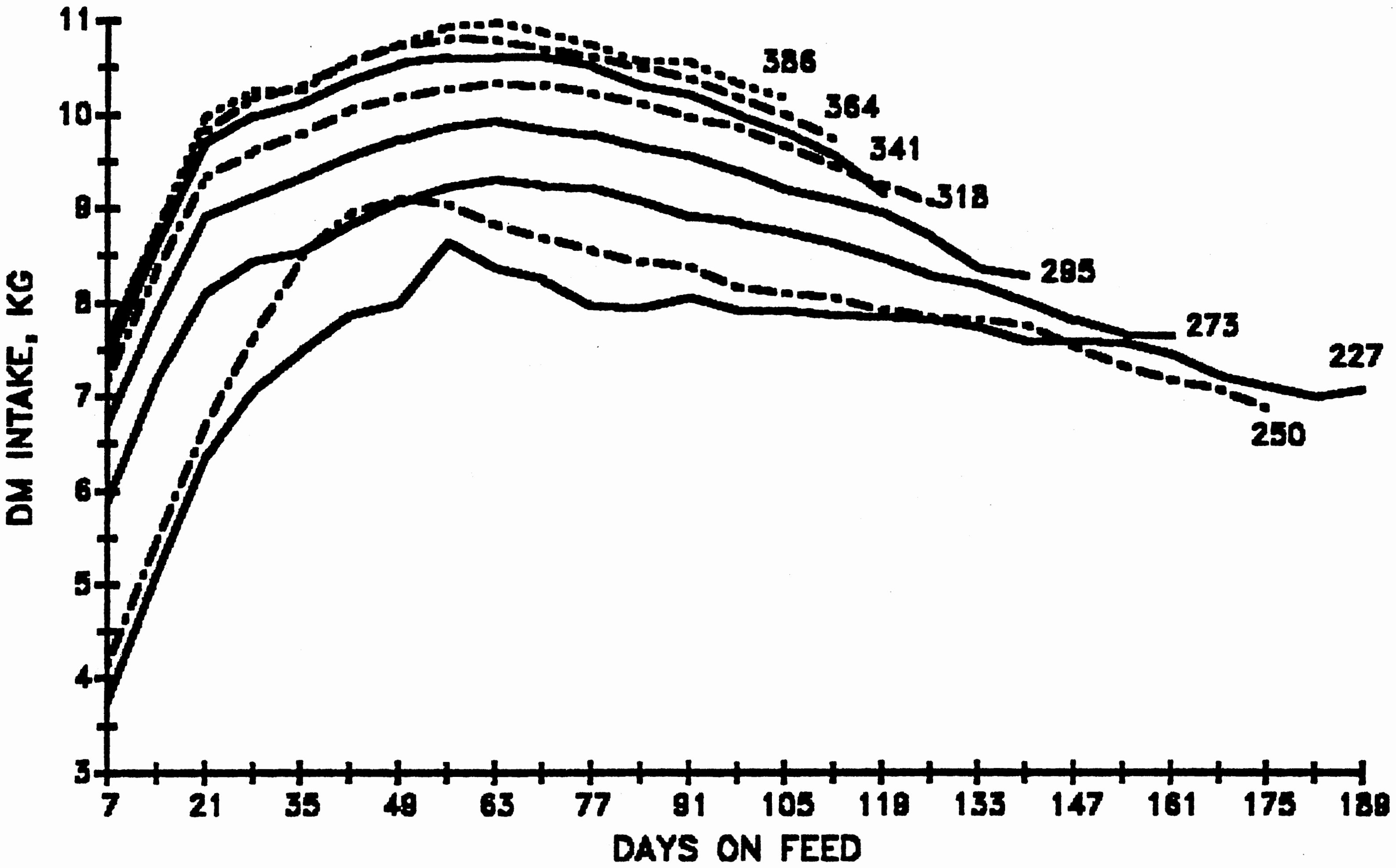

Figure 7. Feed Intake Versus Days on Feed for Steers Received July 31 - October 29 with Different Initial Weights

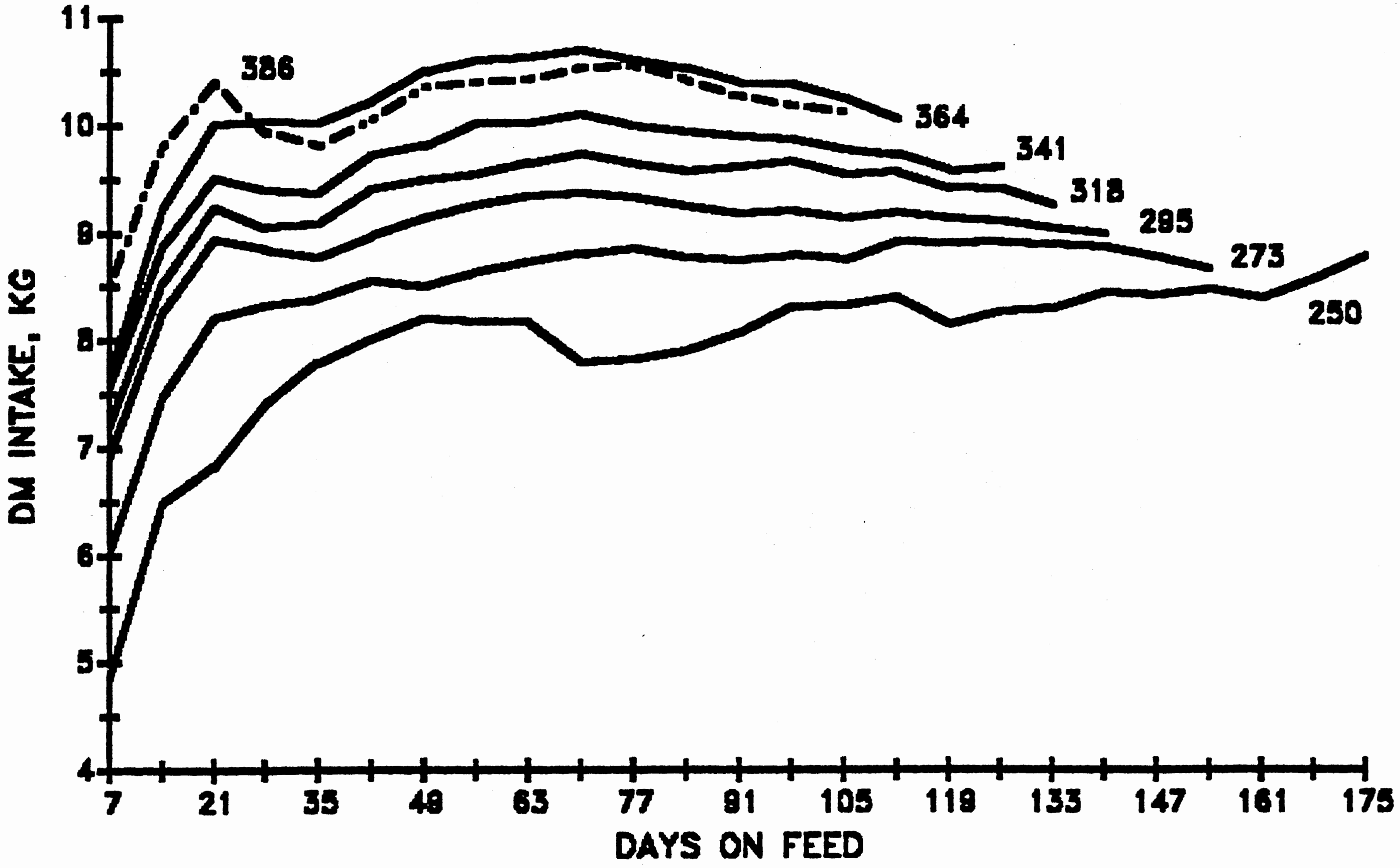

Figure 8. Feed Intake Versus Days on Feed for Steers Received October 30 - January 28 with Different Initial Weights

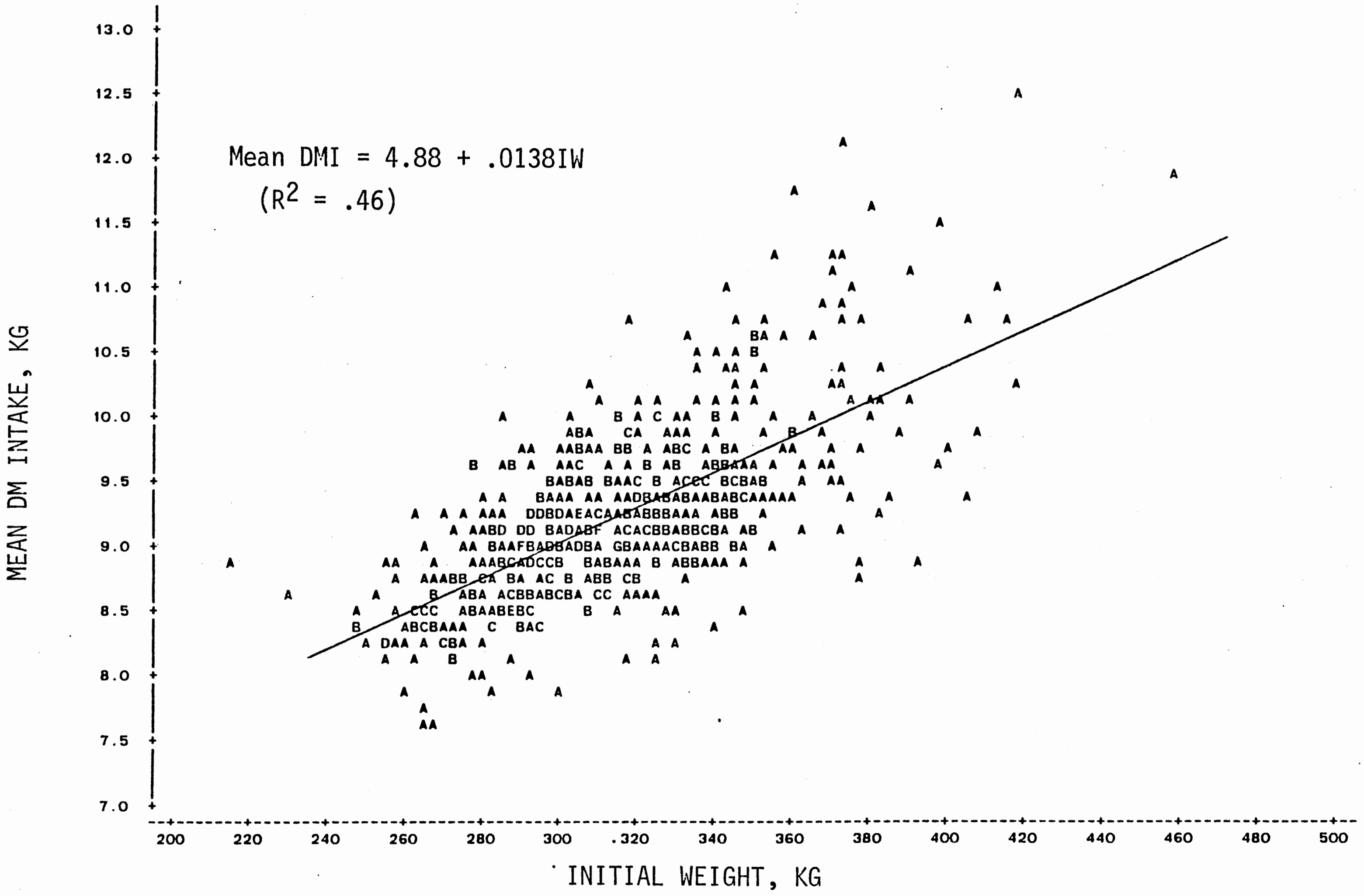

Figure 9. Mean Feed Intake Versus Initial Weight for Steers Received January 29 - April 30

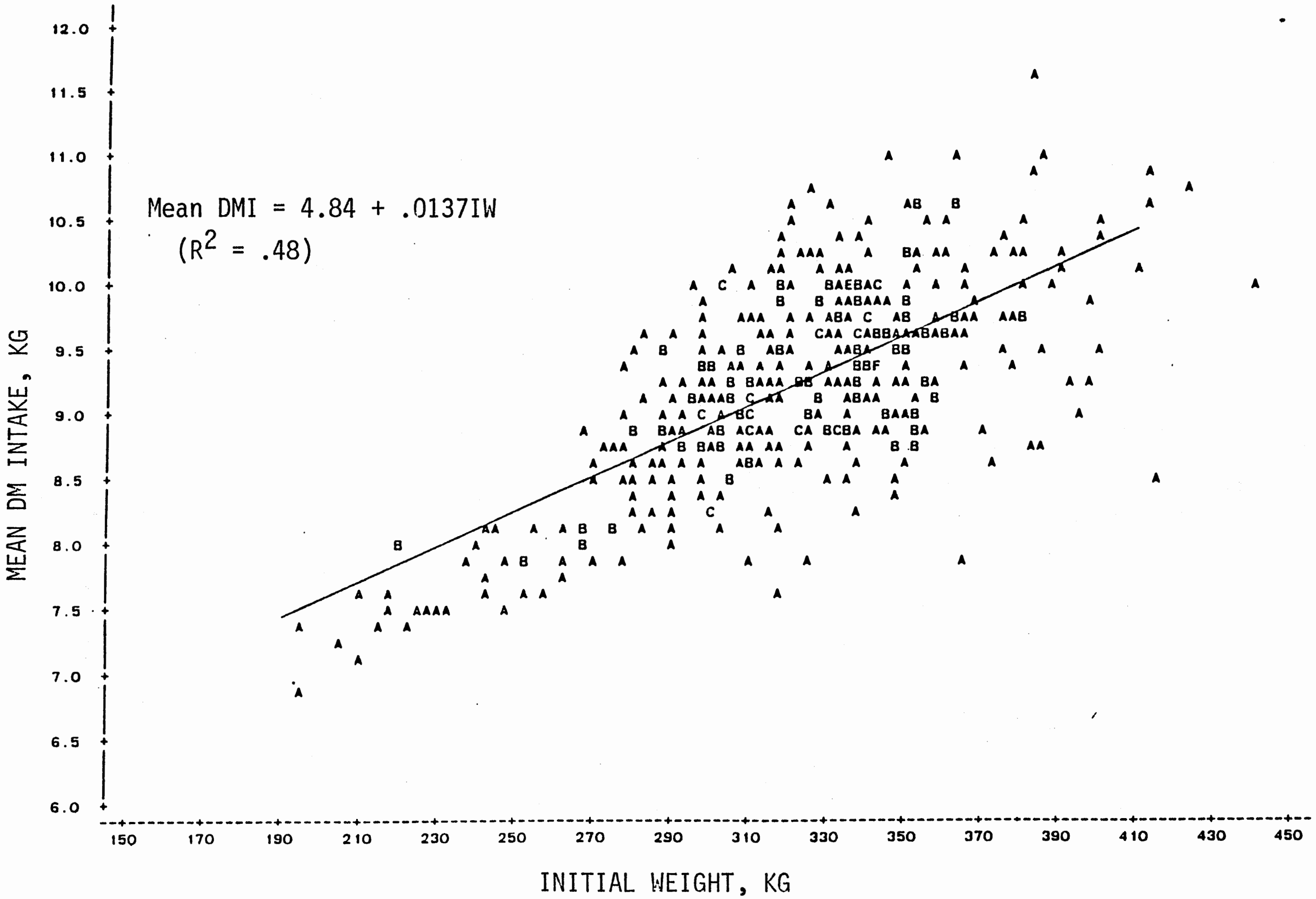

Figure 10. Mean Feed Intake Versus Initial Weight for Steers Received May 1 - July 30

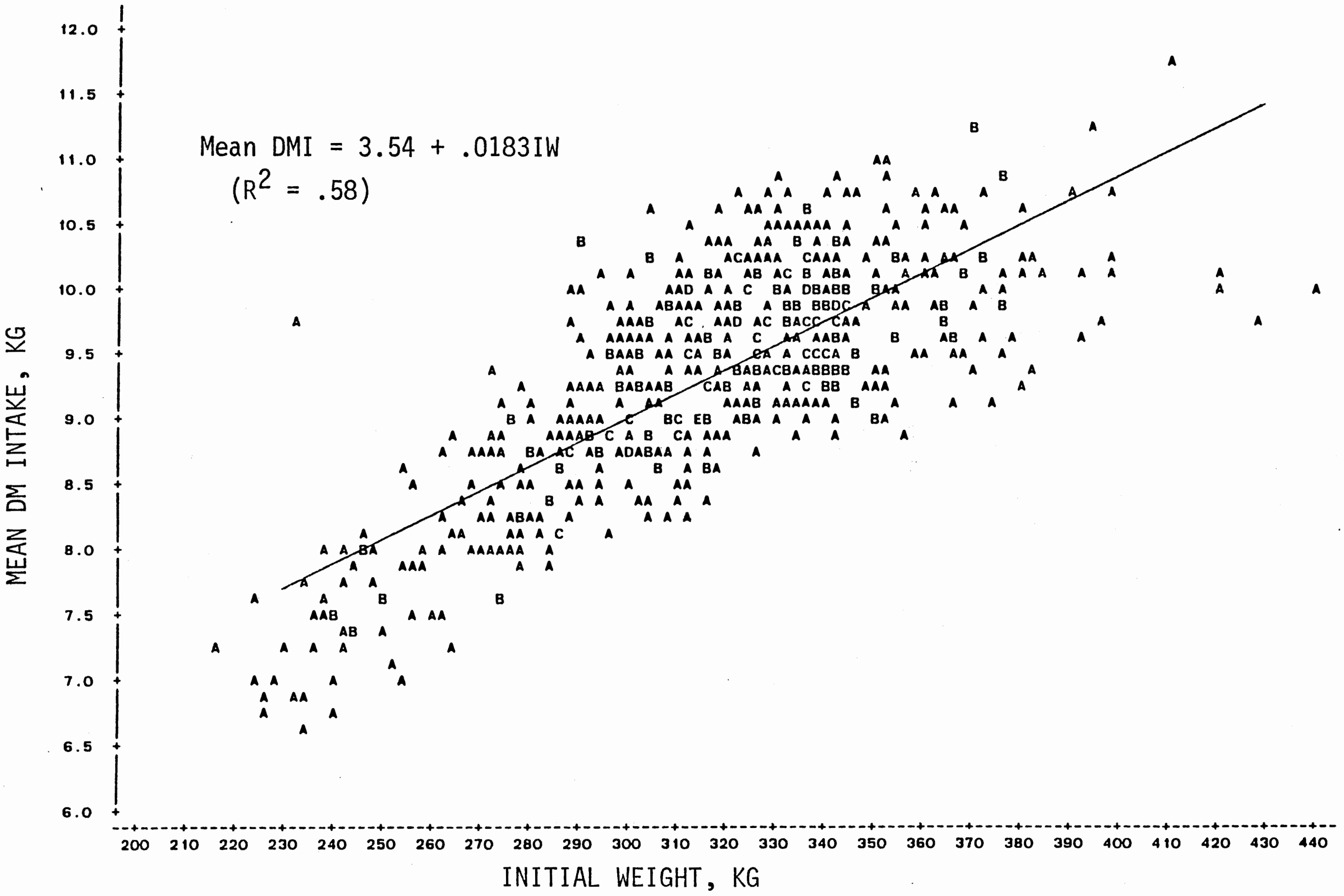

Figure 11. Mean Feed Intake Versus Initial Weight for Steers Received July 31 - October 29

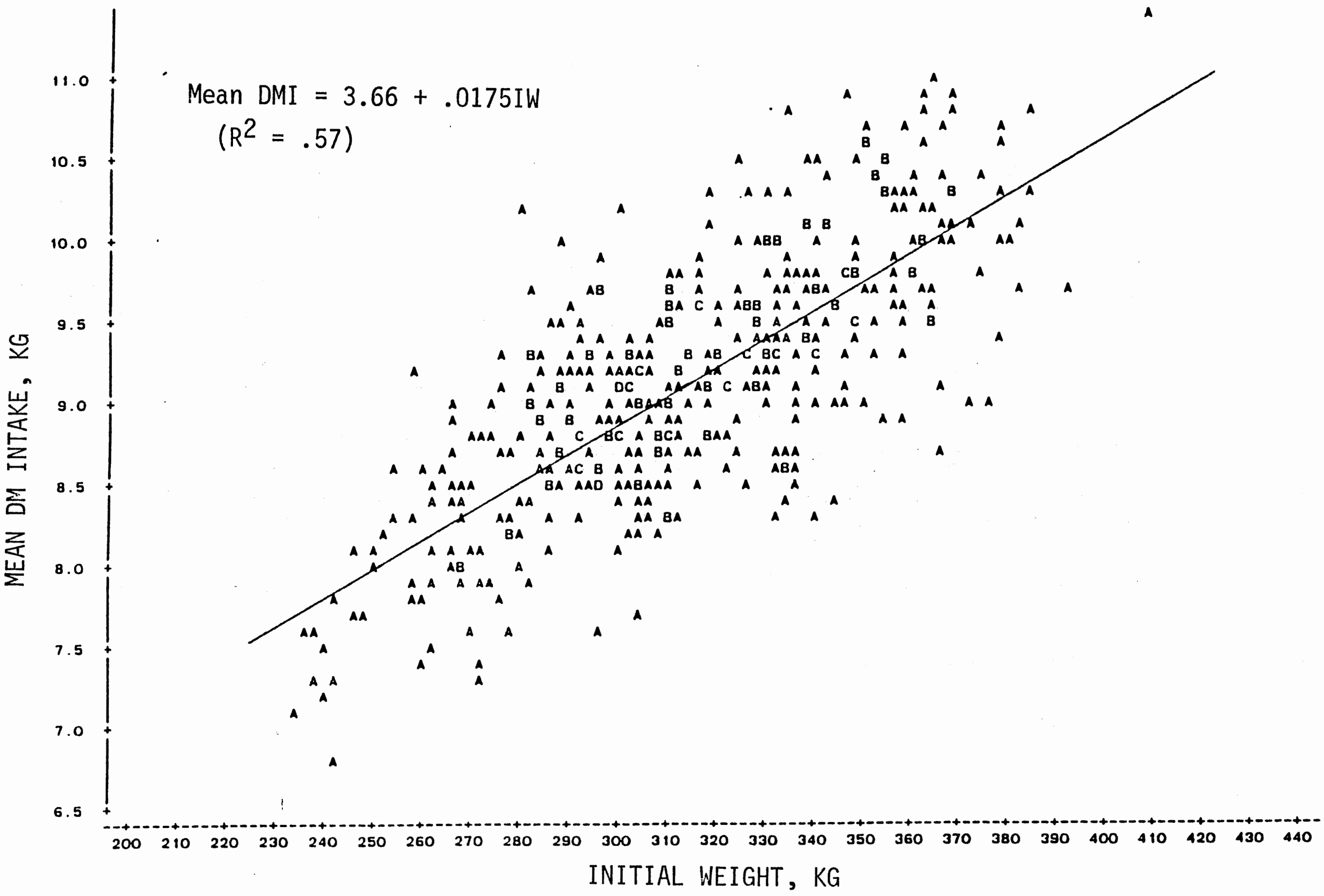

Figure 12. Mean Feed Intake Versus Initial Weight for Steers Received October 30 - January 28

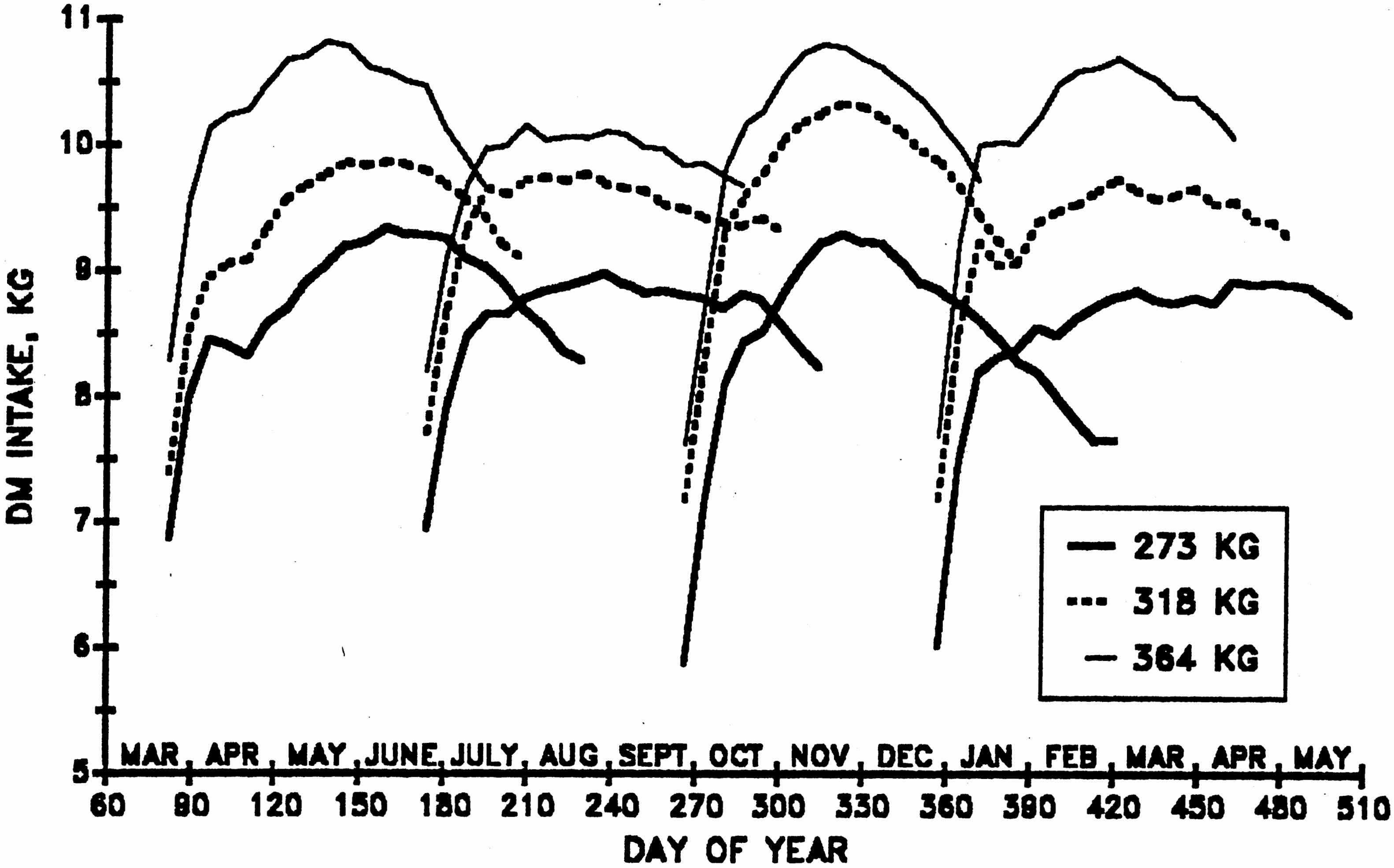

Figure 13. Feed Intake Versus Days on Feed Across Seasons for Steers with Initial Weights of 273, 318 and 364 Kilograms

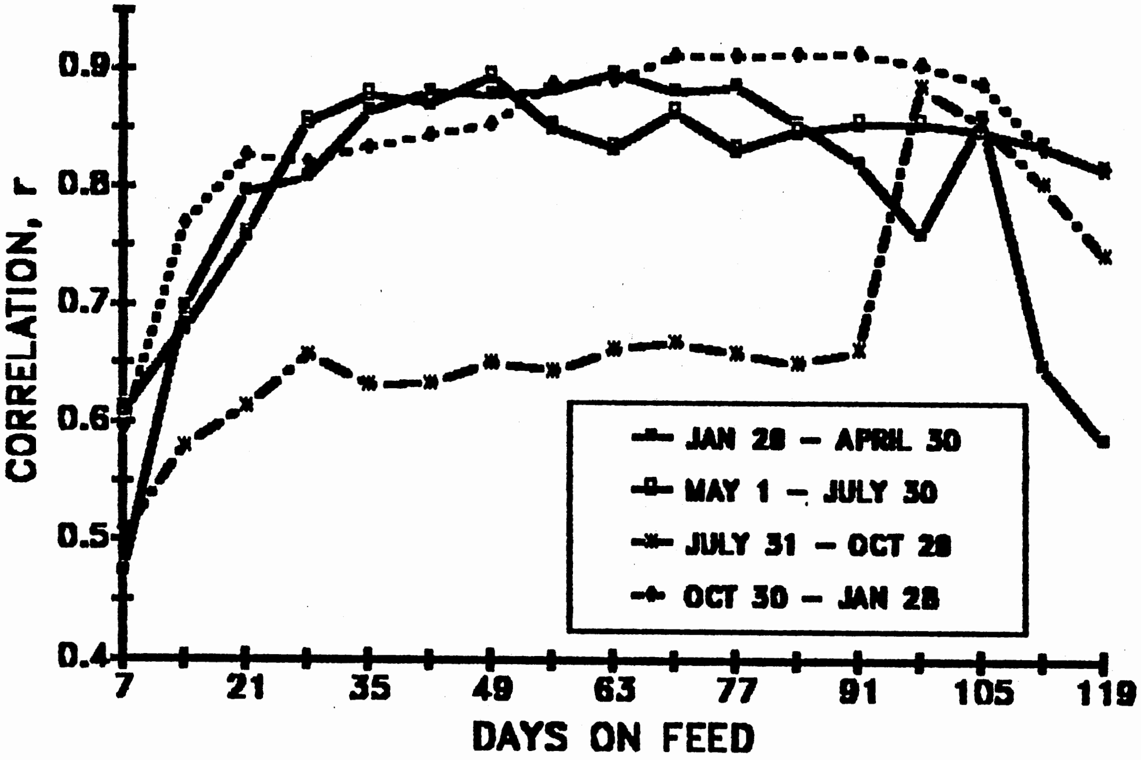

Figure 14. Correlation Between Feed Intake at Various Days on Feed and Overall Mean Feed Intake for Each Receiving Season

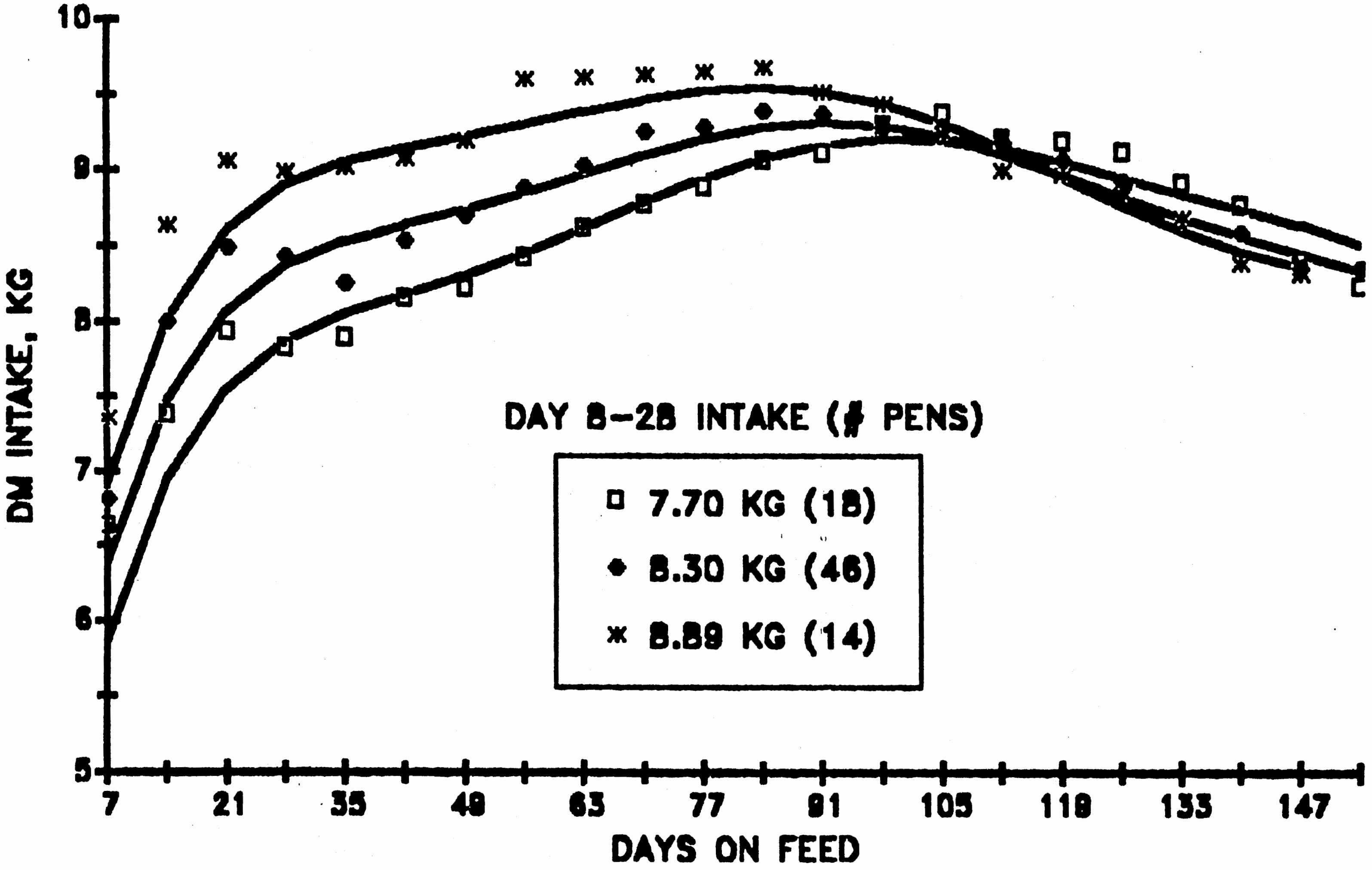

Figure 15. Predicted and Observed Feed Intakes Versus Days on Feed for 273 kg Steers Received January 29 - April 30 Eating Below Average, Average or Above Average Over Days 8-28

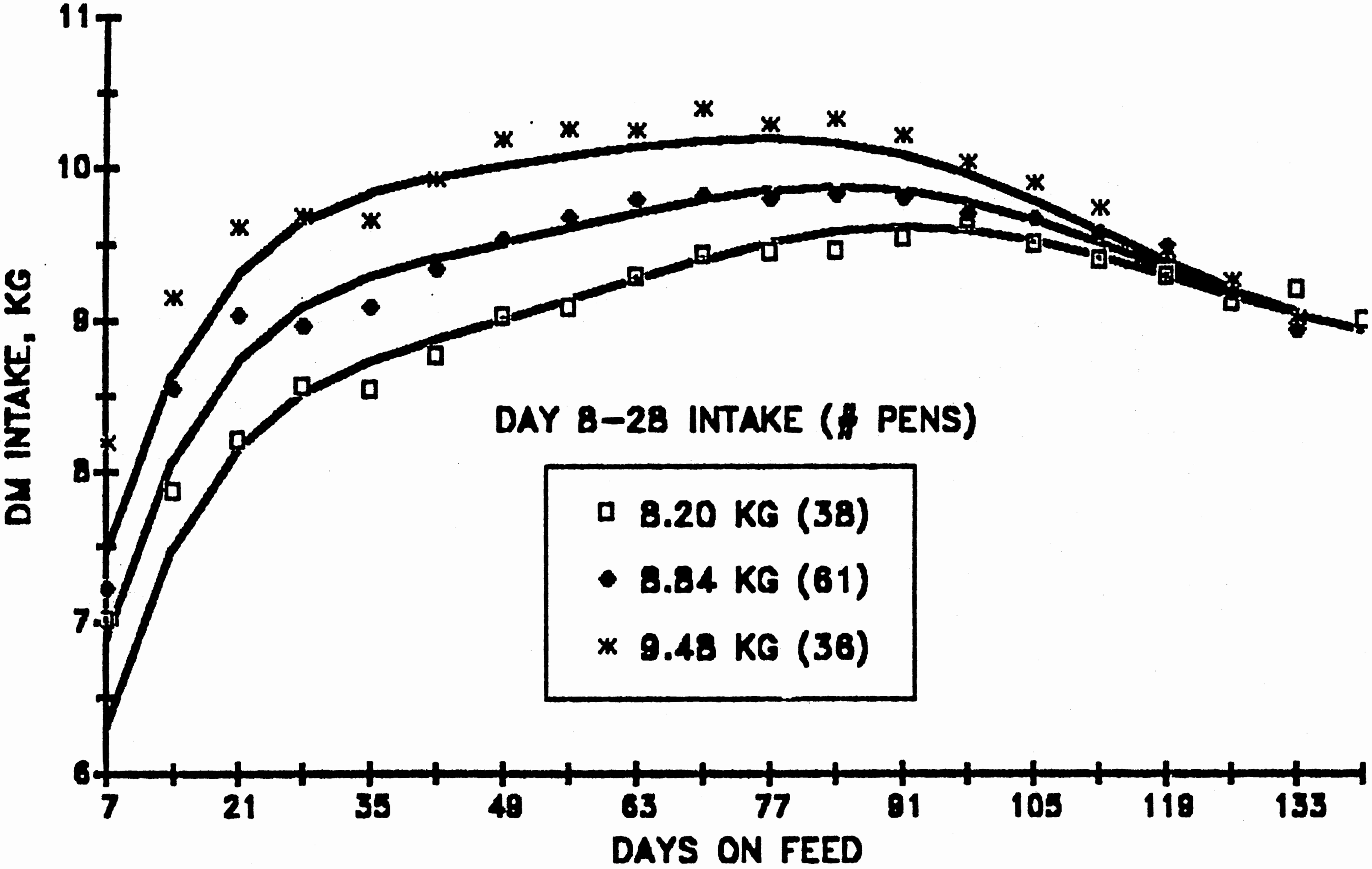

Figure 16. Predicted and Observed Feed Intakes Versus Days on Feed for 318 kg Steers Received January 29 - April 30 Eating Below Average, Average or Above Average Over Days 8-28

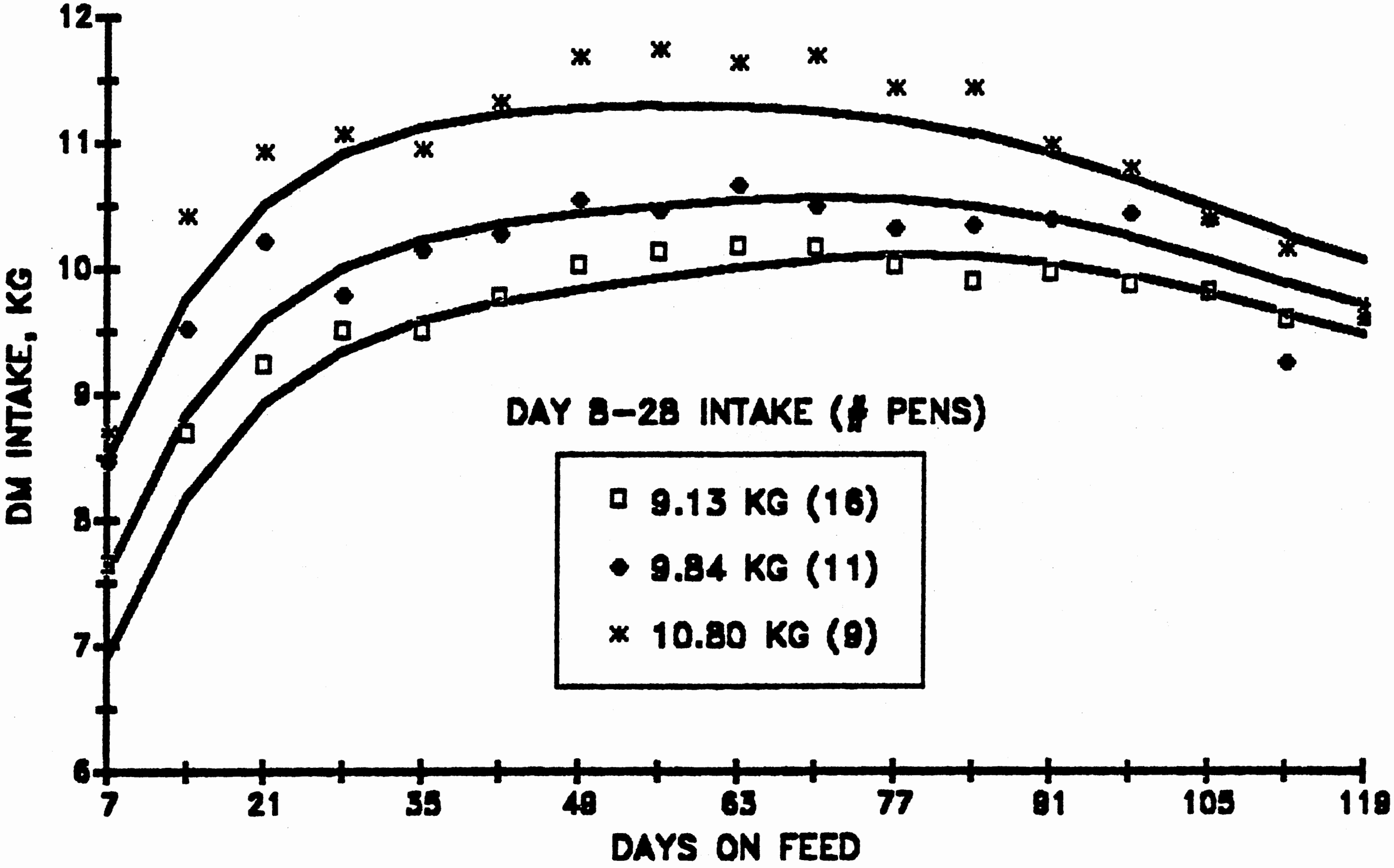

Figure 17. Predicted and Observed Feed Intakes Versus Days on Feed for 364 kg Steers Received January 29 - April 30 Eating Below Average, Average or Above Average Over Days 8-28

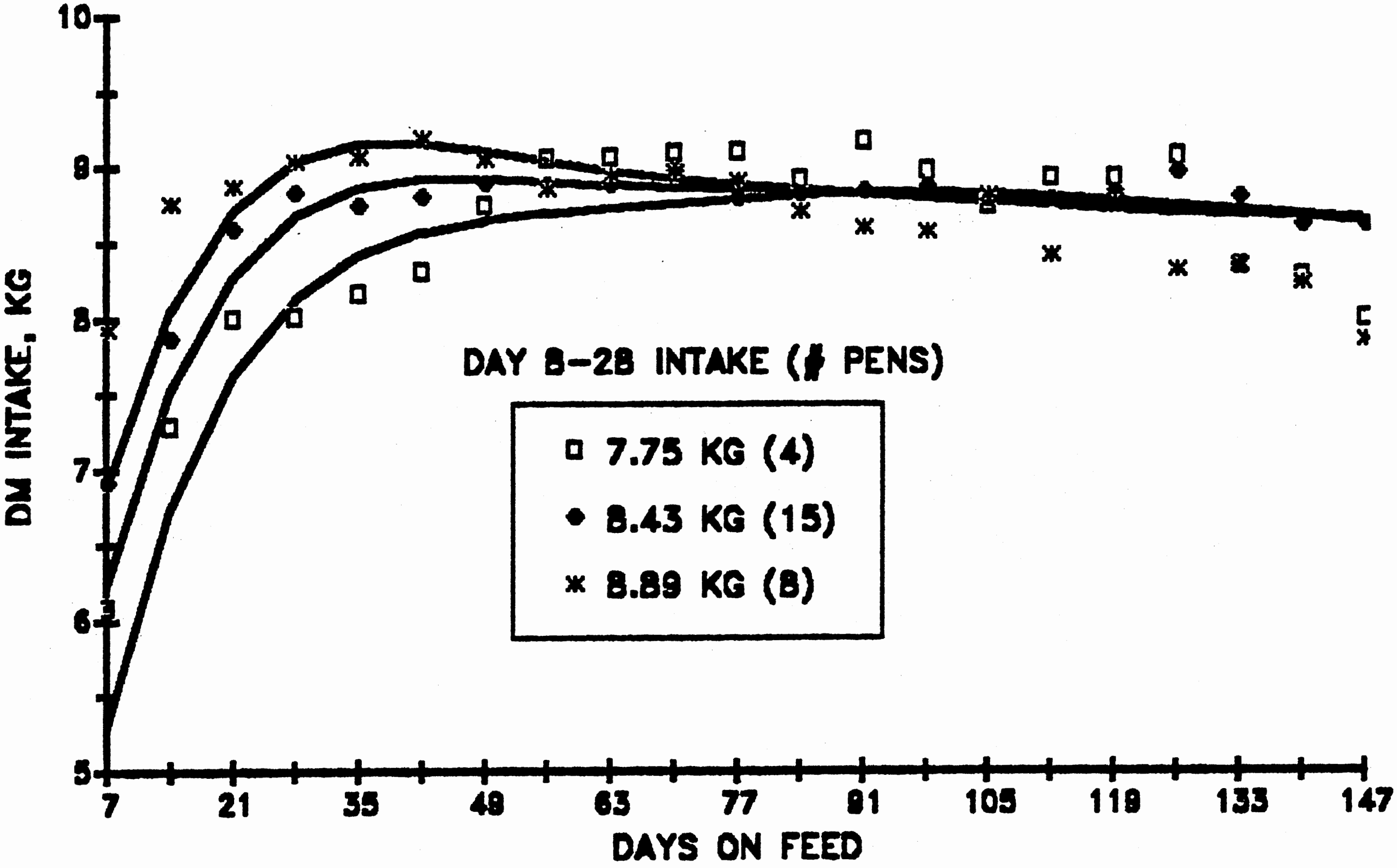

Figure 18. Predicted and Observed Feed Intakes Versus Days on Feed for 273 kg Steers Received May 1 - July 30 Eating Below Average, Average or Above Average Over Days 8-28

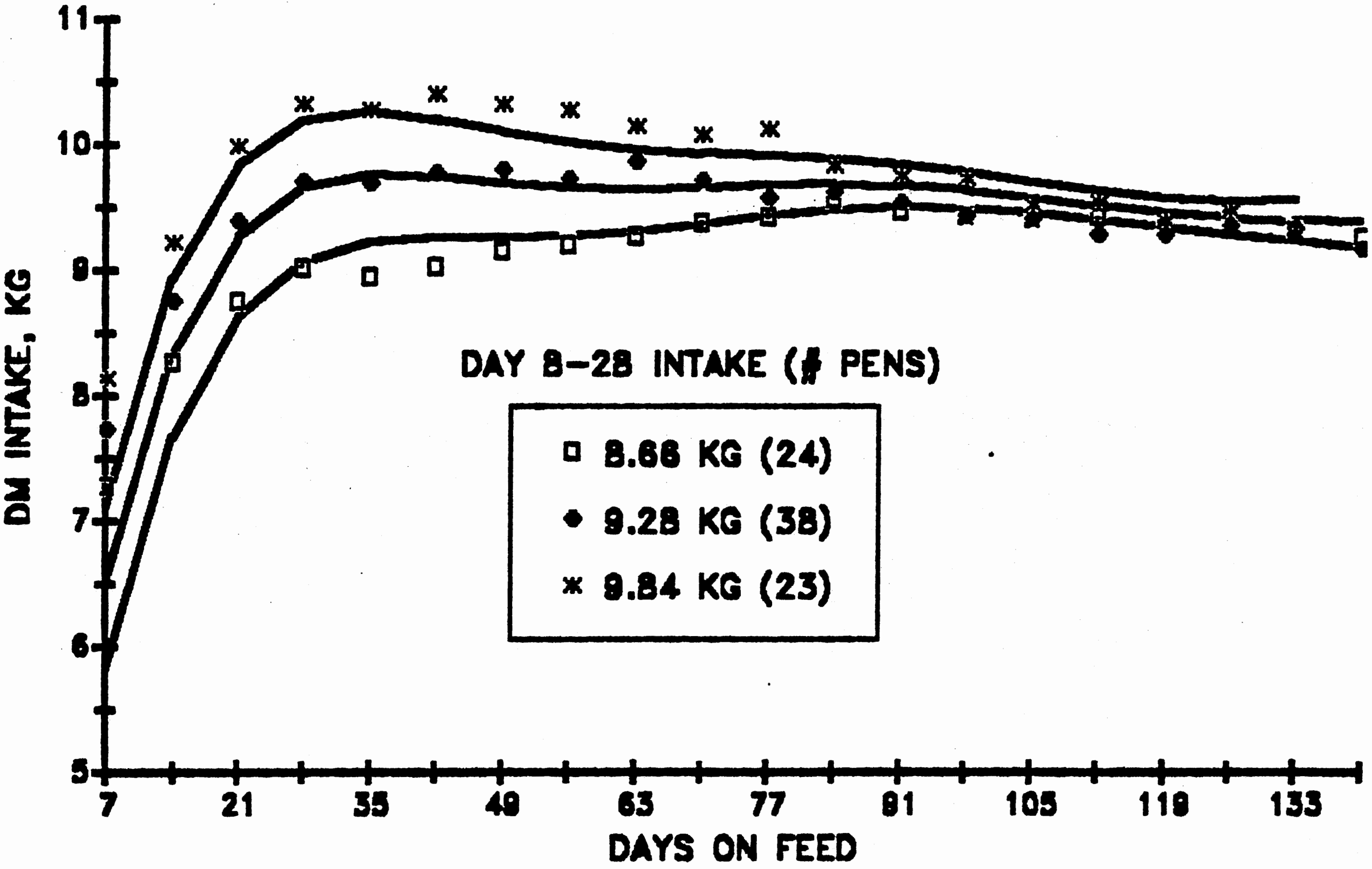

Figure 19. Predicted and Observed Feed Intakes Versus Days on Feed for 318 kg Steers Received May 1 - July 30 Eating Below Average, Average or Above Average Over Days 8-28

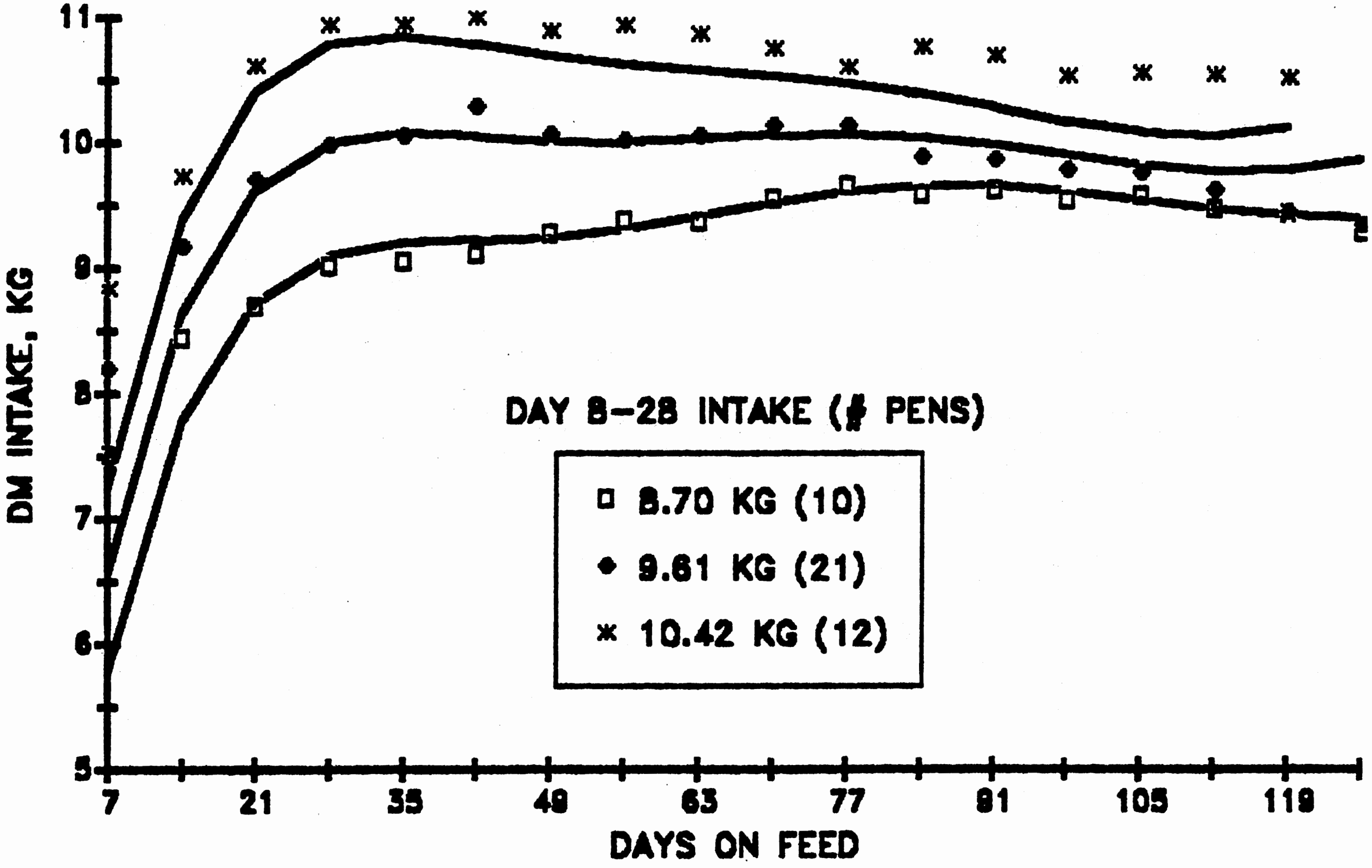

Figure 20. Predicted and Observed Feed Intakes Versus Days on Feed for 364 kg Steers Received May 1 - July 30 Eating Below Average, Average or Above Average Over Days 8-28

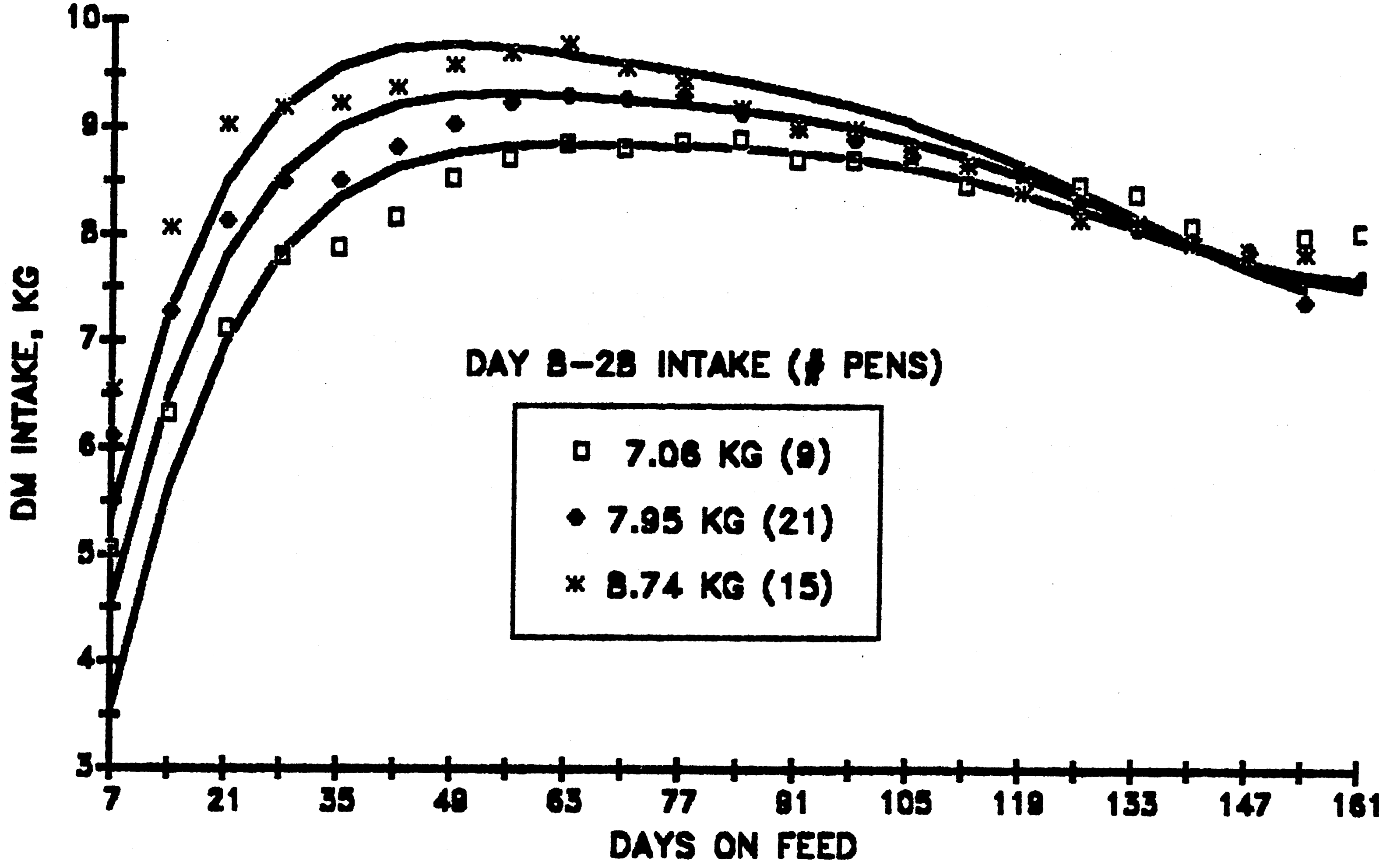

Figure 21. Predicted and Observed Feed Intakes Versus Days on Feed for 273 kg Steers Received July 31 - October 29 Eating Below Average, Average or Above Average Over Days 8-28.

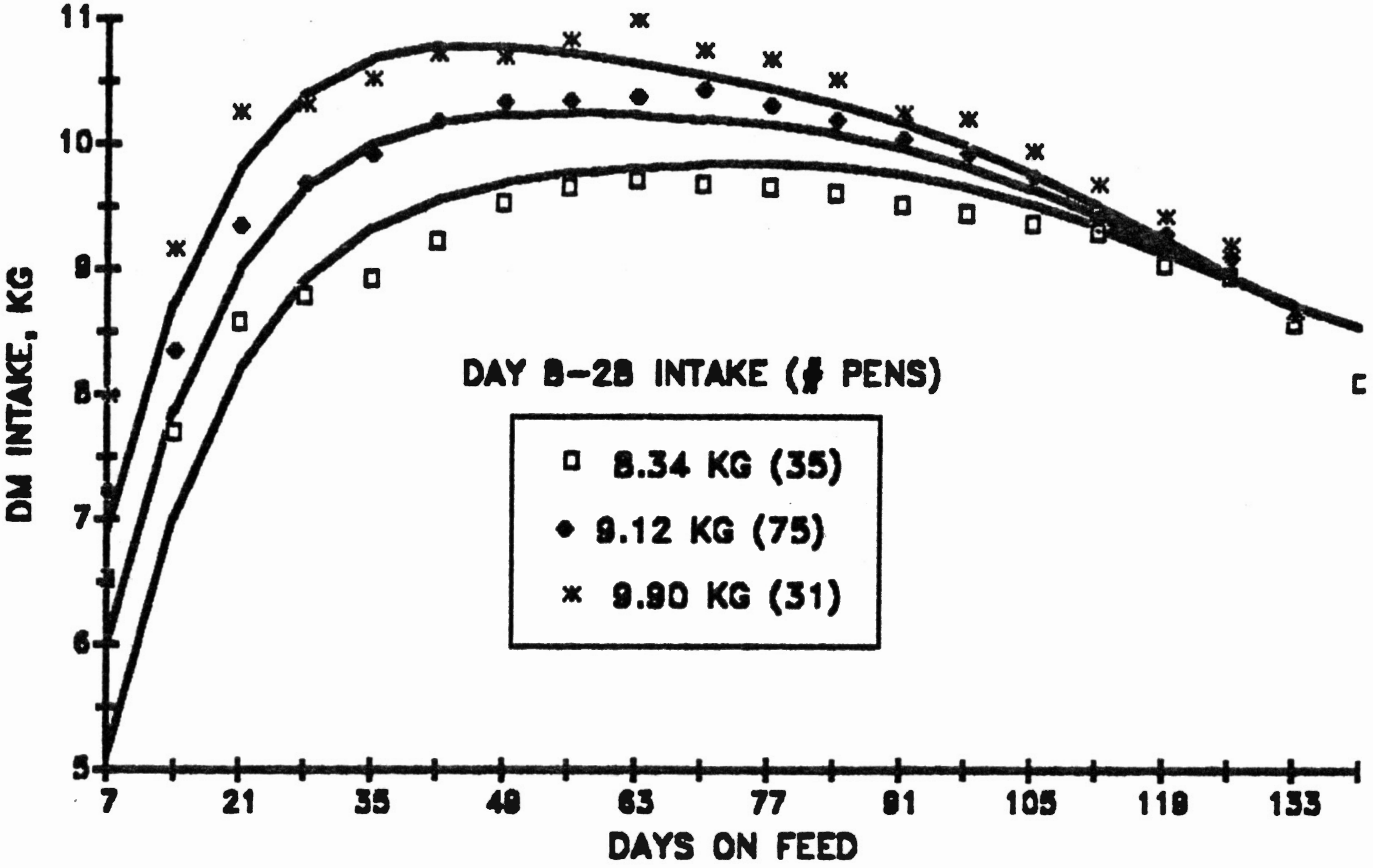

Figure 22. Predicted and Observed Feed Intakes Versus Days on Feed for 318 kg Steers Received July 31 - October 29 Eating Below Average, Average or Above Average Over Days 8-28

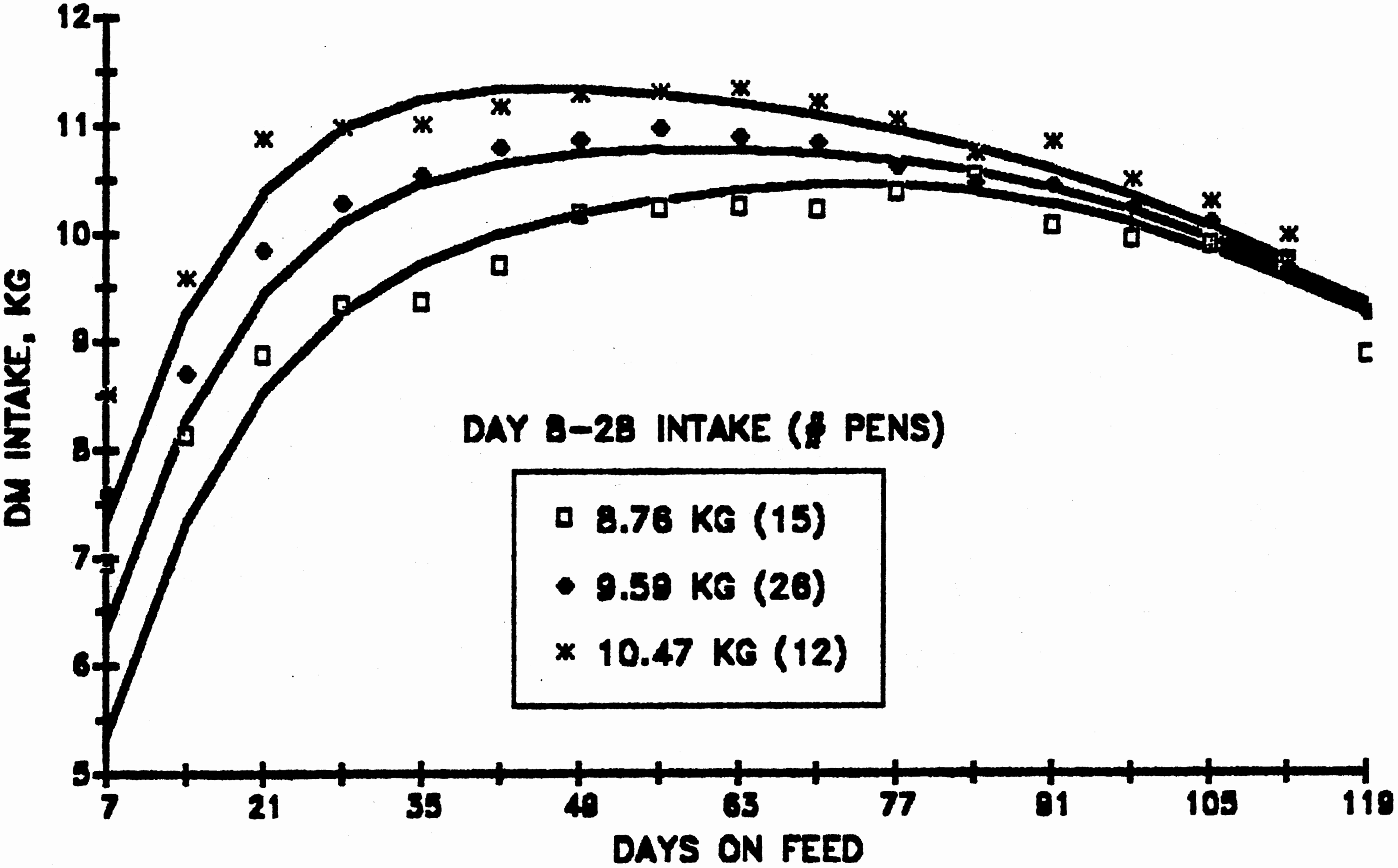

Figure 23. Predicted and Observed Feed Intakes Versus Days on Feed for 364 kg Steers Received July 31 - October 29 Eating Below Average, Average or Above Average Over Days 8-28

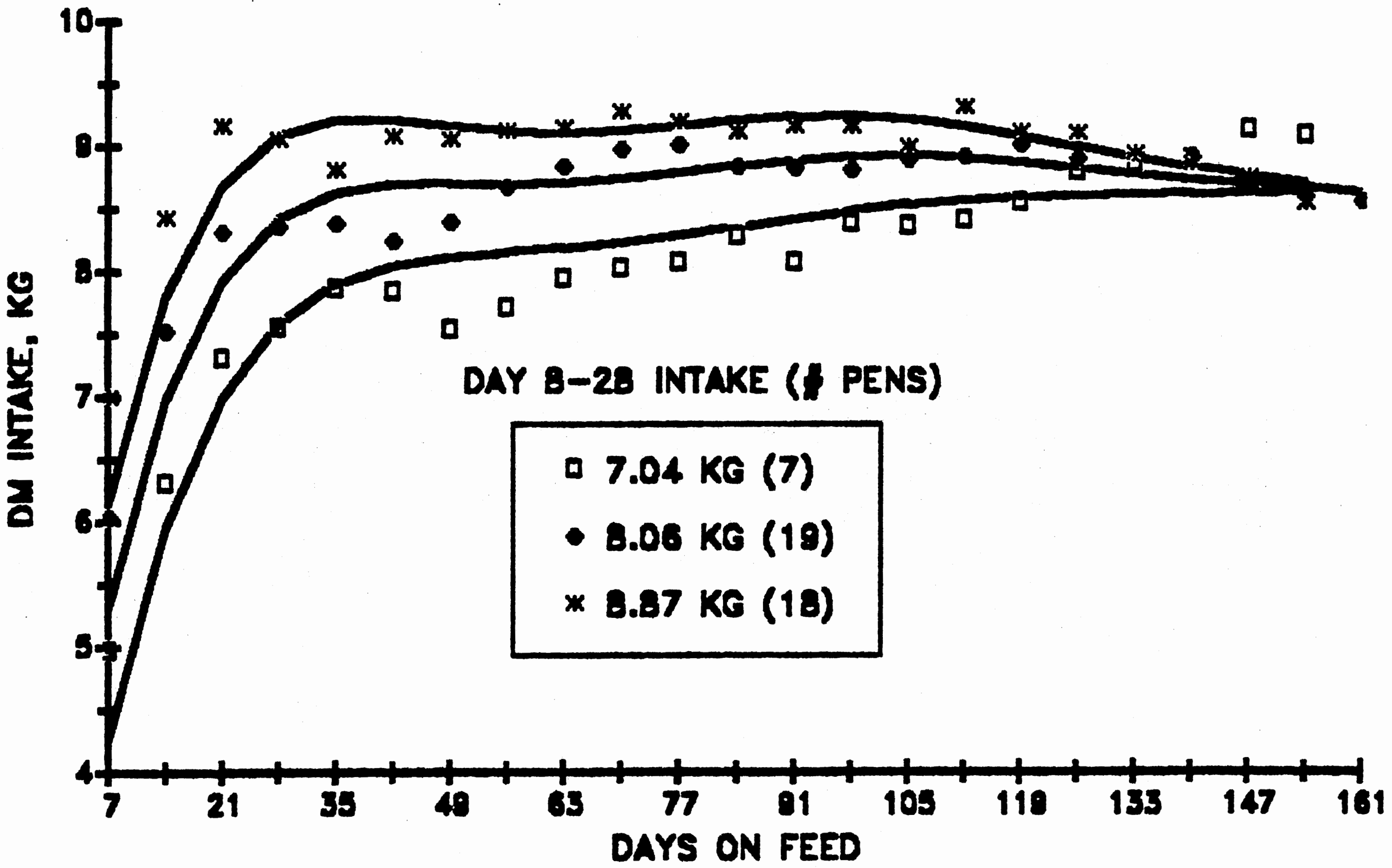

Figure 24. Predicted and Observed Feed Intakes Versus Days on Feed for 273 kg Steers Received October 30 - January 28 Eating Below Average, Average or Above Average Over Days 8-28

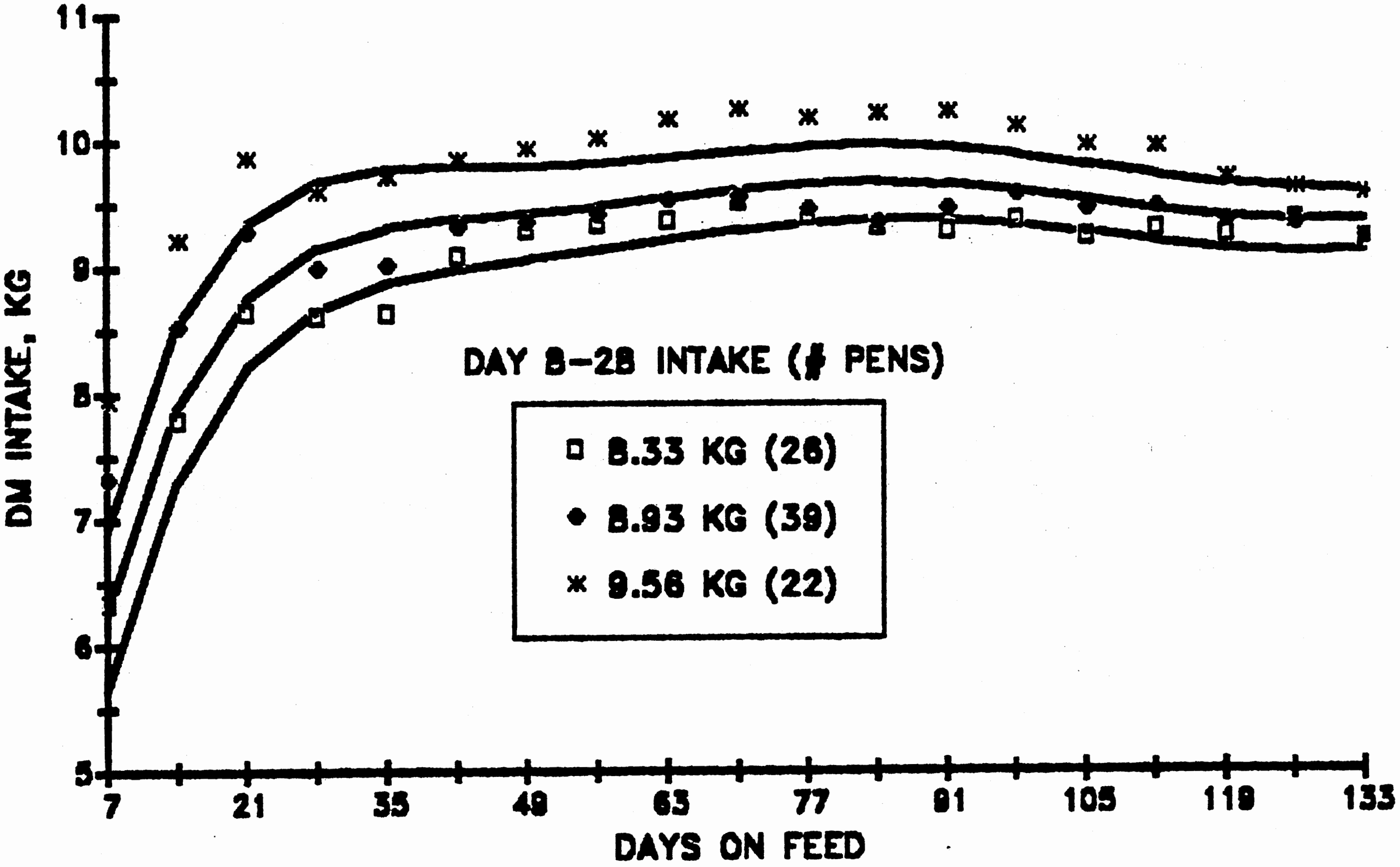

Figure 25. Predicted and Observed Feed Intakes Versus Days on Feed for 318 kg Steers Received October 30 - January 28 Eating Below Average, Average or Above Average Over Days 8-28

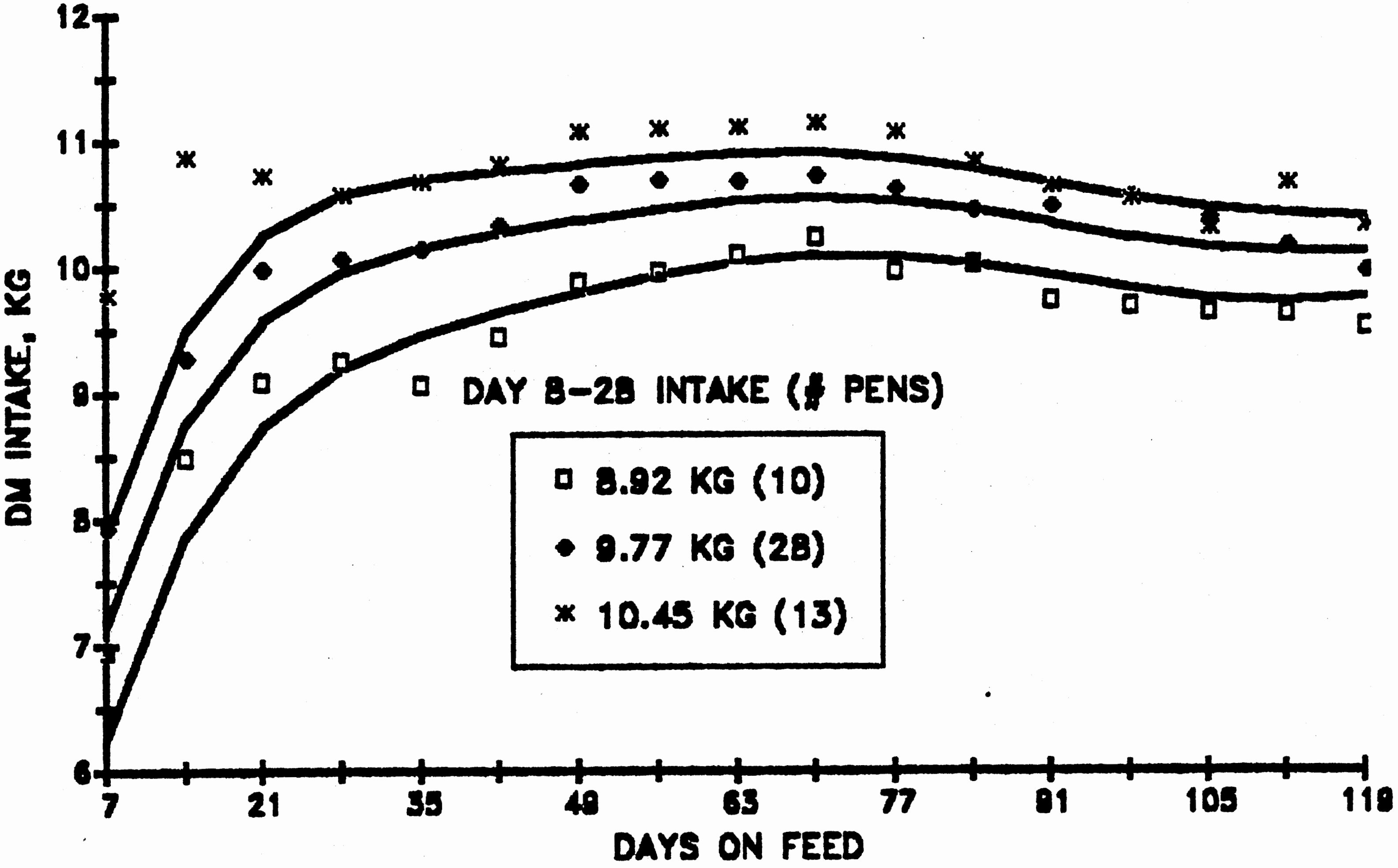

Figure 26. Predicted and Observed Feed Intakes Versus Days on Feed for 364 kg Steers Received October 30 - January 28 Eating Below Average, Average or Above Average Over Days 8-28

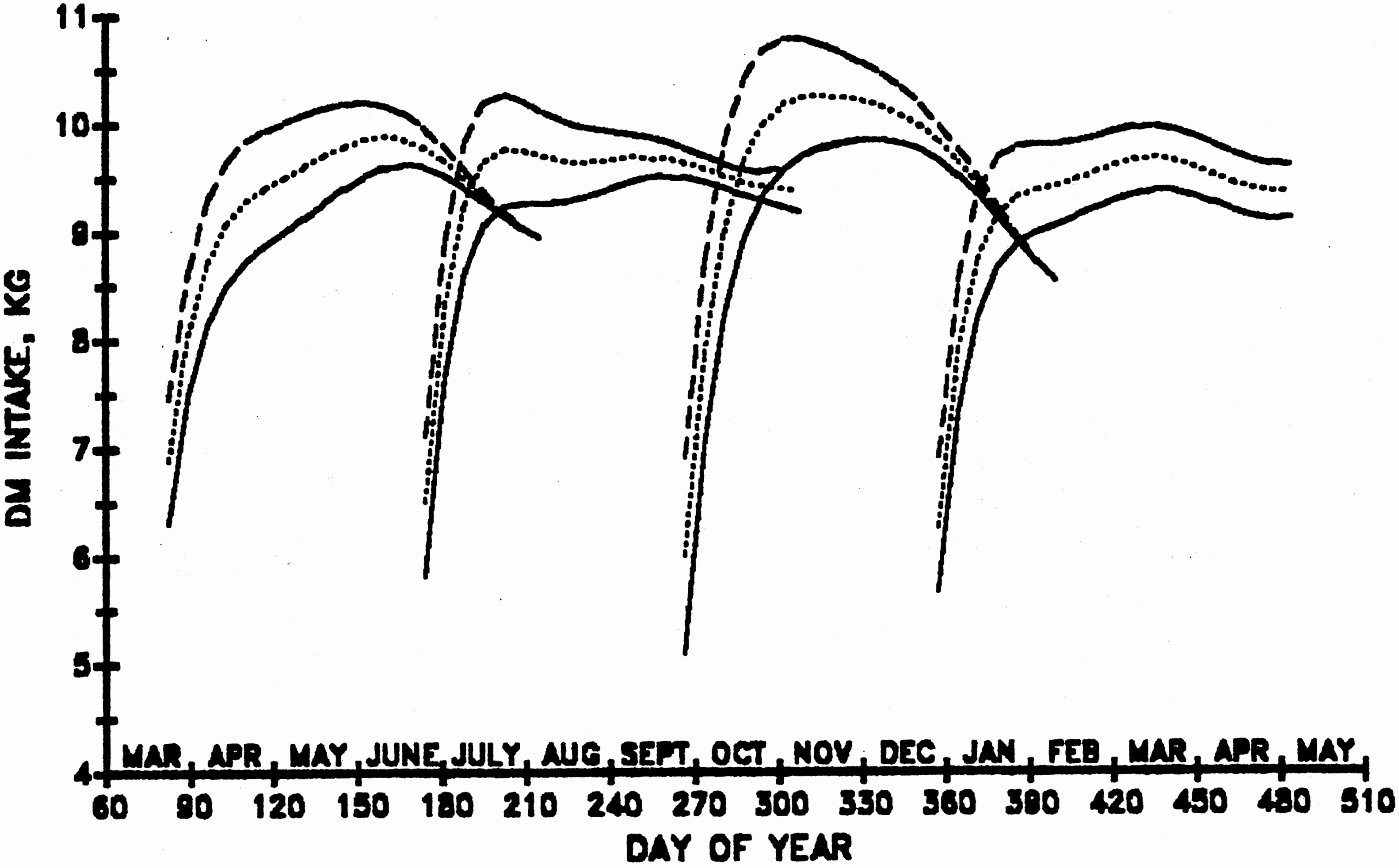

Figure 27. Predicted Feed Intakes Versus Days on Feed Across Seasons for 318 kg Steers Eating Below Average, Average or Above Average Over Days 8-28

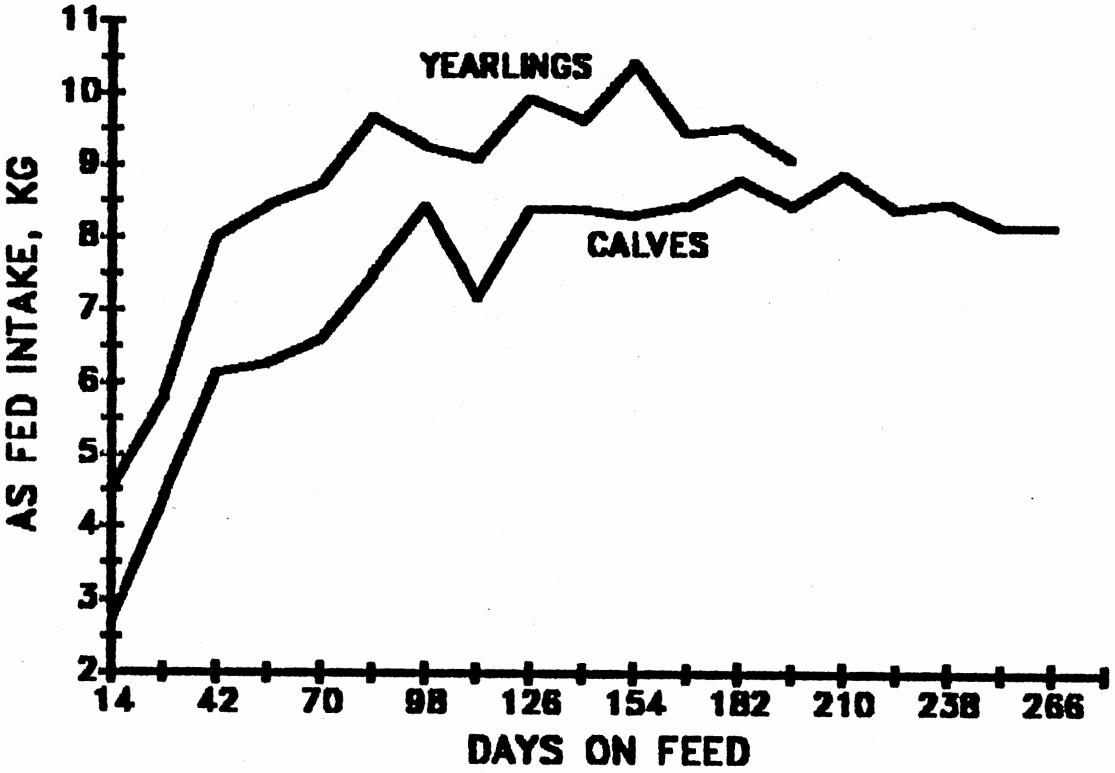

Figure 28. Feed Intake Versus Days on Feed for Calves and Yearlings of Crossbred Breeding from Zinn (1987)

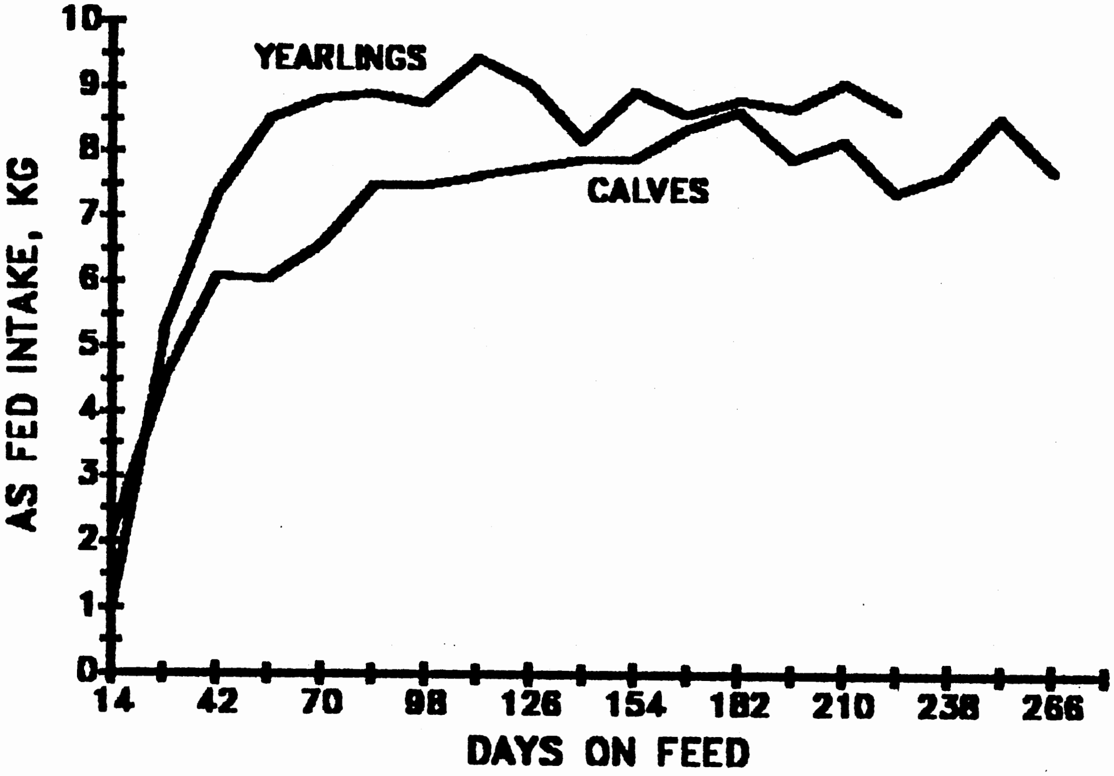

Figure 29. Feed Intake Versus Days on Feed for Calves and Yearlings of Brahman Breeding from Zinn (1987)

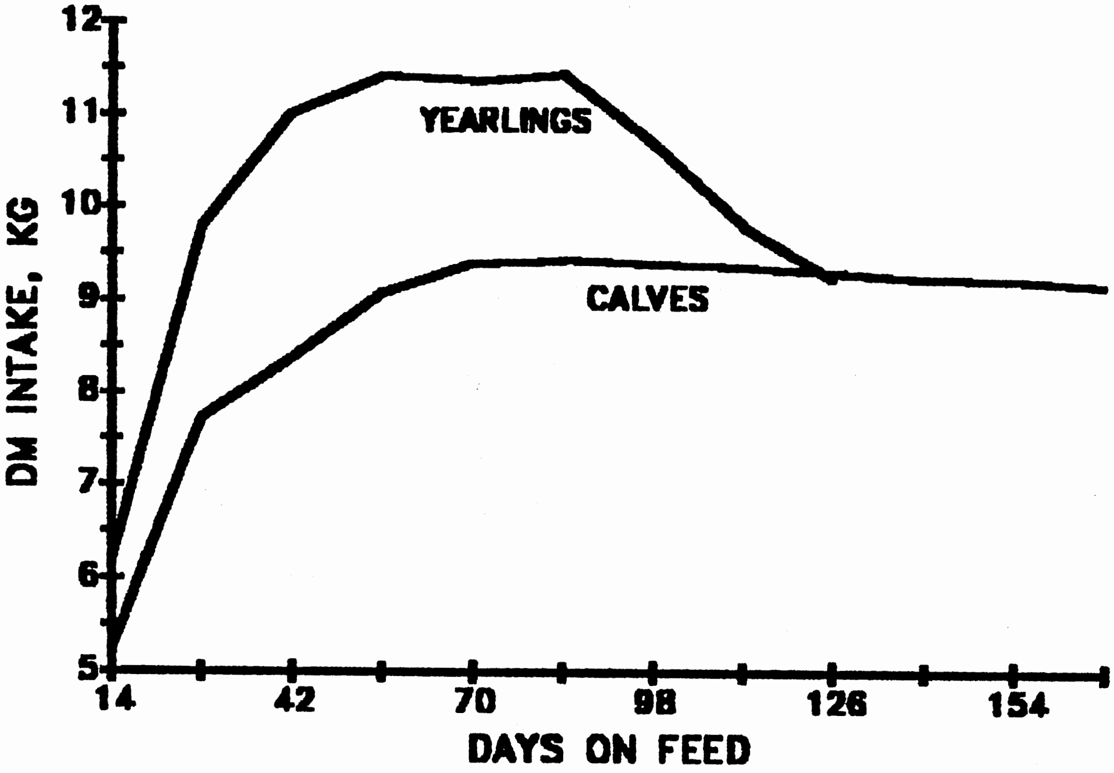

Figure 30. Feed Intake Versus Days on Feed for Calves and Yearling Steers Fed at a Western Kansas Feedyard

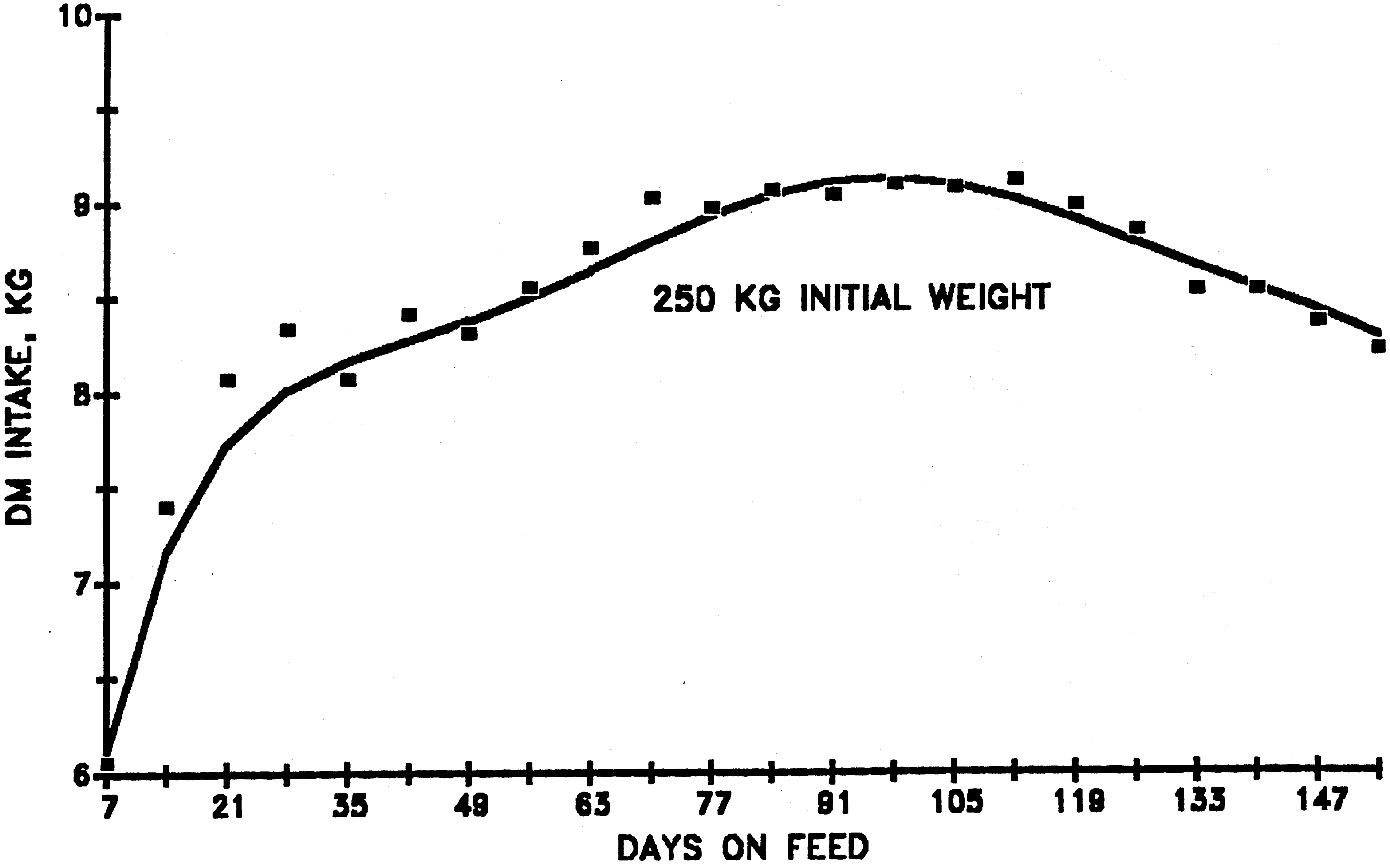

Figure 31. Predicted and Observed Feed Intakes Versus Days on Feed for Steer Calves Received January 29 - April 30

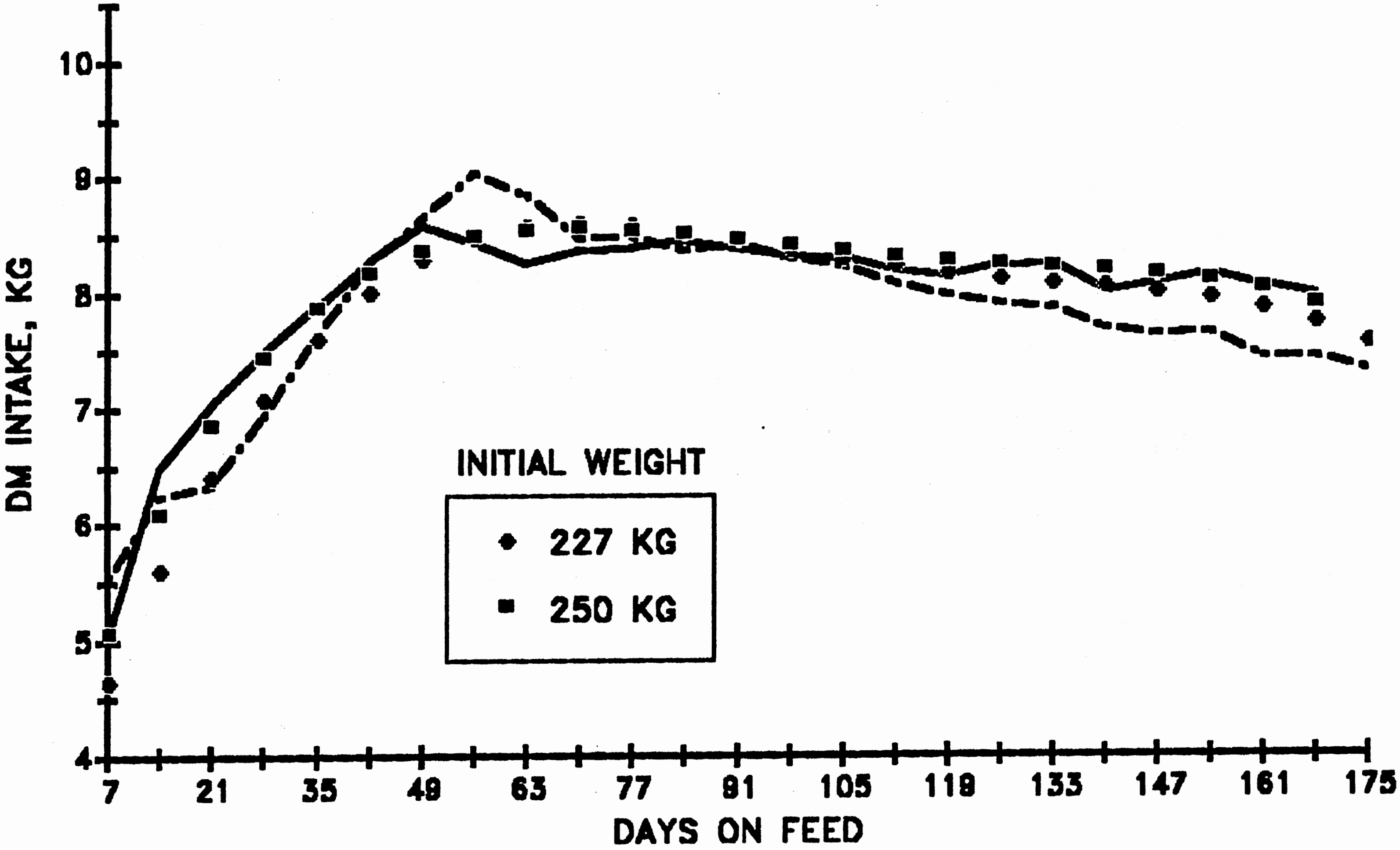

Figure 32. Predicted and Observed Feed Intakes Versus Days on Feed for Steer Calves Received May 1 - July 30

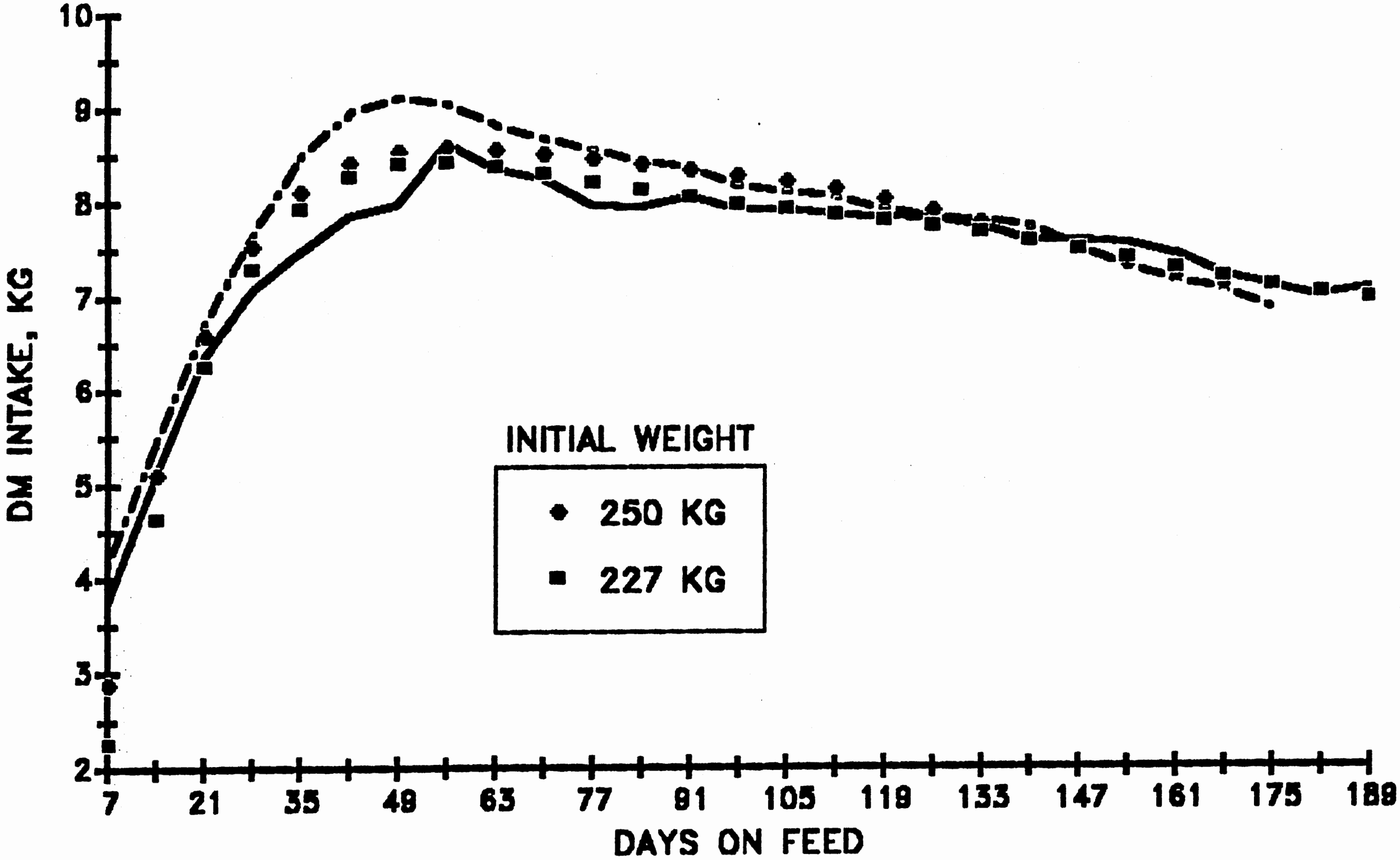

Figure 33. Predicted and Observed Feed Intakes Versus Days on Feed for Steer Calves Received July 31 - October 29

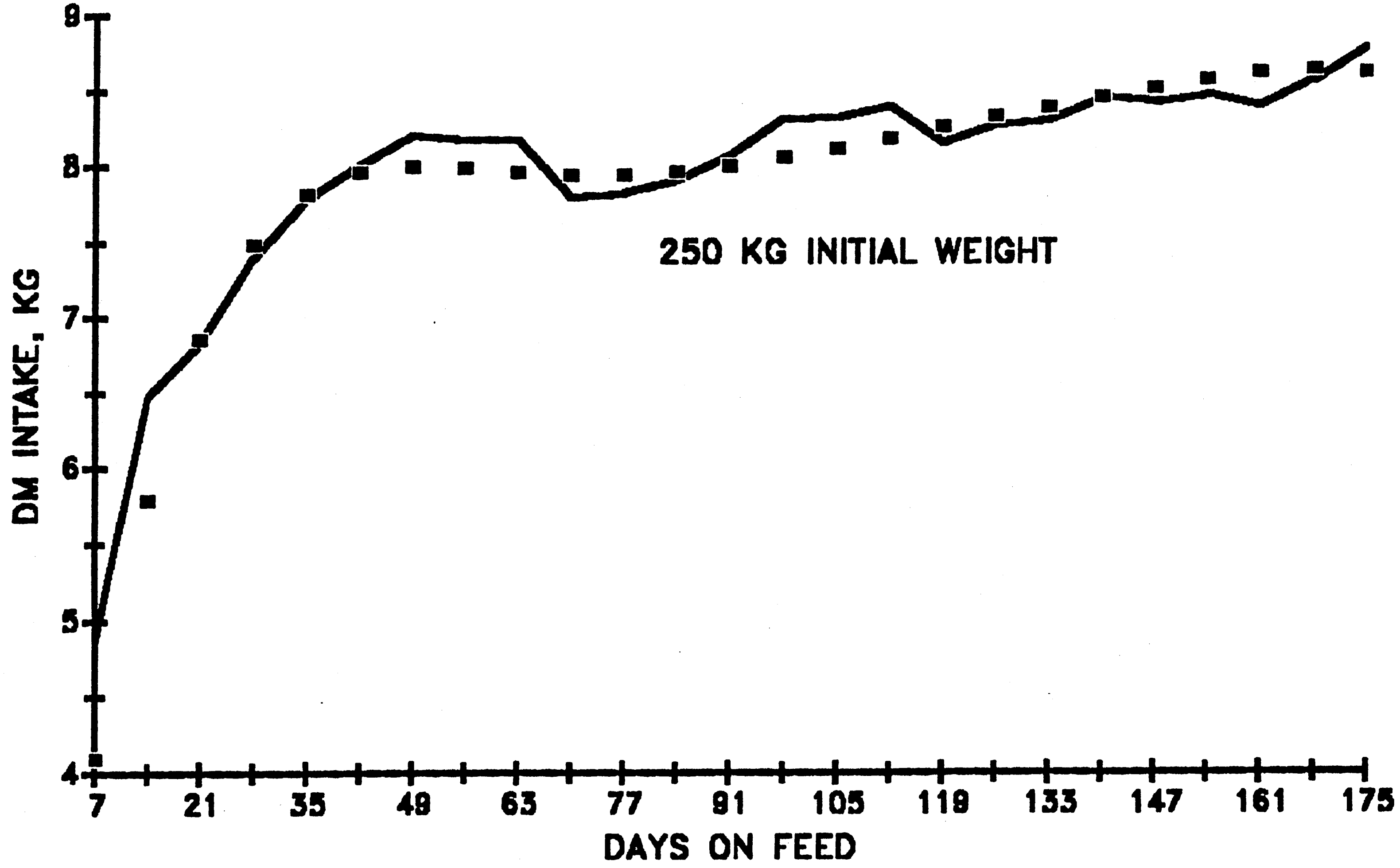

Figure 34. Predicted and Observed Feed Intakes Versus Days on Feed for Steer Calves Received October 30 - January 28

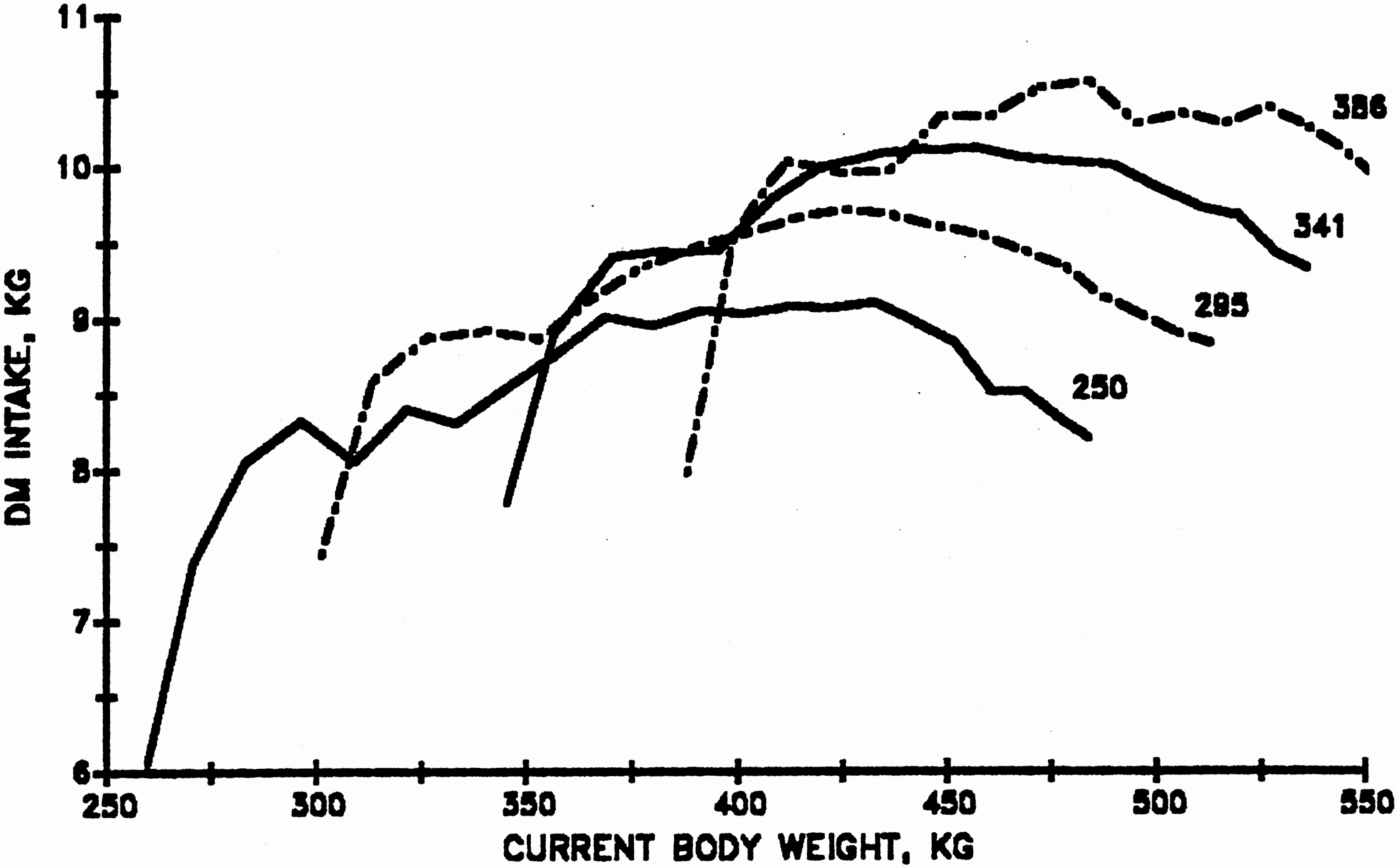

Figure 35. Feed Intake Versus Current Body Weight for Steers Received January 29 - April 30 with Different Initial Weights

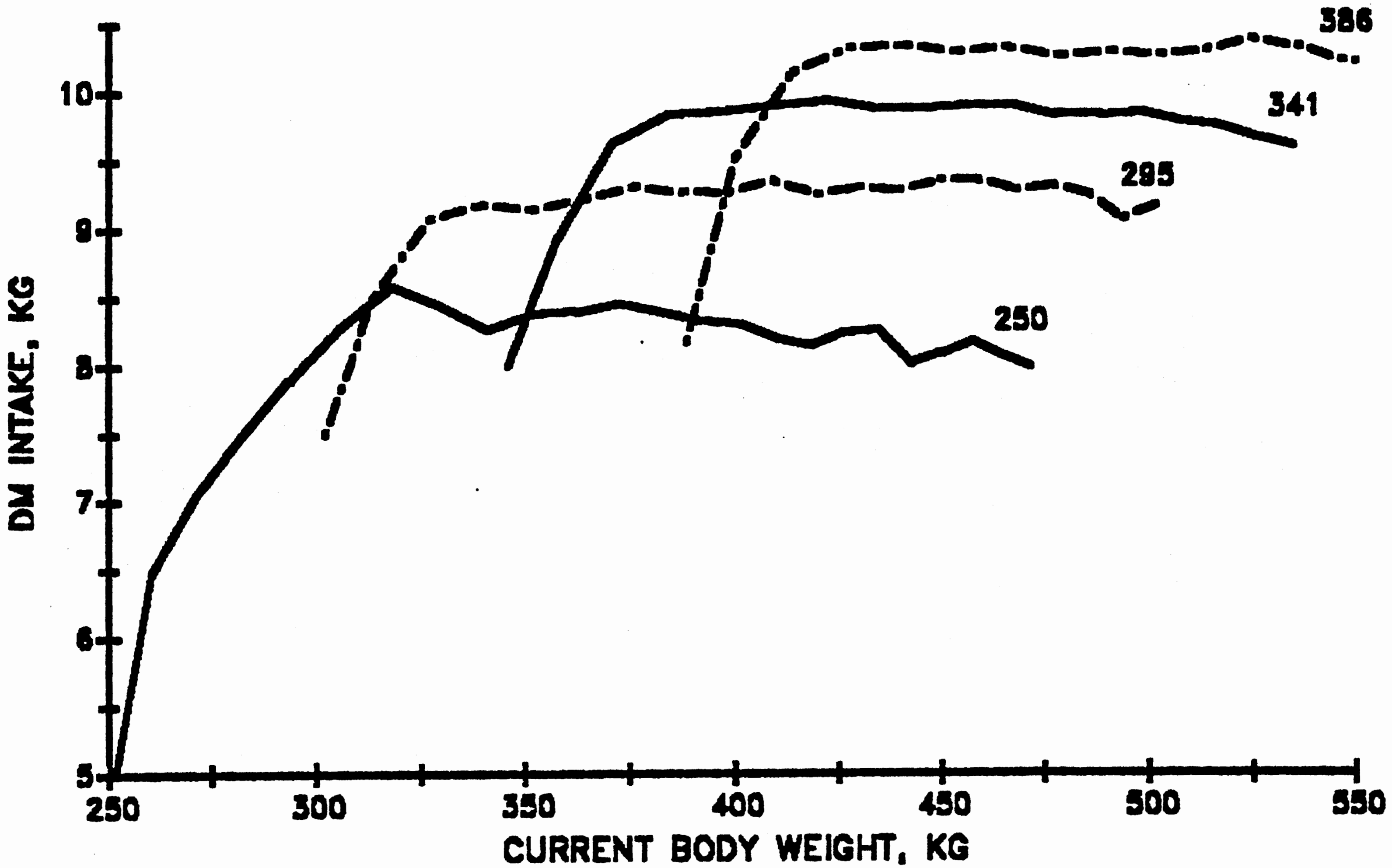

Figure 36. Feed Intake Versus Current Body Weight for Steers Received May 1 - July 30 with Different Initial Weights

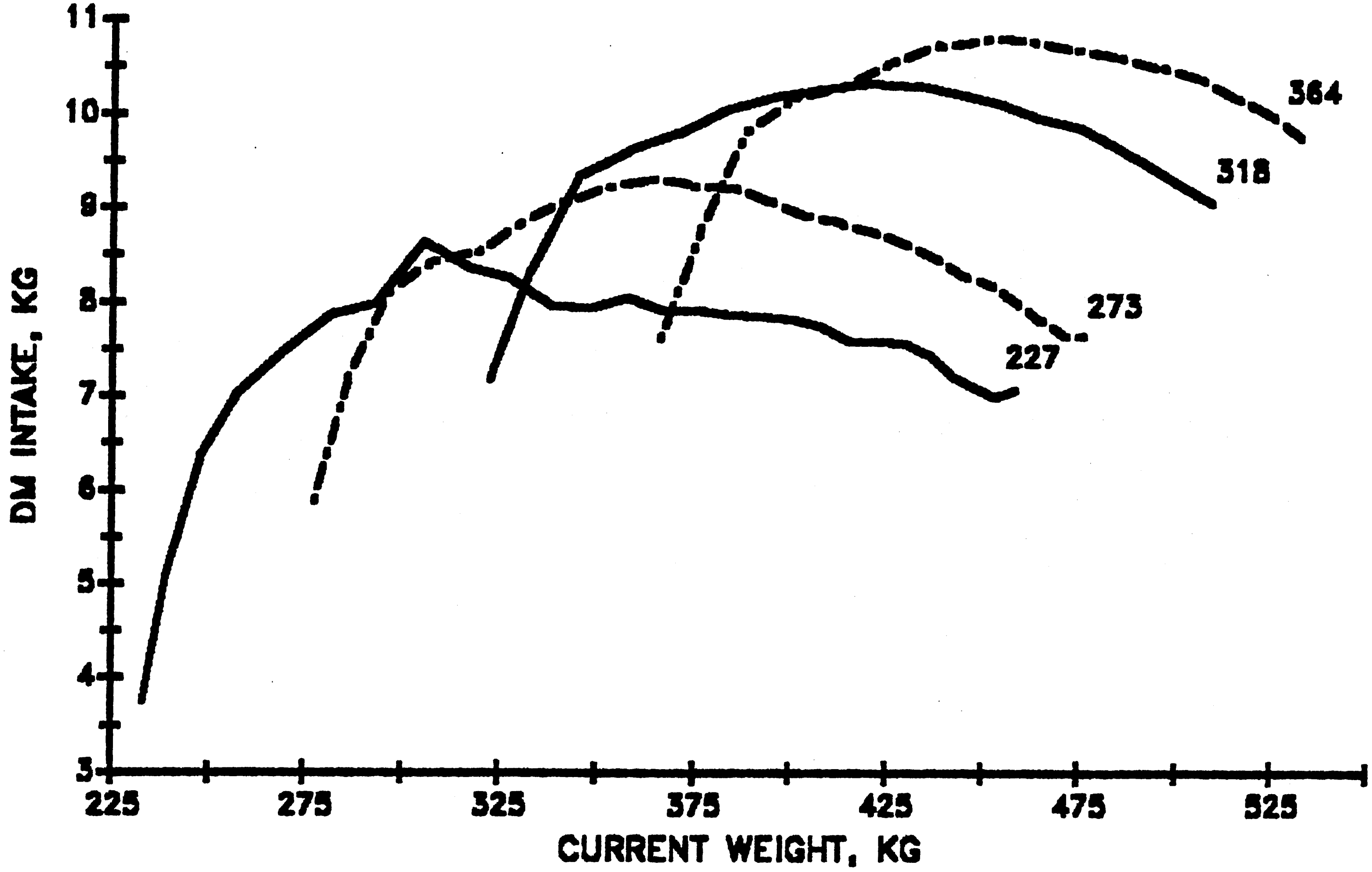

Figure 37. Feed Intake Versus Current Body Weight for Steers Received July 31 - October 29 with Different Initial Weights

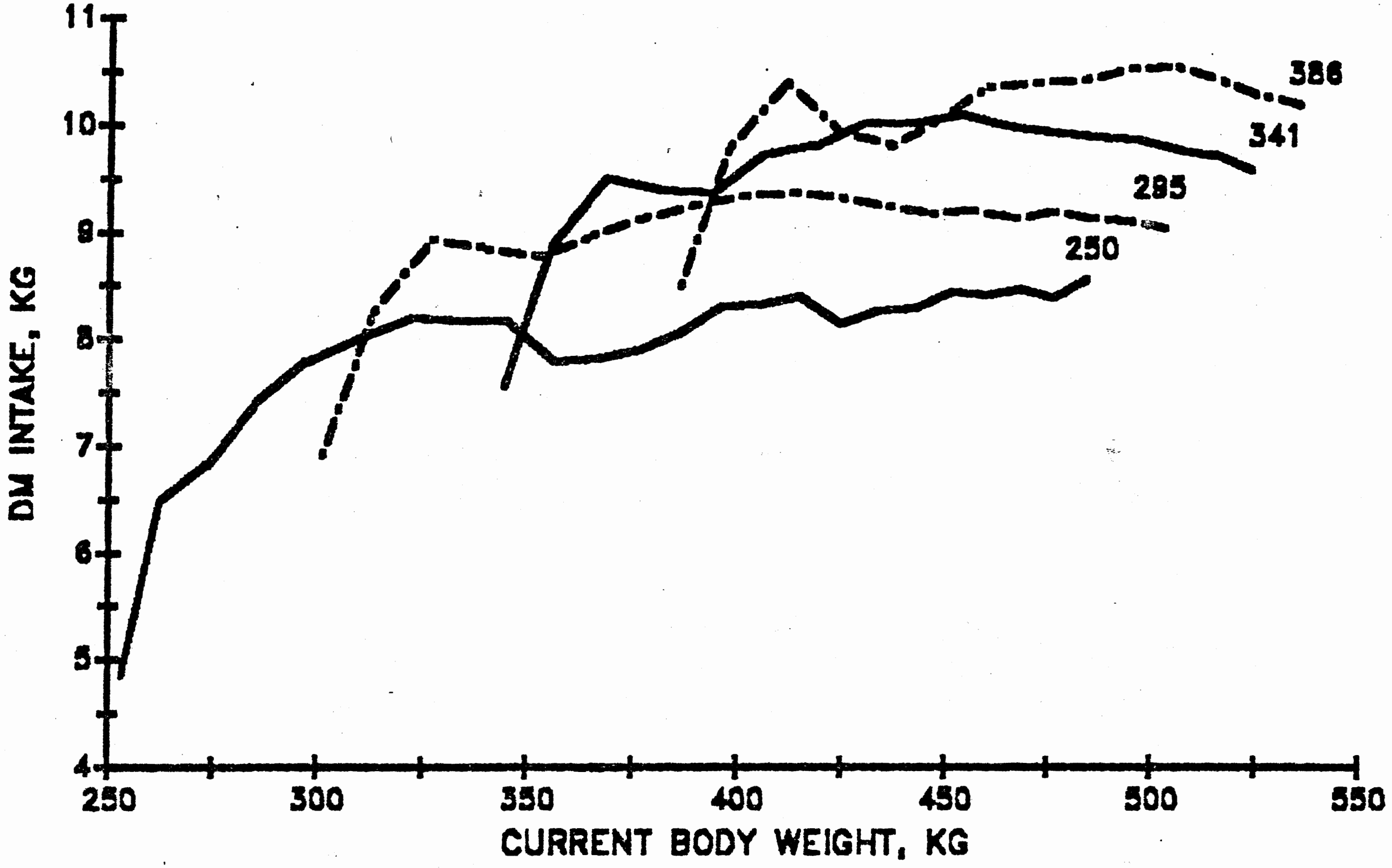

Figure 38. Feed Intake Versus Current Body Weight for Steers Received October 30 - January 28 with Different Initial Weights

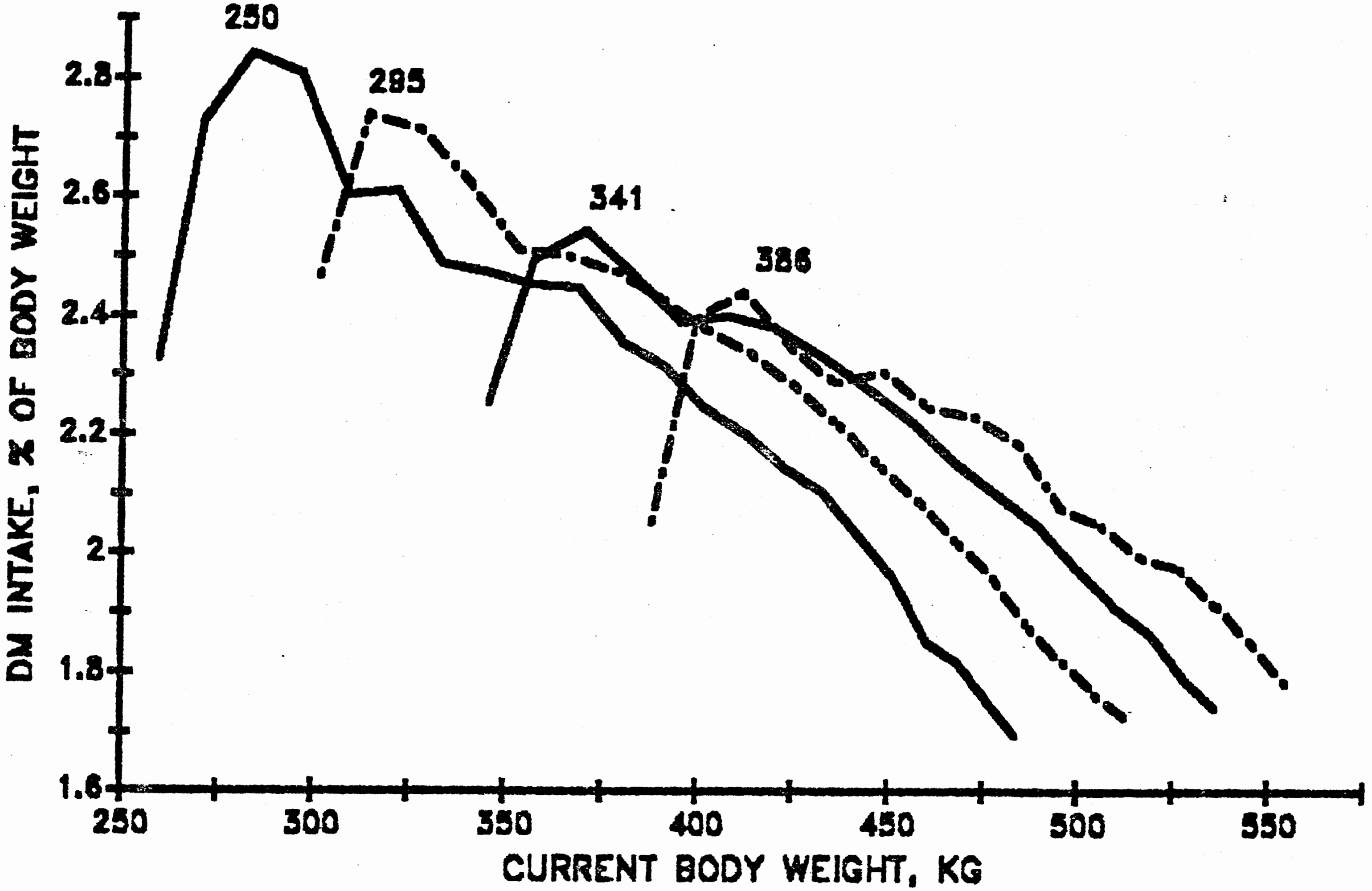

Figure 39. Feed Intake Expressed as a Percentage of Weight Versus Current Body Weight for Steers Received January 29 - April 30 with Different Initial Weights

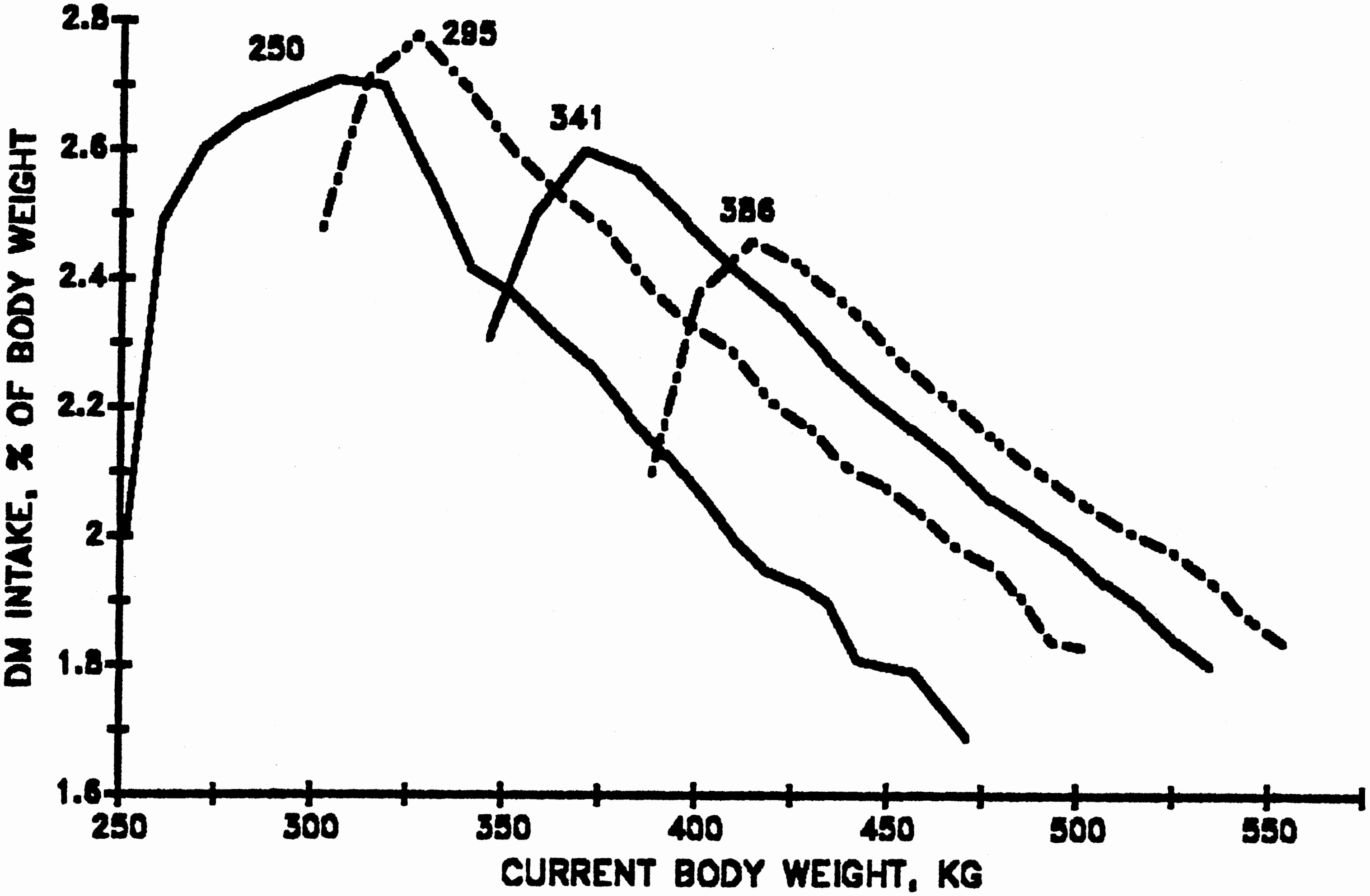

Figure 40. Feed Intake Expressed as a Percentage of Weight Versus Current Body Weight for Steers Received May 1 - July 30 with Different Initial Weights

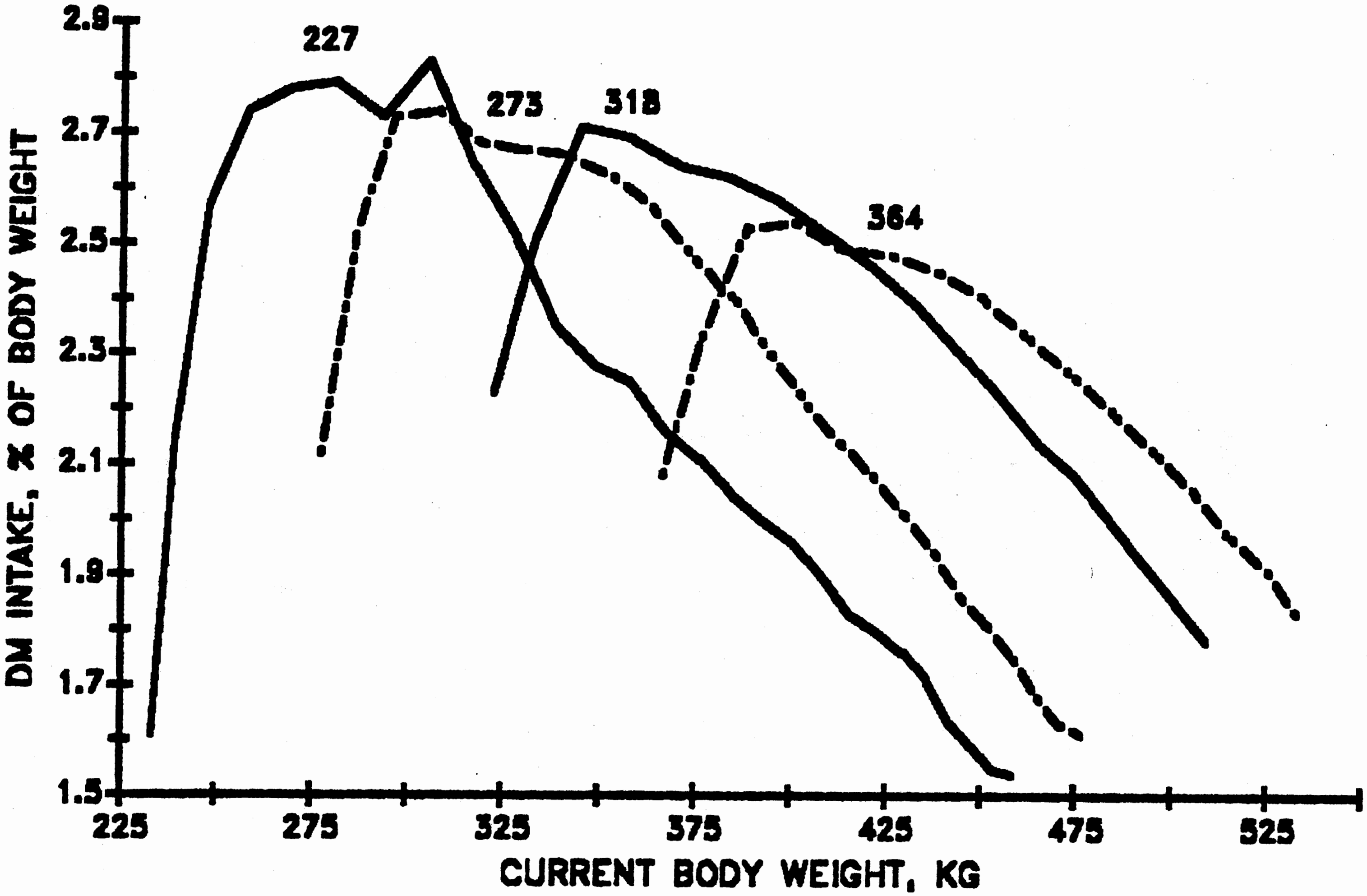

Figure 41. Feed Intake Expressed as a Percentage of Weight Versus Current Body Weight for Steers Received July 31 - October 29 with Different Initial Weights

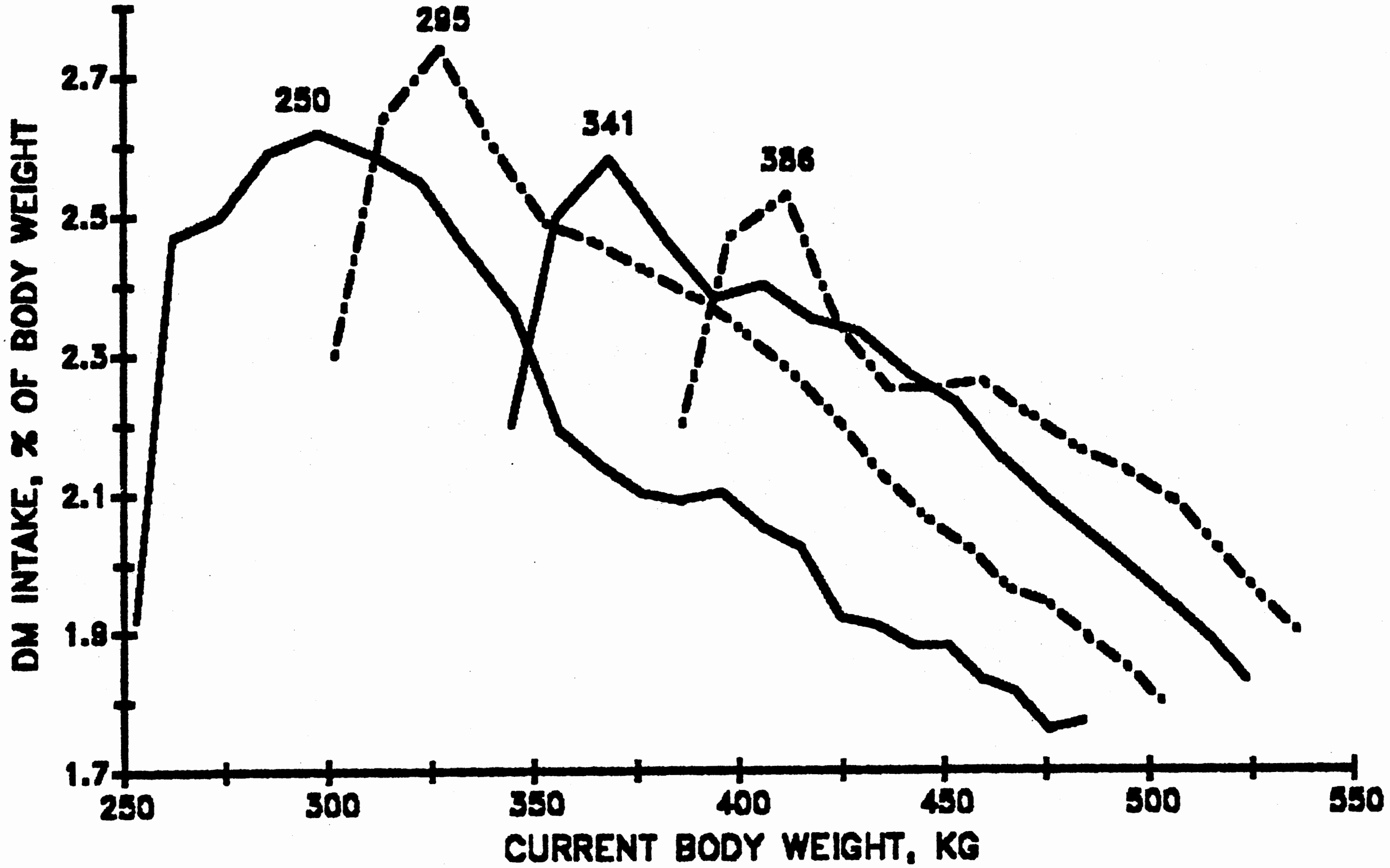

Figure 42. Feed Intake Expressed as a Percentage of Weight Versus Current Body Weight for Steers Received October 30 - January 28 with Different Initial Weights

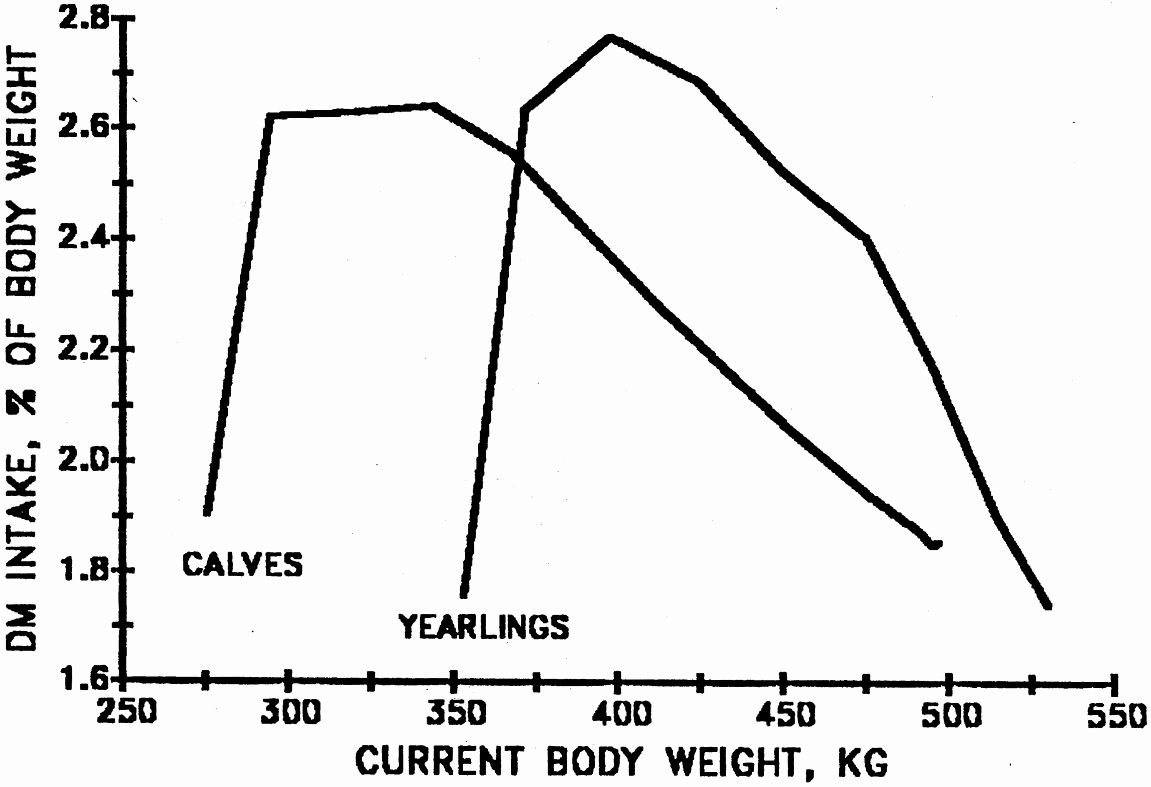

Figure 43. Feed Intake Expressed as a Percentage of Weight Versus Current Body Weight for Calves and Yearling Steers Fed a Western Kansas Feedyard

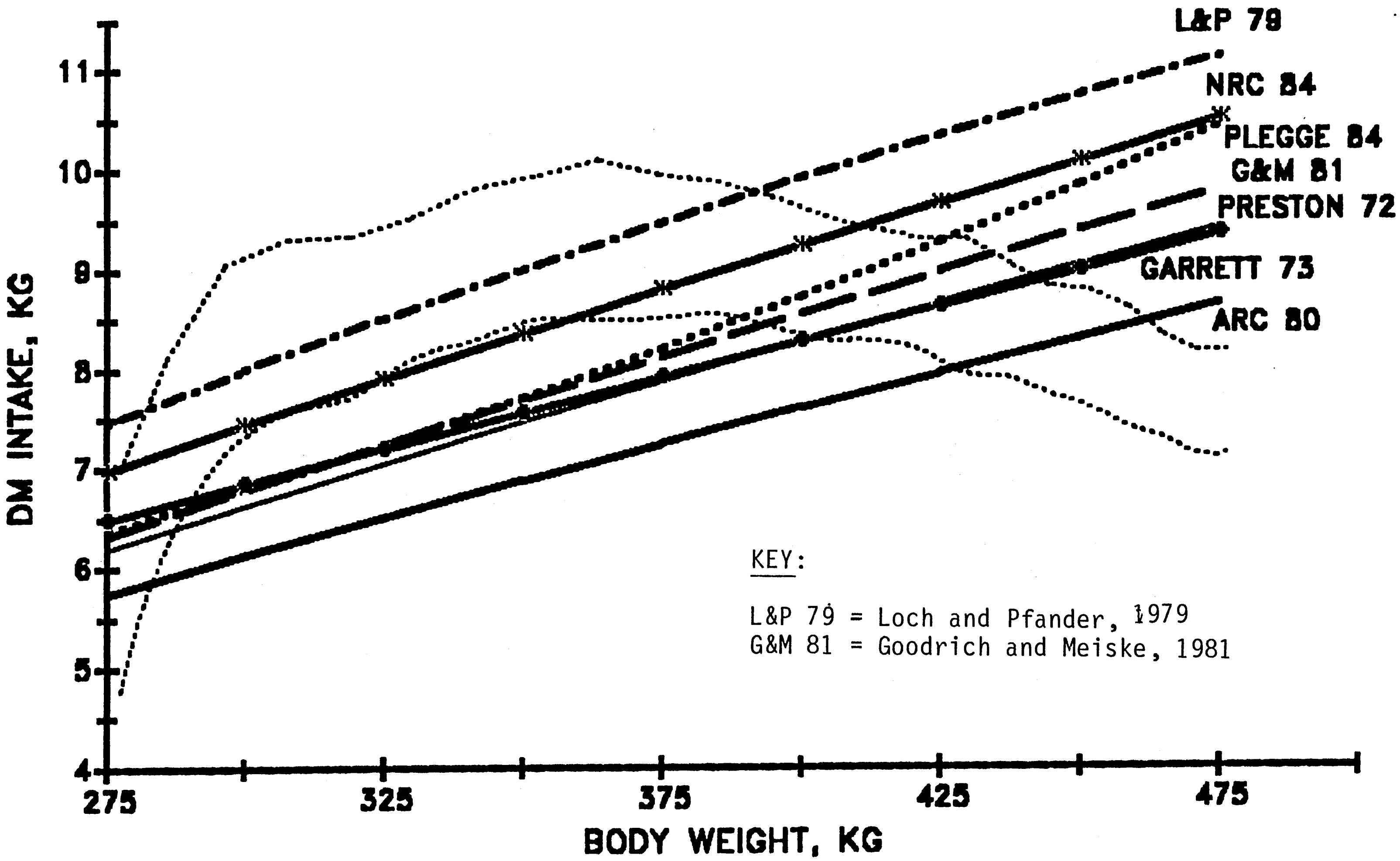

Figure 44. Predicted Dry Matter Intakes of Feedlot Steers Using Equations Based on Average Intakes Versus Observed Intakes for 273 kg Steers Received July 31 - October 29

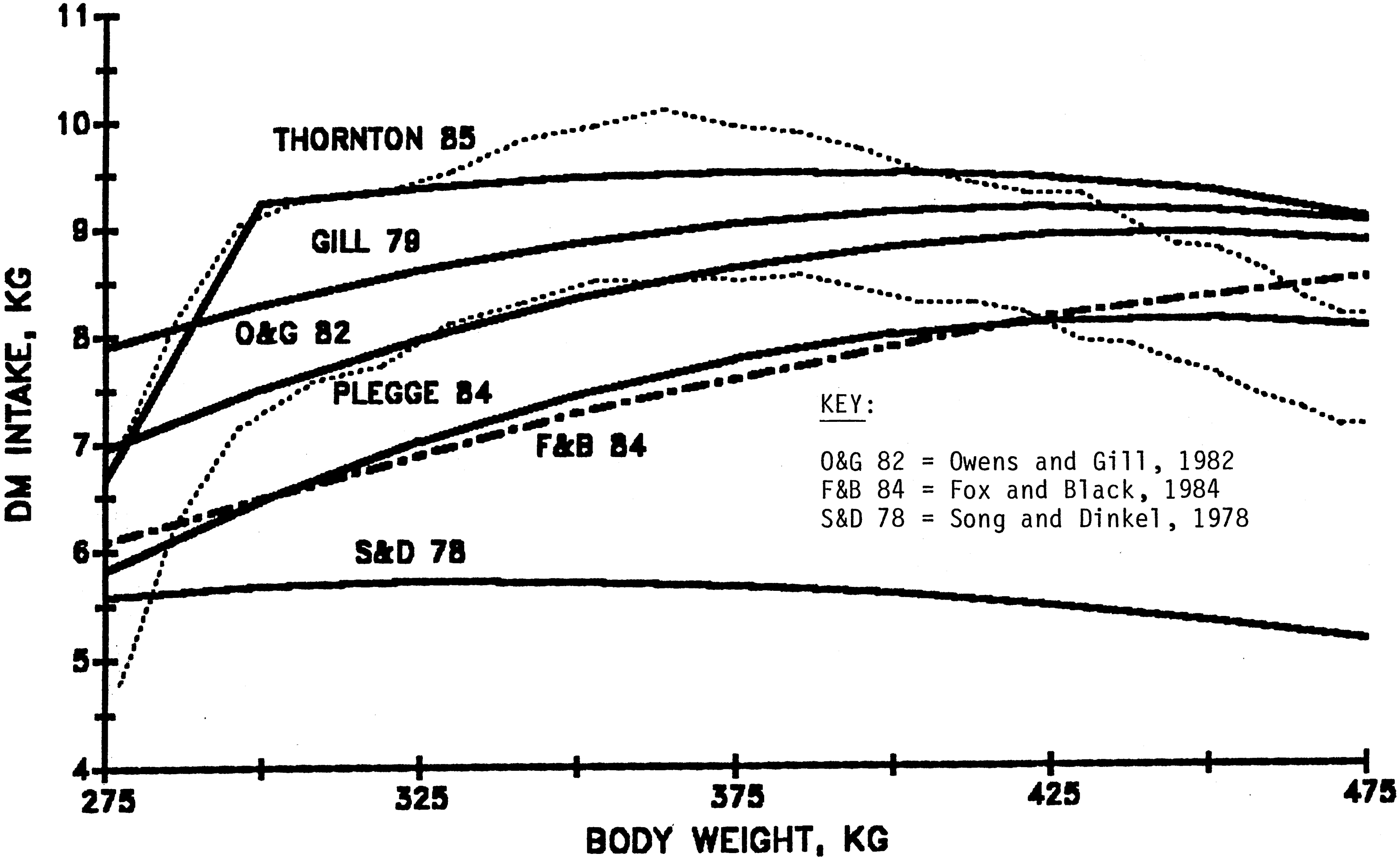

Figure 45. Predicted Dry Matter Intakes of Feedlot Steers Using Equations Based on Interval Intakes Versus Observed Intakes for 273 kg Steers Received July 31 - October 29

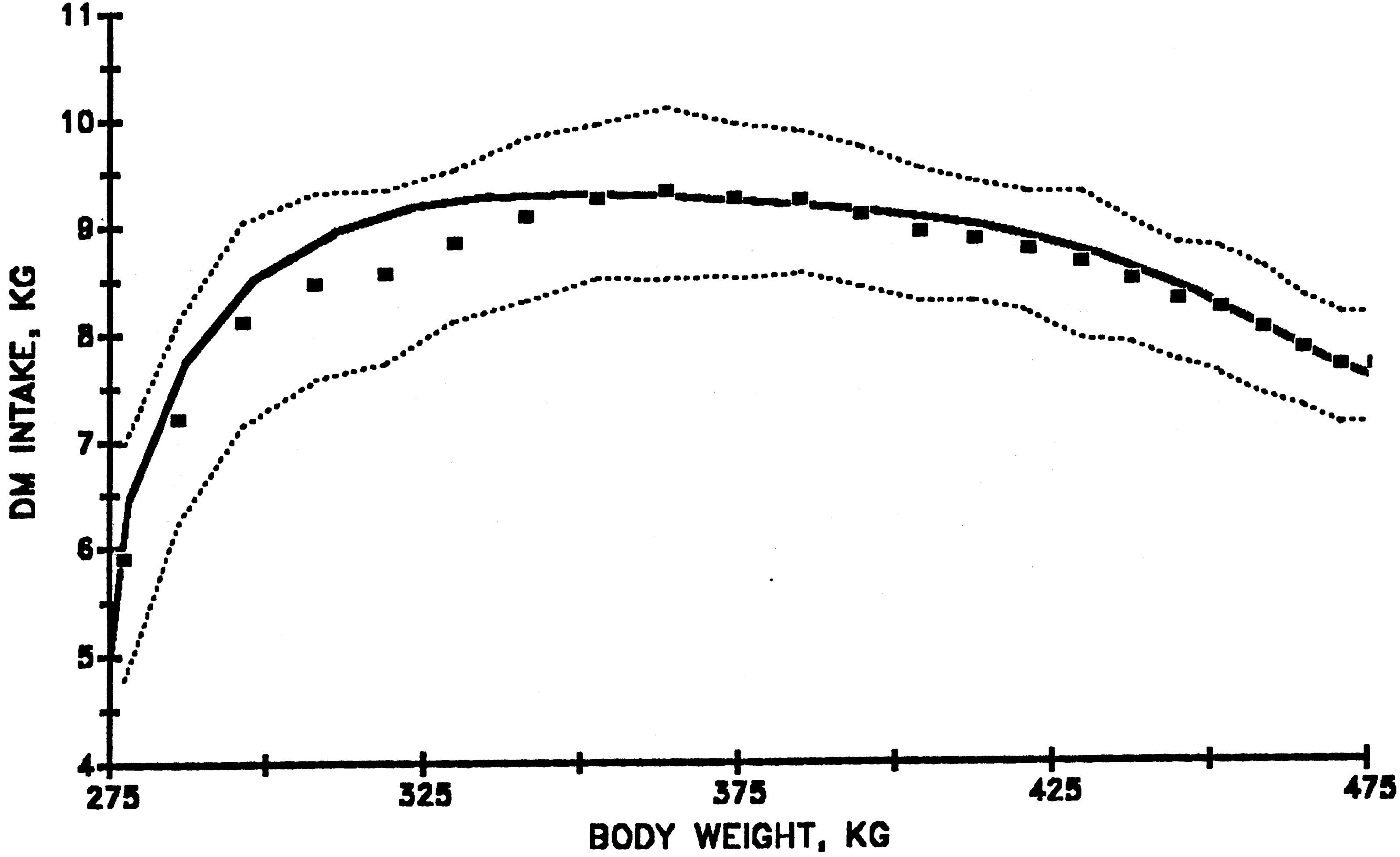

Figure 46. Predicted Feed Intake Versus the Observed Range of Intakes for 273 kg Steers Received July 31 - October 29

CHAPTER IV

DRY MATTER INTAKE BY FEEDLOT CATTLE: INFLUENCE OF BREED AND SEX

Summary

Feed intake records from a large commercial feedlot were analyzed to determine the feed intake differences attributable to sex and breed type. Information was available for dry matter intake of a high concentrate feedlot diet at 7-day intervals from 178 pens of beef heifers and 153 pens of Holstein steers from a three year period (1983-1985). Pens held a mean of 118 beef heifers per pen and 115 Holstein steers per pen for totals of 20,979 and 17,635 cattle. Feed intake averaged about 2% less for beef heifers than for beef steers of equal initial weight. Feed intake by Holstein steers was about 12% greater than that for beef steers of equal initial weight. For analysis, the data for both heifers and Holstein steers was divided by date of entry into the feedlot into the following four seasons: January 29 - April 30 (winter wheat pasture cattle), May 1 - July 30 (graze-out wheat pasture and early intensive gazing program cattle), July 31 - October 29 (grass pasture cattle) and October 30 - January 28 (grass pasture cattle). Beef steers and heifers and Holstein steers exhibited similar seasonal intake patterns. Dry matter intake prediction equations were developed for each season which included initial weight, days on feed and 8 to 28 day mean intake as input variables (R^2=.68 to .80 for heifers; R^2=.73 to

.85 for Holstein steers). By including mean intake from day 8 to 28 as an input variable, accuracy of prediction was increased (R^2 increased by .08 to .15 units in heifers and by .07 to .20 units in Holsteins). Including such data allowed feed intake predictions to be customized for an individual pen and should improve accuracy of gain projections.

(Key Words: Feedlot, Beef heifers, Holstein steers, Feed Intake)

Introduction

Cattle fed in feedlots of the Great Plains vary in breed type and sex with economic conditions. Certain types are more desirable at specific cattle prices. Because DMI (dry matter intake) is the basis on which nutrient requirements, gain and profit all are calculated, it is important that DMI prediction equations adjust for differences due to breed type or gender.

Studies have shown that cattle of different gender (steer, heifer or bull) differ in the weight at which they reach a given degree of carcass and intramuscular fatness (Harpster et al., 1978; Fortin et al., 1980). Thus, the body weight at which DMI begins to decline would be expected to differ. Owens et al. (1985) observed that DMI of beef steers and heifers in a large commercial feedlot were similar when compared at the same liveweights. These workers also noted that DMI tended to peak earlier in the feeding period for heifers (at 28 days) than for steers (at 70 days) and the decline in DMI as cattle reached slaughter weight occurred earlier for heifers. The NRC (1987) concluded that most of the differences in voluntary DMI between sexes can be attributed to variation in weight at a given body fat content.

Several studies have shown that Holstein steers consume considerably more feed than do beef steers (Garrett 1971; Dean et al., 1976; Wyatt et al., 1977; Crickenberger et al., 1978; Harpster et al., 1978; Thonney et al., 1981). DMI equations developed by Plegge et al. (1984) indicated that Holstein cattle eat about 8% more than beef breeds, whereas, the equation of Fox and Black (1984) suggested that Holstein crosses consumed 9% more feed than beef breeds while straight Holsteins consumed about 17% more feed. Commercial feedlot data from Kansas (Owens et al., 1985) indicated that DMI of Holstein steers was 9% greater than that of beef steers of equal feeding weight. Data from California feedlots showed that DMI by Holsteins was 13% greater than by beef breeds at a given weight (Zinn, 1987). These data indicate that DMI of Holstein crossbred or straightbred Holstein cattle typically is 8 to 20% greater than that of beef breeds.

The objectives of this study were to characterize the DMI patterns of beef heifers and Holstein steers fed a high energy feedlot diet and to determine if the same seasonal patterns occur as have been detected with beef steers (Chapter III of this manuscript). Another objective was to employ prediction equations utilizing initial weight and days on feed as input variables to detect and account for seasonal effects on DMI by beef heifers and by Holstein steers.

Materials and Methods

Weekly DMI records were obtained from a large feedlot in Western Oklahoma (Hitch I Feeders, Hooker, OK) for all pens of cattle marketed between January 1983 and December 1985. This represented 2,051 pens of non-dairy steers, 178 pens of beef heifers and 153 pens of Holstein steers. Most cattle were obtained from Western Oklahoma and the Texas Panhandle. Most were yearlings when started on feed and were fed for 114 to 165 days. Feed dry matter intakes for this three year period for heifers were based on a total of 20,979 cattle or a mean of 118 heifers per pen. Intakes for Holstein steers were based on a total of 17,635 cattle or a mean of 115 steers per pen. Further information on the beef steers was presented in Chapter III of this manuscript.

Data available for each set of cattle included feedlot purchase weight, initial feedlot arrival weight, final weight, sex, cattle type (breed), flesh condition (thin, medium, fleshy), origin of cattle (region of the US), number of cattle in the pen, head-days in hospital pens for all reasons, deaths per pen for all reasons and head-days removed due to riding by other animals (bullers). No information on backgrounding or history of the cattle was available. All cattle were run through a dipping vat at the start and received routine medical attention and growth-stimulating ear implants. During the first three to four weeks on feed, cattle typically were fed a 35% roughage diet (NEm=1.88; NEg=1.16 Mcal/kg DM) for 14 days, a 20% roughage diet (NEm=1.98; NEg=1.25 Mcal/kg DM) for 10 days and a 10% roughage diet (NEm=2.09; NEg=1.34 Mcal/kg DM) thereafter. The highest energy diet consisted primarily of steam flaked corn grain, corn silage, chopped alfalfa hay and a soybean meal, urea supplement. Monensin was included in all diets at concentrations between 22 and 30 ppm.

For statistical analysis, the year was divided into the following four receiving seasons: January 29 - April 30, May 1 - July 30, July 31 - October 29 and October 30 - January 28. The number of pens of heifers received in each of these seasons were 27 (3,475 hd), 54 (6,852 hd), 55

(6,247 hd) and 42 (4,405 hd). The number of pens of Holstein steers received in each of these seasons were 45 (5,213 hd), 33 (3,750 hd), 34 (3,659 hd) and 41 (5,013 hd). Further information for cattle received during each of these four seasons is presented in Table 1 for beef heifers and Table 2 for Holstein steers. Data for cattle groups classified by season received in the yard and initial shrunk weight groups are presented in Tables 3-6 (heifers) and 7-10 (Holstein steers). For presentation, the heifers were divided into the following initial weight groups: 250, 273, 295 and 318 kg which corresponds to 550 (525-574), 600 (575-624), 650 (625-674) and 700 (675-724) lb, respectively. Holstein steers were divided into three initial weight groups: 273, 318 and 364 kg which corresponds to 600 (550-649), 700 (650-749) and 800 (750-849) lb, respectively.

In developing DMI equations for each receiving season the original models included initial weight up to the 2nd power, days on feed up to the 6th power, all two- and three-way interactions plus intake from 8 to 28 days. Models were simplified by using the backward elimination regression technique of the statistical analysis system (SAS, 1987). In this technique, variables were deleted from a model one by one not allowing the original R^2 to drop by more than .005.

Results and Discussion

Effect of Sex and Breed on Intake Patterns

Seasonal intake patterns noted previously for beef steers in this large feedlot again were apparent for both beef heifers and Holstein steers (Figures 1-6). In these figures, DMI is plotted versus days on feed for those initial weight groups (273 and 318 kg) common among these cattle classes (beef steers, beef heifers and Holstein steers) within each receiving season. In Figure 7, DMI by day of the year for 273 kg beef steers, beef heifers and Holstein steers within each season were plotted across seasons on a single plot. Similar plots for 250 and 295 kg beef heifers alone (Figure 8) and 273, 318 and 364 kg Holstein steers alone (Figure 9) are included. For these plots, it was assumed that cattle were placed on feed at the mid-point of each of the four seasons. These plots illustrate that seasonal DMI patterns were similar for the three classes and different weight groups of cattle. The overall shape of the DMI curves for beef steers and heifers and Holstein steers within each season proved surprisingly similar.

Mean DMI of beef heifers was about 1 to 3% lower than DMI of beef steers of equal starting weight (Figure 7). However, DMI of heifers tended to decline earlier in the feeding period than that of beef steers; they generally were fed about 3 weeks less than steers of equal starting weight. This was expected because heifers finish at lighter weights than do steers (Harpster et al., 1978; Fortin et al., 1980). Similar DMI differences between beef steers and heifers were observed previously in data from a Western Kansas feedlot (Owens et al., 1985). Peak DMI generally was greatest for heifers fed in the fall (Table 1) as was observed previously for steers. Peak intakes for the other feeding seasons (winter, spring and summer) were of similar magnitude. Mean feed intakes over the entire feeding period were similar for heifers fed in the fall or in the spring, both being about .2 kg per day greater than those for heifers fed in the summer or the winter.

Mean DMI for Holstein steers was 8 to 15% greater than DMI of beef steers of equal starting weight (Figure 7). This difference is within the range observed previously (Thonney et al., 1981 - 12%; Plegge et al., 1984 - 8.2%; Owens et al., 1985 - 9%; Zinn, 1987 - 13%) but less than the 17% proposed by Fox and Black (1984). Higher DMI may be due to a higher maintenance energy demand; Holsteins appear to have a higher proportion of organ and gut tissue which increases metabolic rate (Jones, 1985). The higher DMI of Holstein cattle also might be ascribed to their larger mature size and(or) to genetic or phenotypic selection of Holstein cattle for high milk production and, thereby, high DMI (Owens et al., 1985). In contrast to the DMI curves for beef steers, peak feed intakes and mean feed intakes over the entire feeding period were the greatest for Holstein steers placed on feed in the summer (May through July) and lowest for steers placed on feed in the fall (Aug. through Oct.; Table 2). This was due partly to lower initial weights of Holsteins entering the feedlot in the fall and is less evident when equal weights are considered (Figure 7). For beef steers, DMI was highest in the fall and lowest in the summer.

Development of Prediction equations

The effect of early intake data on subsequent DMI was tested for each of the four seasons for both beef heifers and Holstein steers using different periods of previous DMI data (none, 0-7, 0-14, 0-21, 0-28, 0-56, 0-84, 8-28, 15-28, 22-28, 29-56, 29-84, and 57-84 days). In addition to the respective previously observed intakes, the full models included initial shrunk weight up to the 2nd power, days on feed up to the 6th power, all two- and three-way interactions.

Beef Heifers. Prior to developing separate DMI equations for beef heifers, predicted dry matter intakes using the beef steer DMI equations developed previously were compared to observed intakes by heifers for the various initial weight groups (Figures 10-13). These equations would be expected to predict heifer DMI reasonably well because the heifer DMI patterns and mean intakes were reasonably similar to those of beef steers. Predicted intakes were quite similar to observed intakes with the exception that feed intakes by heifers declined sooner in the feeding period because heifers finish (fatten) at lighter body weights.

The root mean square errors (MSE) and R^2's for each of the tested beef heifer DMI models are reported in Tables 11 and 12. These data illustrate that by including DMI early in the feeding period in the prediction equation, the MSE decreased (Table 11) and R^2 increased dramatically (Table 12). By including only the first week's DMI in the equations, R^2's were increased by .08 to .15 units. As was noted previously with beef steers (Chapter III), the accuracy of the prediction equations continued to increase as additional DMI data were included in the models. The most accurate equations were those which included the mean DMI for the first 84 days in the model (R^2=.71 to .84). Intakes were predicted most accurately for heifers received between January 29 and April 30 and least accurately for heifers received between May 1 and July 30. Based on these data, we decided to refine those models further which included mean DMI observed from days 8 to 28 (R^2=.68 to .80). Fit was improved further by using subsequent periods, but in a commercial feedyard updating DMI projections after cattle have been on feed would be more practical and more easily implemented using DMI for only 28 days than using DMI from subsequent periods. Updating projections of gain based on previous DMI should increase the accuracy of gain projections and have economic implications. If low DMI pens could be detected early in the feeding period, appropriate corrective measures (altered pen size, diet, management, culling) could be taken.

The final models (prediction equation) for beef heifers received in each of the four seasons are presented in Tables 13-16. Plots of actual observed dry matter intakes (symbols) as compared to predicted intakes (lines) for heifers in the various initial weight groups received in each of the four seasons are illustrated in Figures 14 to 17. Plots of predicted intakes for heifers consuming the mean 8 to 28 day DMI (center line) and one standard deviation above or below the mean also are illustrated across seasons for 250 (Figure 18) and 295 kg heifers (Figure 19).

A total of 499 weekly pen DMI observations were used in developing the prediction equation for beef heifers received between January 29 and April 30 (Table 13). These 21 factors, including initial weight, observed DMI from 8 to 28 days, days on feed and interactions, explained about 80% of the observed variation in DMI (R^2=.7987). The plot of observed versus predicted intakes (Figures 14) illustrate that this equation did a reasonably good job of matching intakes. Predicted DMI curves for 250 kg heifers eating below average, average or above average during days 8 to 28 tended to remain parallel until about day 112 at which point the curves merge (Figure 18). This corresponds with the heifers approaching slaughter weight. Predicted curves for 295 kg heifers remained separate over the entire 112 day feeding period (Figure 19). Similar curves were noted previously for beef steers placed on feed in this season.

A total of 937 weekly pen DMI observations were used in developing the prediction equation (Table 14) for beef heifers received between May 1 and July 30. These 27 factors explained about 68% of the observed variation in DMI (R^2=.6774). Predicted intakes and observed intakes for heifers with various initial weights tended to run parallel to each other with intakes increasing about .45 kg for each 25 kg increase in initial weight (Figure 15). Predicted DMI curves for 250 kg cattle (Figure 18) eating below average, average or above average merged at about day 56. Predicted DMI curves for 273 kg beef steers received during this season were very similar to this shape. Predicted DMI curves for 295 kg heifers (Figure 19) remained separate until just before slaughter (112 days).

A total of 980 weekly pen DMI observations were used in developing the prediction equation (Table 15) for beef heifers received between July 31 and October 29. These 29 factors explained about 77% of the observed variation in DMI (R^2=.7666). Predicted and observed intakes for heifers with various initial weights match reasonably well (Figure 16). Predicted DMI curves for heifers eating below average, average and above average tended to merge at 70 and 80 days for heifers initially weighing 250 and 295 kg (Figures 18 and 19).

A total of 797 weekly pen DMI observations were used in developing the prediction equation (Table 16) for beef heifers received between October 30 and January 28. These 23 factors explained about 76% of the observed variation in DMI (R^2=.7627). Predicted and observed intakes for heifers with various initial weights are plotted in Figure 17. Predicted intake curves for the three consumption groups for 250 and 295 kg heifers tended to remain parallel over the entire feeding period

(Figures 18 and 19). Curves of similar shape were previously noted with beef steers.

Suggested limitations for maximum days on feed and 8 to 28 day DMI for the various initial weight groups within each season are presented in Table 17. Because these equations were developed empirically, extrapolation beyond observed input values can be erroneous and misleading. In addition, because these equations were developed using relatively small data sets, caution is needed when applying them. When these prediction equations are applied outside this data range, results are erratic. It is important to respect these input limitations if one expects output to be reasonable. Applicability of these curves in different environments with different cattle types or ages or feed types needs to be tested. Should daily DMI from 8 to 28 days not be available, mean values for heifers can be calculated using the equation: DMI = 2.28 + .021*initial weight; R^2=.45; MSE=1.36).

Holstein Steers. The root mean square errors (MSE) and R^2's for each of the tested Holstein steer intake models are reported in Tables 18 and 19. As was noted with beef steers and heifers, these data illustrate that by incorporating DMI data from early in the finishing period in the prediction equation, R^2 increased dramatically. By including only the first week's DMI in the equations, R^2's were increased by .07 to .20 units. As noted previously with beef steers (Chapter III) and with heifers, the accuracy of the prediction equations continued to increase as more early DMI data was included in the models. The most accurate equations again were those including the mean DMI for the first 84 days in the model (R^2=.77 to .86). Intakes were most accurately predicted for Holstein steers received between July 31 and

October 29. Those models, which included mean DMI observed from days 8 to 28 (R^2=.74 to .85), were further refined using the same method as used for heifers. The final models (prediction equations) for Holstein steers received in each of the four seasons are presented in Tables 20-23. Plots of actual observed dry matter intakes (symbols) as compared to predicted intakes (lines) for Holstein steers in the various initial weight groups received in each of the four seasons are illustrated in Figures 20 to 23. These four plots illustrate that the equations did a reasonably good job of matching intakes. Plots of predicted intakes for 220 and 295 kg steers consuming the mean 8 to 28 day intake (center line) and one standard deviation above or below the mean also are illustrated for each of the four seasons (Figures 24 to 25).

A total of 774 weekly pen DMI observations were used in developing the prediction equation (Table 20) for Holstein steers received between January 29 and April 30. These 25 factors explained about 74% of the observed variation in DMI (R^2=.7412). Predicted DMI curves for 318 and 364 kg steers eating below average, average or above average during days 8 to 28 tended to remain parallel over the entire feeding periods (Figures 24 and 25).

A total of 538 weekly pen dry matter intake observations were used in developing the prediction equation (Table 21) for steers received between May 1 and July 30. These 20 factors explained about 77% of the observed variation in DMI (R^2=.7731). For Holstein steers initially weighing 273 kg, a DMI pattern characteristic of calves (Zinn, 1987) was observed; DMI climbed continuously over most of the feeding period (Figure 21). Predicted DMI curves for 318 and 364 kg cattle (Figures 24 and 25) eating above or below average over 8 to 28 days crossed at about day 70. Shapes of the predicted intake curves for beef steers and heifers received in this season were similar.

A total of 669 weekly pen DMI observations were used in developing the prediction equation (Table 22) for cattle received between July 31 and October 29. These 25 factors explained about 85% of the observed variation in DMI (R^2=.8476). Predicted and observed intakes for steers with various initial weights match reasonably well (Figure 22). Predicted DMI curves for steers eating below average, average and above average merged at 70 days for steers initially weighing 318 and 364 kg (Figures 24 and 25). Similar DMI patterns were observed for 250 kg beef heifers received in this season.

A total of 783 weekly pen DMI observations were used in developing the prediction equation (Table 23) for steers received between October 30 and January 28. These 25 factors explained about 73% of the observed variation in DMI (R^2=.7346). Predicted DMI curves for the three consumption groups for 318 kg steers tended to remain parallel over the entire feeding period (Figure 24). Predicted curves for 364 kg steers merged at day 77 (Figure 25).

Suggested limitations for maximum days on feed and 8 to 28 days intakes are presented for the various initial weight groups within each season in Table 24. As previously discussed with the heifer equations, these limitations should be heeded. Should daily DMI from 8 to 28 days not be available, mean values for Holstein steers can be calculated using the equation: DMI = 5.10 + .0155*initial weight; R^2=.44; MSE=1.79).

TABLE 1. SUMMARY BY SEASON RECEIVED FOR BEEF HEIFERS

Item	Jan 29- April 30	May 1- July 30	July 31- Oct 29	Oct 30- Jan 28
Pens	27	54	55	42
No. Head/pen	129±44	127±51	114±46	105±43
Total Head	3475	6852	6247	4405
Weights, kg				
Purchase	283±27.2	297±30.1	290±33.8	289±41.6
Initial	274±26.4	287±30.8	279±33.0	280±41.2
Finished	457±16.4	458±21.4	446±22.2	455±22.3
Daily Gain, kg	1.25±.12	1.23±.11	1.18±.14	1.18±.13
Feed/Gain	6.72±.56	6.96±.45	7.29±.64	7.17±.69
Yard Days	137±18	130±19	134±27	139±27
Sick Days	256±254	177±520	248±318	203±321
Buller Days	1±5	1±5	3±15	2±16
Dead, %	2.13	0.92	1.14	1.73
DM Intake, kg				
0-7 days	5.95±1.72	6.80±1.26	6.11±1.23	6.24±1.31
8-14 days	7.38±1.43	7.80±1.23	7.28±1.08	7.80±1.11
15-21 days	8.07±1.06	8.42±1.19	8.18±1.17	8.40±1.32
22-28 days	8.38±0.76	8.71±1.06	8.67±1.22	8.50±1.14
29-35 days	8.58±0.73	8.85±0.96	9.05±1.31	8.54±0.94
36-42 days	8.76±0.90	8.86±0.94	9.13±1.24	8.66±1.00
43-49 days	8.84±0.92	8.95±0.93	9.31±1.16	8.79±0.94
50-56 days	8.86±0.94	8.93±0.86	9.20±1.10	8.89±0.98
57-63 days	8.93±0.89	8.91±0.80	9.28±1.09	8.92±0.87
64-70 days	8.95±0.81	8.96±0.94	9.16±0.95	8.90±0.87
71-77 days	9.02±0.78	8.96±0.86	9.22±0.84	8.76±0.75
78-84 days	9.03±0.59	8.87±0.82	9.14±0.86	8.78±0.71
85-91 days	8.96±0.61	8.81±0.79	8.90±0.78	8.74±0.66
92-98 days	8.86±0.61	8.83±0.82	8.83±0.63	8.58±0.69
99-105 days	8.80±0.64	8.88±0.64	8.58±0.54	8.45±0.64
106-112 days	8.58±0.69	8.86±0.63	8.43±0.51	8.47±0.53
113-119 days	8.45±0.49	8.72±0.72	8.11±0.39	8.24±0.48
120-126 days	8.26±0.47	8.59±0.58	8.03±0.40	8.16±0.54
127-133 days	8.20±0.48		7.86±0.36	8.07±0.58
Mean	8.35±0.62	8.56±0.69	8.55±0.73	8.40±0.71

TABLE 2. SUMMARY BY SEASON RECEIVED FOR HOLSTEIN STEERS

Item	Jan 29- April 30	May 1- July 30	July 31- Oct 29	Oct 30- Jan 28
Pens	45	33	34	41
No. Head/pen	116±46	114±62	108±57	122±35
Total Head	5213	3750	3659	5013
Weights, kg				
Purchase	340±42.1	354±51.7	315±64.6	342±44.9
Initial	322±42.6	337±53.1	299±64.9	325±40.9
Finished	552±64.0	541±32.1	514±37.8	547±26.0
Daily Gain, kg	1.59±.37	1.55±.10	1.39±.16	1.43±.12
Feed/Gain	6.61±.72	6.93±.46	7.13±.42	7.10±.66
Yard Days	128±18	122±22	149±55	140±25
Sick Days	236±250	128±146	695±1127	391±353
Buller Days	513±722	618±669	842±740	483±422
Dead, %	1.64	0.40	2.50	1.93
DM Intake, kg				
0-7 days	8.45±1.17	9.20±1.55	7.10±1.78	7.95±1.09
8-14 days	9.89±0.85	10.25±1.46	8.75±1.77	9.47±0.87
15-21 days	10.40±0.90	10.90±1.38	9.82±1.59	10.06±0.88
22-28 days	10.31±0.86	11.20±1.40	10.21±1.58	9.93±0.98
29-35 days	10.45±1.00	11.06±1.22	10.59±1.37	9.80±0.84
36-42 days	10.59±0.96	11.12±1.07	10.60±1.27	10.06±1.01
43-49 days	10.72±0.89	11.09±1.08	10.61±1.28	10.25±0.93
50-56 days	10.85±0.92	11.16±1.03	10.73±1.34	10.37±0.78
57-63 days	10.87±0.98	11.14±0.89	10.79±1.29	10.64±0.82
64-70 days	10.85±0.93	11.19±0.90	10.56±1.16	10.71±0.93
71-77 days	10.79±0.97	11.06±0.91	10.64±1.10	10.74±0.87
78-84 days	10.78±0.92	11.10±0.84	10.50±1.29	10.61±0.88
85-91 days	10.88±0.87	10.94±0.83	10.24±1.17	10.54±0.83
92-98 days	10.76±0.80	10.72±0.94	9.97±1.22	10.53±0.78
99-105 days	10.71±0.78	10.72±0.99	9.88±1.20	10.59±0.84
106-112 days	10.44±0.69	10.56±0.79	9.65±1.14	10.51±0.87
113-119 days	10.27±0.70	10.28±1.12	9.31±1.12	10.35±0.93
120-126 days	10.12±0.74	10.05±0.73	9.16±1.13	9.98±0.79
127-133 days			8.75±0.95	10.09±1.18
134-140 days			8.54±0.87	9.54±0.76
Mean	10.31±0.75	10.71±0.88	9.91±1.14	10.09±0.69

TABLE 3. SUMMARY BY INITIAL WEIGHT FOR BEEF HEIFERS RECEIVED JANUARY 29 - APRIL 30

	Initial Weight Grouping (kg)		
Item	250	273	295
Pens	6	9	7
No. Head/pen	154±49	122±44	102±39
Total Head	922	1095	713
Weights, kg			
Purchase	260±6.2	284±7.0	308±6.5
Initial	251±6.2	273±7.0	298±6.5
Finished	438±11.9	460±14.7	470±5.1
Daily Gain, kg	1.25±.05	1.15±.13	1.34±.08
Feed/Gain	6.41±.15	7.10±.76	6.66±.30
Yard Days	142±15	144±10	121±6
Sick Days	155±107	375±314	138±135
Buller Days	0	3±9	0
Dead, %	0.76	4.75	0.84
DM Intake, kg			
0-7 days	5.64±1.15	5.25±1.83	6.91±1.03
8-14 days	6.91±0.83	6.68±1.37	8.36±0.90
15-21 days	7.73±0.66	7.50±0.88	9.01±0.73
22-28 days	8.20±0.36	8.00±0.47	9.05±0.53
29-35 days	8.50±0.49	8.27±0.61	9.06±0.60
36-42 days	8.28±0.37	8.43±0.90	9.63±0.74
43-49 days	8.25±0.36	8.47±0.63	9.76±0.96
50-56 days	8.52±0.65	8.37±0.93	9.68±0.65
57-63 days	8.71±0.44	8.57±0.82	9.63±0.72
64-70 days	8.83±0.35	8.57±0.81	9.62±0.58
71-77 days	8.99±0.41	8.71±0.81	9.42±0.75
78-84 days	8.79±0.19	8.78±0.58	9.47±0.56
85-91 days	8.53±0.27	8.81±0.52	9.48±0.52
92-98 days	8.51±0.30	8.77±0.39	9.31±0.76
99-105 days	8.32±0.30	8.86±0.26	9.22±0.92
106-112 days	8.19±0.26	8.71±0.60	8.96±1.04
113-119 days	8.02±0.33	8.53±0.29	
120-126 days	7.97±0.38	8.28±0.31	
127-133 days	7.93±0.58	8.37±0.33	
Mean	8.00±0.21	8.09±0.44	8.88±0.44

TABLE 4. SUMMARY BY INITIAL WEIGHT FOR BEEF HEIFERS RECEIVED
MAY 1 - JULY 30

	Initial Weight Grouping (kg)			
Item	250	273	295	318
Pens	7	12	18	10
No. Head/pen	123±45	115±33	132±62	120±46
Total Head	862	1383	2369	1203
Weights, kg				
Purchase	261±5.8	278±6.4	306±9.7	326±7.1
Initial	250±5.8	269±6.2	294±8.5	316±5.6
Finished	440±14.1	446±19.8	464±13.3	478±12.6
Daily Gain, kg	1.19±.12	1.22±.10	1.25±.07	1.28±.07
Feed/Gain	6.75±.57	6.73±.31	7.01±.32	7.10±.39
Yard Days	150±11	136±11	125±8	119±8
Sick Days	102±97	115±90	125±93	75±79
Buller Days	0	3±12	0	0
Dead, %	0.70	0.94	0.93	0.42
DM Intake, kg				
0-7 days	5.61±1.25	7.01±0.73	6.82±1.17	7.27±0.92
8-14 days	6.74±0.75	7.90±0.81	8.04±0.89	8.25±0.69
15-21 days	7.83±1.33	8.28±0.86	8.57±0.68	9.03±0.82
22-28 days	7.96±0.83	8.44±0.94	8.87±0.69	9.30±0.94
29-35 days	8.34±0.64	8.45±0.94	9.00±0.68	9.40±0.76
36-42 days	8.41±0.89	8.36±0.71	9.06±0.63	9.37±0.81
43-49 days	8.40±0.62	8.39±0.68	9.27±0.50	9.44±0.79
50-56 days	8.23±0.48	8.38±0.76	9.25±0.54	9.49±0.78
57-63 days	8.20±0.78	8.48±0.80	9.13±0.57	9.50±0.52
64-70 days	8.49±0.80	8.38±0.78	9.31±0.66	9.65±0.69
71-77 days	8.43±0.81	8.51±0.76	9.12±0.48	9.72±0.62
78-84 days	8.44±0.71	8.49±0.76	9.14±0.53	9.42±0.69
85-91 days	8.28±0.64	8.37±0.57	9.15±0.54	9.47±0.62
92-98 days	8.35±0.73	8.44±0.52	9.11±0.80	9.47±0.58
99-105 days	8.35±0.68	8.62±0.58	9.14±0.51	9.33±0.58
106-112 days	8.27±0.66	8.61±0.55	9.19±0.40	9.34±0.48
113-119 days	8.26±0.66	8.63±0.79	9.21±0.40	
120-126 days	8.23±0.67	8.52±0.44		
127-133 days	8.13±0.61			
Mean	7.96±0.42	8.21±0.52	8.75±0.39	9.07±0.50

TABLE 5. SUMMARY BY INITIAL WEIGHT FOR BEEF HEIFERS RECEIVED JULY 31 - OCTOBER 29

Item	Initial Weight Grouping (kg)			
	250	273	295	318
Pens	19	8	9	14
No. Head/pen	107±34	104±61	138±53	108±50
Total Head	2031	828	1240	1516
Weights, kg				
Purchase	264±7.8	284±4.9	304±8.4	328±12.0
Initial	252±6.2	275±3.1	294±6.8	318±7.3
Finished	431±8.8	449±11.0	450±12.9	465±17.9
Daily Gain, kg	1.14±.10	1.25±.13	1.21±.14	1.22±.16
Feed/Gain	7.27±.49	6.87±.45	7.33±.45	7.57±.82
Yard Days	145±13	139±37	120±15	110±10
Sick Days	300±392	217±215	265±324	87±100
Buller Days	3±12	0	8±23	0
Dead, %	1.28	1.81	1.05	0.92
DM Intake, kg				
0-7 days	5.29±1.19	5.92±0.85	6.88±0.71	6.82±1.00
8-14 days	6.78±1.14	7.31±0.63	7.88±0.90	7.76±0.93
15-21 days	7.82±0.98	8.23±0.81	8.63±1.48	8.73±0.81
22-28 days	8.41±1.06	8.51±0.77	9.23±1.09	9.39±0.77
29-35 days	9.21±1.40	8.61±0.91	9.29±1.22	9.49±0.85
36-42 days	9.04±1.10	9.01±0.98	9.37±0.89	9.79±0.93
43-49 days	9.23±1.12	9.38±0.92	9.40±0.76	9.87±0.78
50-56 days	8.97±0.86	9.09±0.61	9.53±0.67	9.95±0.78
57-63 days	8.97±0.74	9.52±0.44	9.46±0.81	9.97±0.93
64-70 days	8.94±0.71	9.26±0.30	9.14±0.38	9.90±0.82
71-77 days	9.06±0.63	9.12±0.43	9.42±0.51	9.80±0.54
78-84 days	8.86±0.56	9.17±0.44	9.24±0.54	9.93±0.72
85-91 days	8.62±0.47	9.14±0.31	8.74±0.48	9.64±0.84
92-98 days	8.58±0.54	9.09±0.43	8.75±0.24	9.34±0.56
99-105 days	8.35±0.52	8.81±0.33	8.64±0.32	9.22±0.51
106-112 days	8.33±0.44	8.80±0.30		
113-119 days	8.03±0.29	8.54±0.37		
120-126 days	8.02±0.40			
127-133 days	7.83±0.39			
134-140 days	7.64±0.34			
Mean	8.23±0.47	8.56±0.42	8.84±0.60	9.11±0.52

TABLE 6. SUMMARY BY INITIAL WEIGHT FOR BEEF HEIFERS RECEIVED OCTOBER 30 - JANUARY 28

	Initial Weight Grouping (kg)		
Item	250	273	295
Pens	8	7	16
No. Head/pen	118±30	118±36	112±31
Total Head	946	823	1797
Weights, kg			
Purchase	261±8.5	286±5.8	307±7.7
Initial	252±6.2	276±5.7	297±7.0
Finished	441±14.4	447±14.6	464±16.0
Daily Gain, kg	1.15±.11	1.11±.11	1.25±.09
Feed/Gain	6.89±.38	7.33±.34	7.02±.33
Yard Days	157±17	143±18	123±12
Sick Days	318±545	296±448	126±111
Buller Days	13±36	0	0
Dead, %	1.80	1.94	1.11
DM Intake, kg			
0-7 days	5.56±1.24	5.84±1.35	6.79±0.79
8-14 days	7.08±1.16	7.49±0.83	8.31±0.61
15-21 days	7.81±0.97	8.11±1.07	8.65±0.75
22-28 days	8.13±0.87	8.01±0.91	8.82±0.76
29-35 days	8.29±0.77	8.47±0.82	8.74±0.53
36-42 days	7.99±0.71	8.49±0.74	8.98±0.40
43-49 days	8.22±0.65	8.51±0.68	9.06±0.46
50-56 days	8.43±0.63	8.67±0.81	9.26±0.40
57-63 days	8.33±0.50	8.85±0.68	9.24±0.45
64-70 days	8.36±0.66	8.59±0.49	9.35±0.40
71-77 days	8.25±0.52	8.56±0.50	9.25±0.35
78-84 days	8.31±0.47	8.45±0.29	9.21±0.39
85-91 days	8.48±0.31	8.42±0.46	9.01±0.45
92-98 days	8.17±0.39	8.47±0.40	8.98±0.39
99-105 days	8.06±0.62	8.38±0.29	8.96±0.36
106-112 days	8.08±0.47	8.41±0.29	8.88±0.48
113-119 days	7.91±0.23	8.13±0.18	8.76±0.52
120-126 days	8.09±0.57	8.03±0.22	
127-133 days	7.96±0.57		
134-140 days	7.93±0.39		
141-147 days	7.89±0.50		
Mean	7.91±0.41	8.10±0.46	8.74±0.31

TABLE 7. SUMMARY BY INITIAL WEIGHT FOR HOLSTEIN STEERS RECEIVED JANUARY 29 - APRIL 30

	Initial Weight Grouping (kg)		
Item	273	318	364
Pens	5	22	13
No. Head/pen	145±79	111±43	111±42
Total Head	724	2431	1442
Weights, kg			
Purchase	293±3.1	337±13.3	373±12.5
Initial	277±5.5	316±10.8	359±12.4
Finished	506±6.8	542±23.7	564±21.0
Daily Gain, kg	1.44±.10	1.53±.12	1.64±.14
Feed/Gain	6.48±.27	6.77±.43	6.66±.52
Yard Days	143±8	133±12	115±12
Sick Days	528±437	218±204	125±127
Buller Days	1698±1629	383±350	303±143
Dead, %	2.21	1.52	0.97
DM Intake, kg			
0-7 days	7.64±0.41	8.35±1.03	9.12±1.24
8-14 days	9.07±0.74	9.77±0.78	10.44±0.71
15-21 days	9.60±0.98	10.37±0.83	10.77±0.66
22-28 days	9.43±0.97	10.30±0.64	10.75±0.73
29-35 days	9.53±0.73	10.55±0.82	10.85±0.81
36-42 days	9.66±0.64	10.60±0.73	11.25±0.62
43-49 days	9.64±0.55	10.78±0.70	11.33±0.51
50-56 days	9.77±0.47	10.82±0.76	11.56±0.65
57-63 days	9.78±0.53	10.89±0.84	11.50±0.64
64-70 days	9.80±0.42	10.88±0.81	11.44±0.58
71-77 days	9.58±0.21	10.85±0.85	11.37±0.74
78-84 days	9.73±0.47	10.78±0.72	11.45±0.64
85-91 days	9.68±0.48	10.87±0.67	11.51±0.64
92-98 days	9.73±0.59	10.78±0.58	11.32±0.73
99-105 days	9.93±0.35	10.81±0.70	11.16±0.78
106-112 days	9.57±0.39	10.55±0.63	10.88±0.58
113-119 days	9.53±0.25	10.44±0.59	
120-126 days	9.47±0.23	10.36±0.62	
127-133 days	9.31±0.45		
134-140 days	9.24±0.44		
Mean	9.33±0.39	10.30±0.54	10.87±0.50

TABLE 8. SUMMARY BY INITIAL WEIGHT FOR HOLSTEIN STEERS RECEIVED MAY 1 - JULY 30

	Initial Weight Grouping (kg)			
Item	273	318	364	409
Pens	9	7	10	5
No. Head/pen	163±81	87±30	99±36	76±58
Total Head	1467	612	990	382
Weights, kg				
Purchase	296±19.5	350±8.7	381±12.8	425±15.5
Initial	274±14.2	331±3.6	368±11.5	407±17.2
Finished	511±18.8	545±19.2	552±22.0	579±19.6
Daily Gain, kg	1.49±.07	1.57±.11	1.56±.12	1.62±.06
Feed/Gain	6.61±.21	6.91±.43	7.04±.36	7.35±.54
Yard Days	145±12	126±10	108±6	95±8
Sick Days	267±171	65±55	113±132	17±38
Buller Days	1106±794	241±173	491±458	320±645
Dead, %	0.48	0.16	0.51	0.00
DM Intake, kg				
0-7 days	7.95±1.25	9.09±1.77	9.67±0.67	11.03±1.08
8-14 days	8.84±0.75	10.50±1.15	10.62±0.43	11.79±1.40
15-21 days	9.54±1.33	10.96±0.88	11.20±0.76	12.75±1.25
22-28 days	9.79±0.83	11.41±0.59	11.51±0.78	12.90±1.26
29-35 days	9.73±0.64	11.37±0.61	11.43±0.72	12.52±0.81
36-42 days	9.92±0.89	11.43±0.75	11.31±0.57	12.58±0.82
43-49 days	10.10±0.62	11.10±0.68	11.41±0.85	12.55±0.39
50-56 days	10.09±0.48	11.25±0.53	11.52±0.76	12.53±0.47
57-63 days	10.29±0.78	11.13±0.43	11.40±0.70	12.37±0.73
64-70 days	10.40±0.80	11.21±0.43	11.53±0.80	12.24±1.03
71-77 days	10.31±0.81	11.29±0.44	11.42±0.97	11.85±0.99
78-84 days	10.55±0.71	11.33±0.67	11.32±0.95	11.71±0.87
85-91 days	10.60±0.64	11.00±0.52	11.30±1.14	
92-98 days	10.56±0.73	10.91±0.94	10.96±1.21	
99-105 days	10.48±0.68	11.00±0.95		
106-112 days	10.36±0.66	10.97±0.87		
113-119 days	10.16±0.66	10.77±1.75		
120-126 days	10.10±0.67			
127-133 days	9.85±0.61			
Mean	9.84±0.41	10.78±0.40	10.99±0.47	11.91±0.64

TABLE 9. SUMMARY BY INITIAL WEIGHT FOR HOLSTEIN STEERS RECEIVED JULY 31 - OCTOBER 29

	Initial Weight Grouping (kg)		
Item	273	318	364
Pens	6	9	9
No. Head/pen	117±34	79±32	87±45
Total Head	701	714	787
Weights, kg			
Purchase	289±14.4	337±10.0	373±15.9
Initial	273±10.3	316±14.6	359±12.1
Finished	475±31.0	520±17.0	516±45.0
Daily Gain, kg	1.37±.09	1.43±.14	1.50±.09
Feed/Gain	7.21±.30	7.25±.59	7.19±.42
Yard Days	134±22	125±7	110±18
Sick Days	636±745	148±119	137±188
Buller Days	994±417	269±178	592±549
Dead, %	2.43	1.68	0.64
DM Intake, kg			
0-7 days	7.86±1.86	7.56±0.79	7.96±0.78
8-14 days	9.46±2.18	9.05±0.66	9.78±1.09
15-21 days	10.11±1.89	9.77±0.60	10.84±0.98
22-28 days	10.74±2.22	10.34±0.74	10.83±0.84
29-35 days	10.57±1.89	10.93±0.81	11.10±0.63
36-42 days	11.00±1.68	10.85±0.82	11.14±0.71
43-49 days	10.75±0.98	11.04±0.78	11.37±0.62
50-56 days	10.77±0.91	11.16±0.77	11.64±0.62
57-63 days	10.64±1.01	11.45±0.86	11.47±0.77
64-70 days	10.69±0.88	10.78±0.74	11.18±0.53
71-77 days	10.47±0.77	10.95±0.76	11.33±0.55
78-84 days	10.20±0.91	10.97±0.67	11.49±0.53
85-91 days	9.97±0.98	10.71±0.82	11.21±0.60
92-98 days	9.78±1.03	10.27±0.77	11.11±1.04
99-105 days	9.61±0.47	10.51±0.59	10.96±1.15
106-112 days	9.82±0.91	10.43±0.56	
113-119 days	9.39±0.50	10.16±0.68	
120-126 days	9.33±0.47		
127-133 days	8.73±0.71		
134-140 days	8.64±0.68		
Mean	9.92±0.95	10.27±0.48	10.74±0.44

TABLE 10. SUMMARY BY INITIAL WEIGHT FOR HOLSTEIN STEERS RECEIVED OCTOBER 30 -JANUARY 28

	Initial Weight Grouping (kg)		
Item	273	318	364
Pens	10	12	16
No. Head/pen	123±29	127±44	123±35
Total Head	1227	1526	1973
Weights, kg			
Purchase	289±14.2	345±10.2	379±9.1
Initial	277±9.3	325±10.0	359±7.5
Finished	522±21.7	545±22.7	566±14.6
Daily Gain, kg	1.38±.12	1.45±.12	1.45±.11
Feed/Gain	6.71±.50	7.12±.55	7.35±.59
Yard Days	164±16	135±17	125±8
Sick Days	609±520	341±224	323±293
Buller Days	645±560	440±380	492±355
Dead, %	2.69	1.90	1.62
DM Intake, kg			
0-7 days	7.35±1.17	8.10±0.93	8.21±1.07
8-14 days	8.67±0.69	9.53±0.76	9.96±0.75
15-21 days	9.09±0.56	10.31±0.72	10.49±0.75
22-28 days	9.21±0.79	9.77±1.06	10.54±0.72
29-35 days	9.06±0.75	9.77±0.87	10.37±0.50
36-42 days	9.18±0.71	10.06±0.80	10.77±0.79
43-49 days	9.40±0.50	10.30±0.86	10.88±0.73
50-56 days	9.82±0.40	10.33±0.87	10.89±0.56
57-63 days	9.84±0.37	10.82±0.79	11.12±0.55
64-70 days	9.67±0.40	10.90±0.71	11.35±0.62
71-77 days	9.70±0.42	11.03±0.60	11.32±0.54
78-84 days	9.52±0.47	11.09±0.51	11.10±0.52
85-91 days	9.66±0.41	11.01±0.58	10.92±0.55
92-98 days	9.65±0.26	10.74±0.45	11.11±0.49
99-105 days	9.61±0.41	10.81±0.58	11.17±0.54
106-112 days	9.54±0.35	10.65±0.60	11.24±0.53
113-119 days	9.32±0.34	10.63±0.59	11.20±0.52
120-126 days	9.41±0.68	10.49±0.44	
127-133 days	9.54±1.10		
134-140 days	9.32±0.56		
141-147 days	9.19±0.44		
Mean	9.24±0.28	10.24±0.43	10.62±0.38

TABLE 11. EFFECT OF PREVIOUS INTAKE DATA ON ROOT (KG) MSE OF MODEL FOR BEEF HEIFERS

Intake Data, Days	Season of Year Received in Yard			
	Jan 29-April 30	May 1-July 30	July 31-Oct 29	Oct 30-Jan 28
0	0.729	0.765	0.778	0.691
0-7	0.605	0.654	0.695	0.595
0-14	0.568	0.630	0.669	0.577
0-21	0.537	0.618	0.652	0.546
0-28	0.523	0.606	0.629	0.530
0-56	0.489	0.596	0.585	0.492
0-84	0.477	0.572	0.575	0.479
8-28	0.522	0.607	0.622	0.526
15-28	0.546	0.607	0.622	0.526
22-28	0.600	0.606	0.626	0.544
29-56	0.547	0.583	0.584	0.502
29-84	0.496	0.578	0.587	0.497
57-84	0.496	0.555	0.647	0.525

TABLE 12. EFFECT OF PREVIOUS INTAKE DATA ON R^2 OF MODEL FOR BEEF HEIFERS

Intake Data, Days	Season of Year Received in Yard			
	Jan 29-April 30	May 1-July 30	July 31-Oct 29	Oct 30-Jan 28
0	.603	.486	.636	.590
0-7	.736	.632	.714	.704
0-14	.767	.659	.735	.721
0-21	.792	.673	.748	.750
0-28	.803	.684	.766	.765
0-56	.827	.694	.797	.797
0-84	.835	.705	.802	.808
8-28	.803	.683	.771	.768
15-28	.785	.684	.771	.768
22-28	.740	.685	.768	.752
29-56	.783	.707	.798	.789
29-84	.822	.699	.794	.793
57-84	.822	.723	.750	.769

TABLE 13. REGRESSION COEFFICIENTS FOR DRY MATTER INTAKE EQUATION USING DAY 8-28 INTAKE FOR BEEF FEEDLOT HEIFERS RECEIVED JANUARY 29 - APRIL 30 (R^2=0.7987)

Item[a]	b	Standard Error	Sig. Level
Intercept	-3.61409	0.58683	.0001
INWT*DMI	3.29150	0.27269	.0001
DOF*DMI	13.02972	1.30939	.0001
DOF^2*DMI	-92.67945	12.97272	.0001
DOF^3*DMI	184.94254	26.32718	.0001
DOF^4*DMI	-164.61646	28.20602	.0001
DOF^5*DMI	84.60723	18.02118	.0001
DOF^6*DMI	-17.29182	4.27798	.0001
INWT*DOF*DMI	-27.51827	4.54922	.0001
DOF^2	353.45389	62.20882	.0001
INWT*DOF^2	-569.50693	198.56511	.0043
INWT*DOF^2*DMI	203.69642	47.41250	.0001
INWT^2*DOF^2*DMI	-99.33628	27.06423	.0003
DOF^3	-959.37834	159.03602	.0001
INWT*DOF^3	1049.14130	395.66610	.0083
INWT*DOF^3*DMI	-234.41372	64.06490	.0003
DOF^4	959.87570	182.72614	.0001
INWT^2*DOF^4	-872.99981	378.63604	.0216
INWT^2*DOF^4*DMI	220.48519	63.39181	.0006
DOF^5	-521.46755	120.01933	.0001
INWT^2*DOF^5*DMI	-21.98310	10.22963	.0321
DOF^6	111.10902	28.91148	.0001

[a] Terms include INWT, initial shrunk weight in kg/1000; DMI, mean dry matter intake (kg) observed days 8-28; DOF, days on feed/100.

TABLE 14. REGRESSION COEFFICIENTS FOR DRY MATTER INTAKE EQUATION USING DAY 8-28 INTAKE FOR BEEF FEEDLOT HEIFERS RECEIVED MAY 1 - JULY 30 (R^2=0.6774)

Item[a]	b	Standard Error	Sig. Level
Intercept	-24.63510	5.04647	.0001
INWT	91.26233	19.41612	.0001
DMI	7.87065	1.57373	.0001
INWT*DMI	-40.25021	9.56687	.0001
INWT^2*DMI	49.72978	13.76872	.0003
DOF*DMI	-44.13334	6.90196	.0001
DOF^3*DMI	143.15295	31.40581	.0001
DOF^4*DMI	-181.22450	45.66978	.0001
DOF^5*DMI	80.08774	22.71363	.0004
DOF^6*DMI	-12.35301	3.76839	.0011
DOF	117.42262	15.44681	.0001
INWT*DOF	-586.00196	82.03464	.0001
INWT*DOF*DMI	299.70787	54.54729	.0001
INWT^2*DOF*DMI	-388.88370	87.53072	.0001
DOF^2	342.01603	84.54423	.0001
INWT*DOF^2*DMI	-362.12543	80.41245	.0001
INWT^2*DOF^2*DMI	615.79096	164.59950	.0002
DOF^3	-1304.39159	276.11277	.0001
INWT*DOF^3	1849.00374	363.60689	.0001
INWT^2*DOF^3*DMI	-363.10989	106.43055	.0007
DOF^4	1440.46358	331.61505	.0001
INWT*DOF^4	-2268.94836	569.05340	.0001
INWT^2*DOF^4	597.10378	215.87381	.0058
INWT*DOF^4*DMI	216.50310	68.96349	.0017
DOF^5	-610.35122	158.91455	.0001
INWT*DOF^5	593.40859	196.22765	.0026
INWT*DOF^5*DMI	-65.38949	26.59509	.0141
DOF^6	89.96403	25.75900	.0005

[a] Terms include INWT, initial shrunk weight in kg/1000; DMI, mean dry matter intake (kg) observed days 8-28; DOF, days on feed/100.

TABLE 15. REGRESSION COEFFICIENTS FOR DRY MATTER INTAKE EQUATION USING DAY 8-28 INTAKE FOR BEEF FEEDLOT HEIFERS RECEIVED JULY 31 - OCTOBER 29 (R^2=0.7666)

Item[a]	b	Standard Error	Sig. Level
Intercept	168.20943	39.14081	.0001
INWT	-1201.99222	299.11181	.0001
INWT^2	2137.85203	570.48602	.0002
DMI	-17.81242	4.62517	.0001
INWT*DMI	129.12703	34.71094	.0002
INWT^2*DMI	-226.76251	65.45554	.0006
DOF*DMI	136.66369	19.22577	.0001
DOF^2*DMI	-154.39690	22.27574	.0001
DOF^3*DMI	35.41261	8.44447	.0001
DOF^5*DMI	2.80470	0.78057	.0003
DOF^6*DMI	-0.59243	0.15437	.0001
DOF	-1228.61969	165.52737	.0001
INWT*DOF	8806.27582	1239.74291	.0001
INWT^2*DOF	-15963.47797	2383.71738	.0001
INWT*DOF*DMI	-935.02208	138.51997	.0001
INWT^2*DOF*DMI	1674.55773	262.89878	.0001
DOF^2	1299.68081	174.76438	.0001
INWT*DOF^2	-8662.01523	1198.39517	.0001
INWT^2*DOF^2	16213.01579	2413.72900	.0001
INWT*DOF^2*DMI	908.63450	132.37500	.0001
INWT^2*DOF^2*DMI	-1645.58979	263.75829	.0001
INWT*DOF^3	-904.94847	323.03822	.0052
INWT^2*DOF^3*DMI	133.10262	53.48237	.0130
DOF^4	-325.48634	64.30167	.0001
INWT*DOF^4	2532.53123	586.21674	.0001
INWT^2*DOF^4	-2630.49027	562.15011	.0001
INWT*DOF^4*DMI	-116.41717	28.81007	.0001
DOF^5	71.03756	16.98139	.0001
INWT*DOF^5	-416.96544	113.60015	.0003
INWT^2*DOF^5*DMI	87.50234	21.92674	.0001

[a] Terms include INWT, initial shrunk weight in kg/1000; DMI, mean dry matter intake (kg) observed days 8-28; DOF, days on feed/100.

TABLE 16. REGRESSION COEFFICIENTS FOR DRY MATTER INTAKE EQUATION USING DAY 8-28 INTAKE FOR BEEF FEEDLOT HEIFERS RECEIVED OCTOBER 30 - JANUARY 28 (R^2=0.7627)

Item[a]	b	Standard Error	Sig. Level
Intercept	-0.95091	0.52592	.0710
INWT*DMI	4.05287	0.71259	.0001
INWT^2*DMI	-6.41149	1.86654	.0006
DOF*DMI	12.55056	1.95263	.0001
DOF^2*DMI	-58.78746	8.32056	.0001
DOF^3*DMI	73.15813	11.13827	.0001
DOF^4*DMI	-38.27656	5.89408	.0001
DOF^5*DMI	7.43748	1.11702	.0001
INWT*DOF*DMI	-51.74021	12.82336	.0001
INWT^2*DOF*DMI	84.36213	23.51248	.0004
DOF^2	86.61430	13.02438	.0001
INWT*DOF^2	-256.68035	48.98095	.0001
INWT^2*DOF^2	250.67213	68.32377	.0003
INWT*DOF^2*DMI	255.72903	46.62563	.0001
INWT^2*DOF^2*DMI	-421.11037	78.17540	.0001
DOF^3	-70.32628	13.53251	.0001
INWT*DOF^3	97.95520	23.84595	.0001
INWT*DOF^3*DMI	-295.63250	55.16795	.0001
INWT^2*DOF^3*DMI	547.89595	92.87651	.0001
DOF^4	14.98473	3.63344	.0001
INWT*DOF^4*DMI	123.83253	22.17626	.0001
INWT^2*DOF^4*DMI	-312.84624	46.03025	.0001
INWT^2*DOF^5*DMI	62.93562	9.99253	.0001
INWT*DOF^6*DMI	-8.21238	1.24650	.0001

[a] Terms include INWT, initial shrunk weight in kg/1000; DMI, mean dry matter intake (kg) observed days 8-28; DOF, days on feed/100.

TABLE 17. SUGGESTED LIMITATIONS FOR BEEF HEIFER INTAKE EQUATIONS

Initial Weight Grouping, kg	Maximum Yard Days (DOF)	DMI, kg Days 8-28[a]
January 29 - April 30:		
250	150	7.61±0.84
273	145	7.39±1.12
295	125	8.81±1.02
May 1 - July 30:		
250	147	7.51±1.31
273	145	8.20±1.21
295	130	8.50±0.91
318	120	8.86±1.18
July 31 - October 29:		
250	147	7.67±1.28
273	135	8.02±0.98
295	130	8.58±1.63
318	115	8.63±1.04
October 30 - January 28:		
250	160	7.68±1.34
273	150	7.87±1.32
295	140	8.59±0.85

[a] Mean Intake ± 1.5 standard deviations.

TABLE 18. EFFECT OF PREVIOUS INTAKE DATA ON ROOT MSE (KG) OF MODEL FOR HOLSTEIN STEERS

Intake Data, Days	Season of Year Received in Yard			
	Jan 29-April 30	May 1-July 30	July 31-Oct 29	Oct 30-Jan 28
0	0.788	0.710	0.863	0.666
0-7	0.629	0.629	0.747	0.589
0-14	0.588	0.610	0.700	0.588
0-21	0.559	0.602	0.673	0.578
0-28	0.541	0.594	0.648	0.568
0-56	0.495	0.594	0.628	0.545
0-84	0.469	0.584	0.640	0.538
8-28	0.552	0.603	0.645	0.572
15-28	0.568	0.605	0.650	0.576
22-28	0.609	0.626	0.662	0.601
29-56	0.497	0.603	0.669	0.546
29-84	0.475	0.584	0.696	0.543
57-84	0.498	0.590	0.759	0.565

TABLE 19. EFFECT OF PREVIOUS INTAKE DATA ON R^2 OF MODEL FOR HOLSTEIN STEERS

Intake Data, Days	Season of Year Received in Yard			
	Jan 29-April 30	May 1-July 30	July 31-Oct 29	Oct 30-Jan 28
0	.469	.680	.728	.636
0-7	.670	.759	.802	.722
0-14	.711	.773	.826	.723
0-21	.739	.778	.839	.732
0-28	.755	.784	.851	.742
0-56	.796	.784	.860	.751
0-84	.816	.785	.855	.768
8-28	.745	.777	.852	.738
15-28	.731	.776	.851	.734
22-28	.690	.760	.845	.710
29-56	.794	.777	.842	.761
29-84	.812	.785	.828	.764
57-84	.793	.780	.796	.744

TABLE 20. REGRESSION COEFFICIENTS FOR DRY MATTER INTAKE EQUATION USING DAY 8-28 INTAKE FOR HOLSTEIN FEEDLOT STEERS RECEIVED JANUARY 29 - APRIL 30 (R^2=0.7412)

Item[a]	b	Standard Error	Sig. Level
Intercept	3.49023	0.62184	.0001
INWT^2*DMI	2.89623	0.51778	.0001
DOF^2*DMI	80.83790	11.94787	.0001
DOF^3*DMI	-136.20633	21.35642	.0001
DOF^4*DMI	57.37169	10.58783	.0001
DOF	63.66230	17.64487	.0003
INWT*DOF	-392.02831	61.32466	.0001
INWT*DOF*DMI	44.26901	6.03995	.0001
INWT^2*DOF*DMI	-43.74645	12.37830	.0004
DOF^2	-1137.49701	160.12510	.0001
INWT*DOF^2	6587.22884	990.51868	.0001
INWT^2*DOF^2	-6564.90475	1181.40486	.0001
INWT*DOF^2*DMI	-613.92873	89.40590	.0001
INWT^2*DOF^2*DMI	716.96175	115.63744	.0001
DOF^3	1930.60297	279.45099	.0001
INWT*DOF^3	-10379.74334	1703.92821	.0001
INWT^2*DOF^3	8524.09277	1548.74783	.0001
INWT*DOF^3*DMI	939.78950	156.06594	.0001
INWT^2*DOF^3*DMI	-878.37431	149.59938	.0001
DOF^4	-974.79080	154.83025	.0001
INWT*DOF^4	4265.06792	819.20120	.0001
INWT*DOF^4*DMI	-371.16515	75.81270	.0001
DOF^5	104.11493	18.25354	.0001
INWT^2*DOF^5	-2055.10274	473.69121	.0001
INWT^2*DOF^5*DMI	212.44413	48.69905	.0001
INWT*DOF^6*DMI	-6.87328	1.69854	.0001

[a] Terms include INWT, initial shrunk weight in kg/1000; DMI, mean dry matter intake (kg) observed days 8-28; DOF, days on feed/100.

TABLE 21. REGRESSION COEFFICIENTS FOR DRY MATTER INTAKE EQUATION USING DAY 8-28 INTAKE FOR HOLSTEIN FEEDLOT STEERS RECEIVED MAY 1 - JULY 30 (R^2=0.7731)

Item[a]	b	Standard Error	Sig. Level
Intercept	-1.76366	1.14904	.1254
DMI	0.85332	0.11245	.0001
DOF*DMI	-5.31610	3.41896	.1206
DOF^2*DMI	16.25401	6.30109	.0102
DOF^4*DMI	-15.79321	5.36382	.0034
DOF^5*DMI	6.46073	3.04964	.0346
DOF^6*DMI	-1.07779	0.68789	.1178
DOF	37.94642	19.28357	.0496
INWT*DOF	-114.18171	67.40375	.0909
INWT*DOF*DMI	40.57914	17.78626	.0229
INWT^2*DOF*DMI	-46.04350	19.04469	.0160
DOF^2	-90.72116	35.36393	.0106
INWT*DOF^2	437.22003	162.39101	.0073
INWT*DOF^2*DMI	-157.54069	43.57775	.0003
INWT^2*DOF^2*DMI	185.47390	51.27090	.0003
INWT^2*DOF^3	-423.63306	207.37445	.0416
INWT*DOF^3*DMI	111.25018	27.36304	.0001
INWT^2*DOF^3*DMI	-136.49469	36.60673	.0002
DOF^4	48.36810	14.18460	.0007
INWT*DOF^4	-254.91932	76.86269	.0010
INWT^2*DOF^4	393.16347	163.64931	.0166

[a] Terms include INWT, initial shrunk weight in kg/1000; DMI, mean dry matter intake (kg) observed days 8-28; DOF, days on feed/100.

TABLE 22. REGRESSION COEFFICIENTS FOR DRY MATTER INTAKE EQUATION USING DAY 8-28 INTAKE FOR HOLSTEIN FEEDLOT STEERS RECEIVED JULY 31 - OCTOBER 29 (R^2=0.8476)

Item[a]	b	Standard Error	Sig. Level
Intercept	-4.65217	1.46051	.0015
$INWT^2$	83.86086	25.42400	.0010
INWT*DMI	5.64022	1.02973	.0001
$INWT^2$*DMI	-15.65284	3.87642	.0001
DOF*DMI	5.95151	1.55451	.0001
DOF^2*DMI	-14.50851	2.99983	.0001
DOF^3*DMI	8.11531	1.43917	.0001
DOF	71.35152	25.16913	.0047
INWT*DOF	-402.07361	111.50568	.0003
INWT*DOF*DMI	-14.72287	3.84580	.0001
$INWT^2$*DOF*DMI	75.56111	16.10856	.0001
DOF^2	-197.76345	63.17885	.0018
INWT*DOF^2	1536.29754	309.32434	.0001
$INWT^2$*DOF^2	-284.44661	88.15155	.0013
$INWT^2$*DOF^2*DMI	-194.61142	45.03919	.0001
DOF^3	153.47035	64.69044	.0001
INWT*DOF^3	-1929.30762	356.46568	.0001
INWT*DOF^3*DMI	33.13612	8.64610	.0001
$INWT^2$*DOF^3*DMI	266.76728	55.76221	.0001
DOF^4	-151.79211	32.22052	.0001
INWT*DOF^4	1089.17929	196.24760	.0001
INWT*DOF^4*DMI	-24.89874	5.18894	.0001
$INWT^2$*DOF^4*DMI	-171.16456	30.29841	.0001
DOF^5	30.44233	6.20007	.0001
INWT*DOF^5	-208.97598	39.49968	.0001
$INWT^2$*DOF^5*DMI	48.90872	7.99137	.0001

[a] Terms include INWT, initial shrunk weight in kg/1000; DMI, mean dry matter intake (kg) observed days 8-28; DOF, days on feed/100.

TABLE 23. REGRESSION COEFFICIENTS FOR DRY MATTER INTAKE EQUATION USING DAY 8-28 INTAKE FOR HOLSTEIN FEEDLOT STEERS RECEIVED OCTOBER 30 - JANUARY 28 (R^2=0.7346)

Item[a]	b	Standard Error	Sig. Level
Intercept	5.84311	0.23822	.0001
DOF*DMI	18.28032	2.88342	.0001
DOF^2*DMI	-169.20417	25.05677	.0001
DOF^3*DMI	275.81670	38.48480	.0001
DOF^4*DMI	-169.56326	23.30385	.0001
DOF^5*DMI	36.13637	5.33660	.0001
DOF	-146.03645	28.15551	.0001
INWT^2*DOF	703.27893	256.92856	.0063
INWT^2*DOF*DMI	-62.26760	25.13976	.0135
DOF^2	1438.76477	240.75423	.0001
INWT*DOF^2	-3591.33728	727.16404	.0001
INWT*DOF^2*DMI	454.84858	81.27805	.0001
INWT^2*DOF^2*DMI	-225.15044	32.34537	.0001
DOF^3	-2335.12243	362.74219	.0001
INWT*DOF^3	3923.31508	786.31971	.0001
INWT^2*DOF^3	6138.66750	890.37853	.0001
INWT*DOF^3*DMI	-613.54534	102.82502	.0001
DOF^4	1399.01732	211.23988	.0001
INWT^2*DOF^4	-9846.98278	1532.49552	.0001
INWT*DOF^4*DMI	217.63483	34.53706	.0001
INWT^2*DOF^4*DMI	262.67731	47.96923	.0001
DOF^5	-279.51200	45.46186	.0001
INWT*DOF^5	-991.30381	186.14088	.0001
INWT^2*DOF^5	3899.22283	653.09912	.0001
INWT*DOF^6	139.99497	30.87276	.0001
INWT^2*DOF^6*DMI	-73.68755	12.86198	.0001

[a] Terms include INWT, initial shrunk weight in kg/1000; DMI, mean dry matter intake (kg) observed days 8-28; DOF, days on feed/100.

TABLE 24. SUGGESTED LIMITATIONS FOR HOLSTEIN STEER INTAKE EQUATIONS

Initial Weight Grouping, kg	Maximum Yard Days (DOF)	DMI, kg Days 8-28
January 29 - April 30:		
273	140	9.37±1.14[a]
318	140	10.15±0.99[a]
364	120	10.65±0.94[a]
May 1 - July 30:		
273	140	9.39±1.18[a]
318	120	10.95±1.19[a]
364	100	11.11±0.86[a]
409	85	12.48±1.21[b]
July 31 - October 29:		
273	140	10.10±2.09[b]
318	120	9.72±0.72[a]
364	105	10.48±0.90[b]
October 30 - January 28:		
273	160	8.99±0.87[a]
318	135	9.87±0.98[a]
364	120	10.33±0.83[a]

[a] Mean Intake ± 1.5 standard deviations.
[b] Mean Intake ± 1 standard deviation.

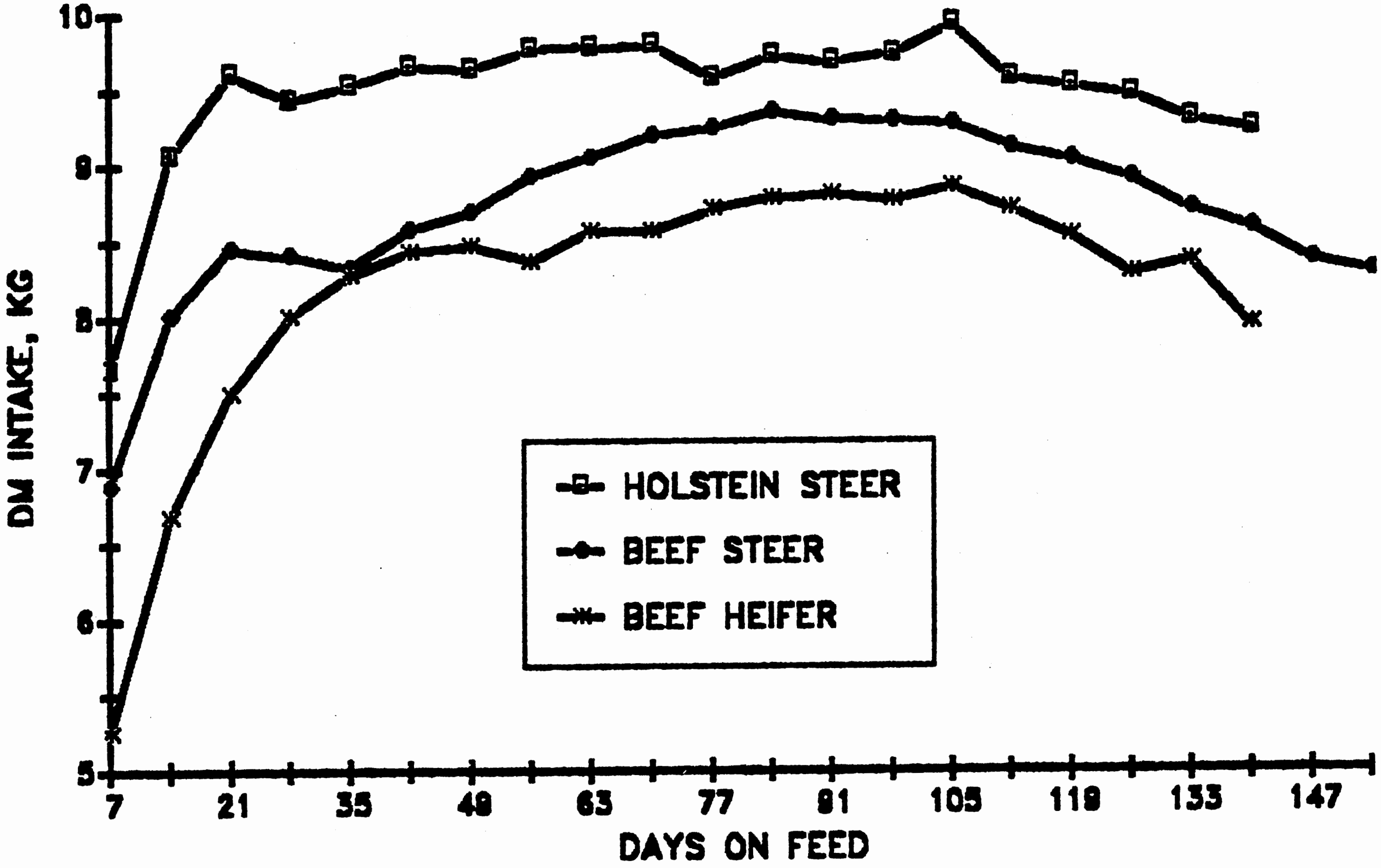

Figure 1. Feed Intake Versus Days on Feed for 273 kg Beef Steers, Beef Heifers and Holstein Steers Received January 29 - April 30

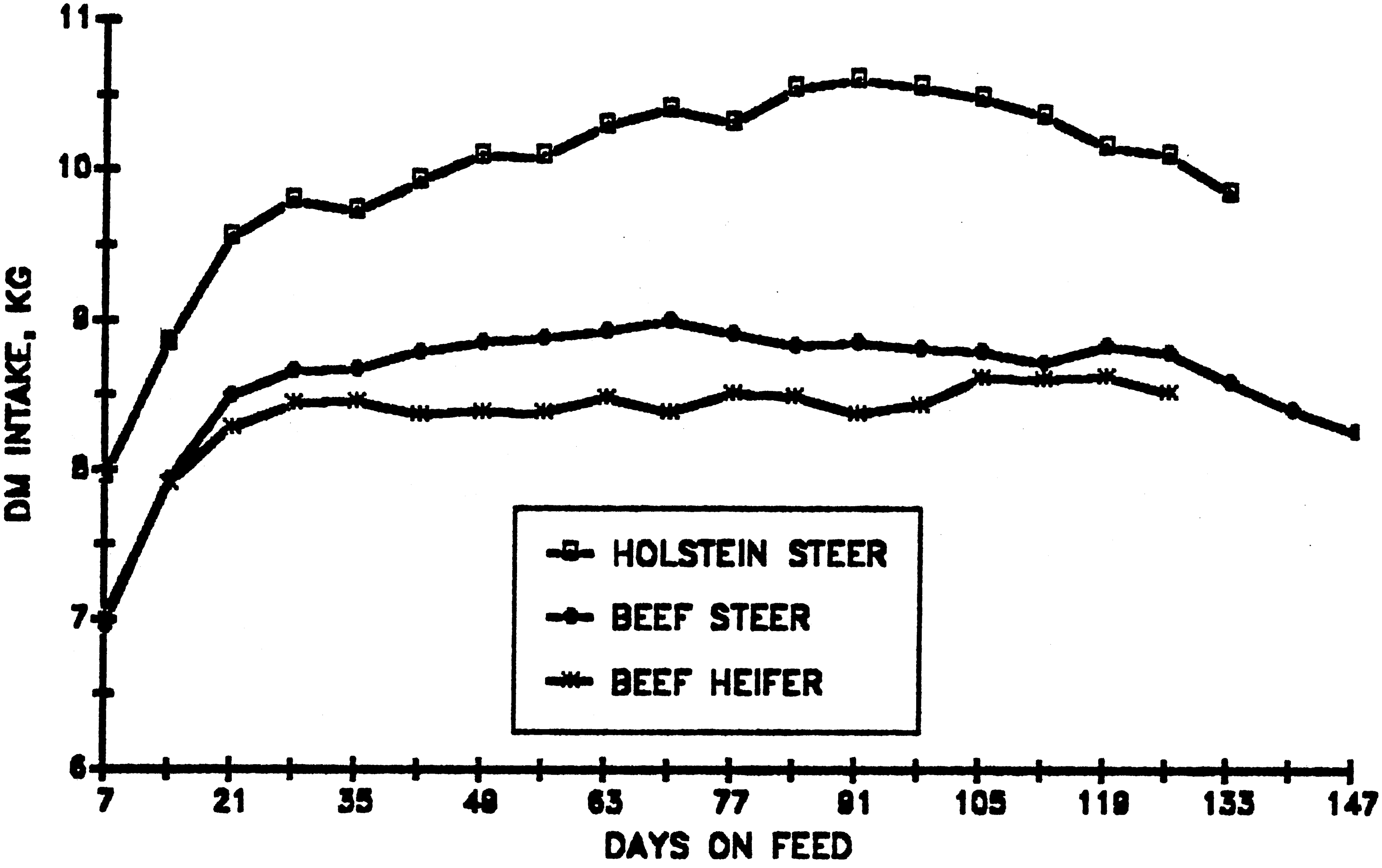

Figure 2. Feed Intake Versus Days on Feed for 273 kg Beef Steers, Beef Heifers and Holstein Steers Received May 1 - July 30

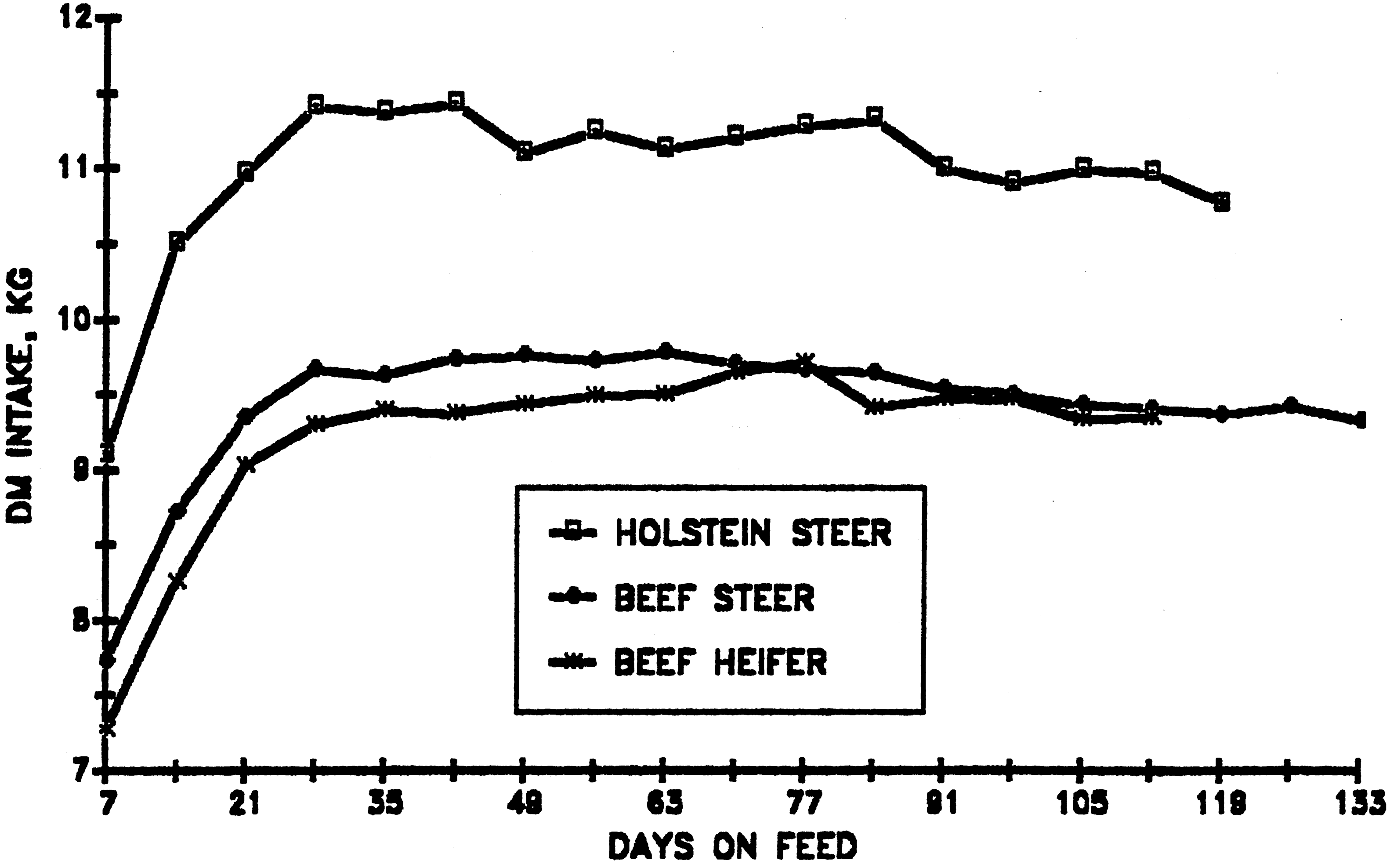

Figure 3. Feed Intake Versus Days on Feed for 318 kg Beef Steers, Beef Heifers and Holstein Steers Received May 1 - July 30

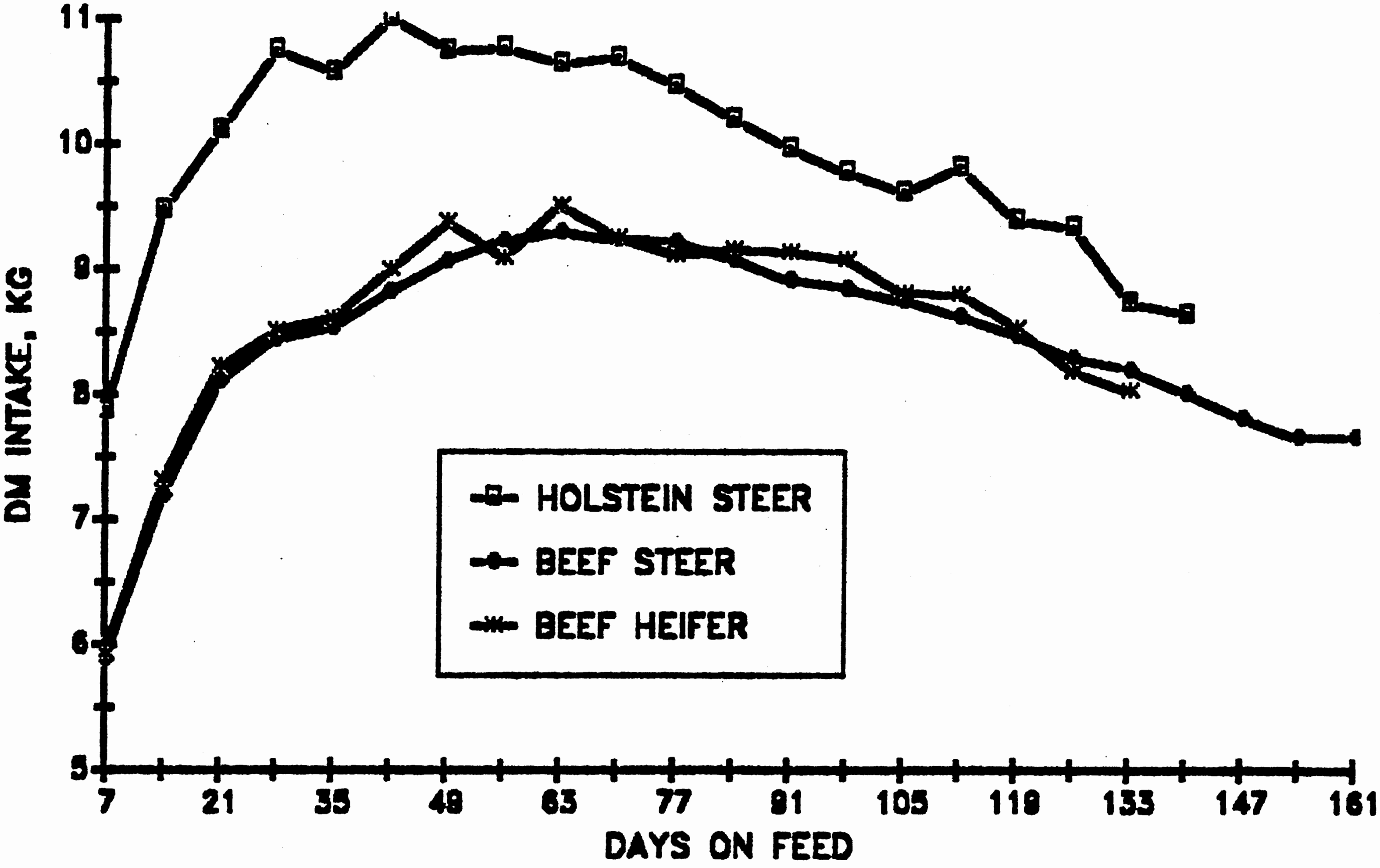

Figure 4. Feed Intake Versus Days on Feed for 273 kg Beef Steers, Beef Heifers and Holstein Steers Received July 31 - October 29

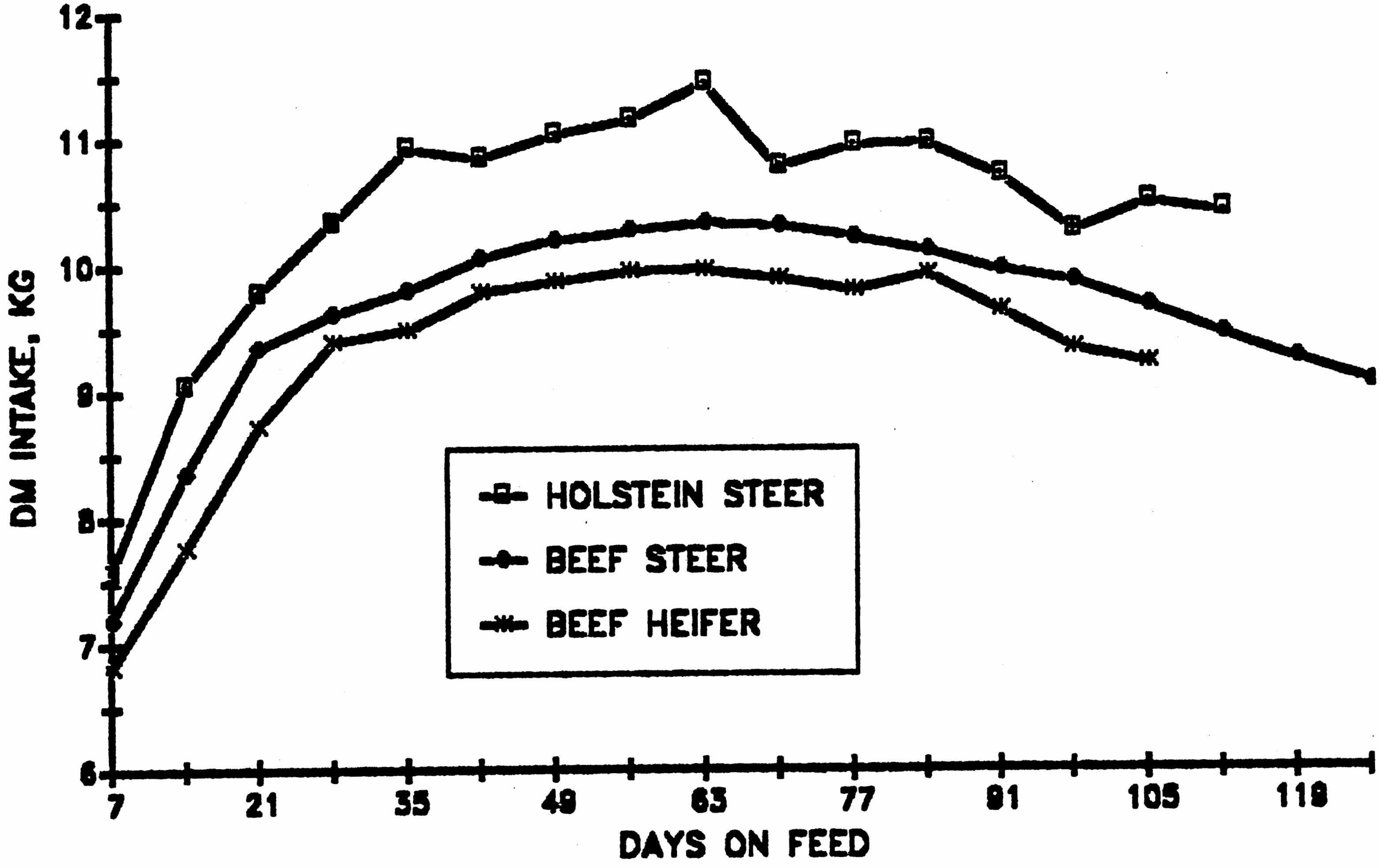

Figure 5. Feed Intake Versus Days on Feed for 318 kg Beef Steers, Beef Heifers and Holstein Steers Received July 31 - October 29

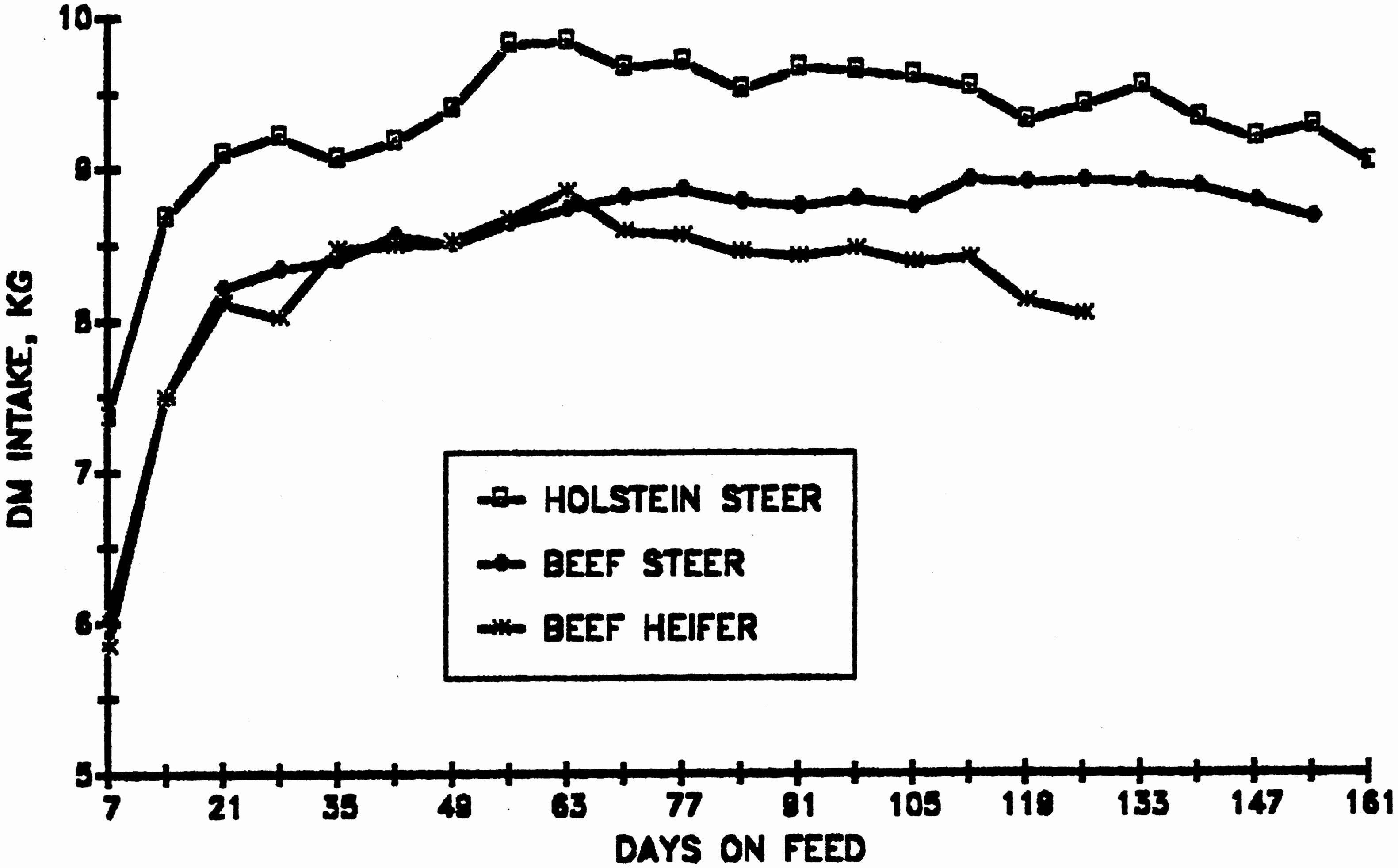

Figure 6. Feed Intake Versus Days on Feed for 273 kg Beef Steers, Beef Heifers and Holstein Steers Received October 30 - January 28

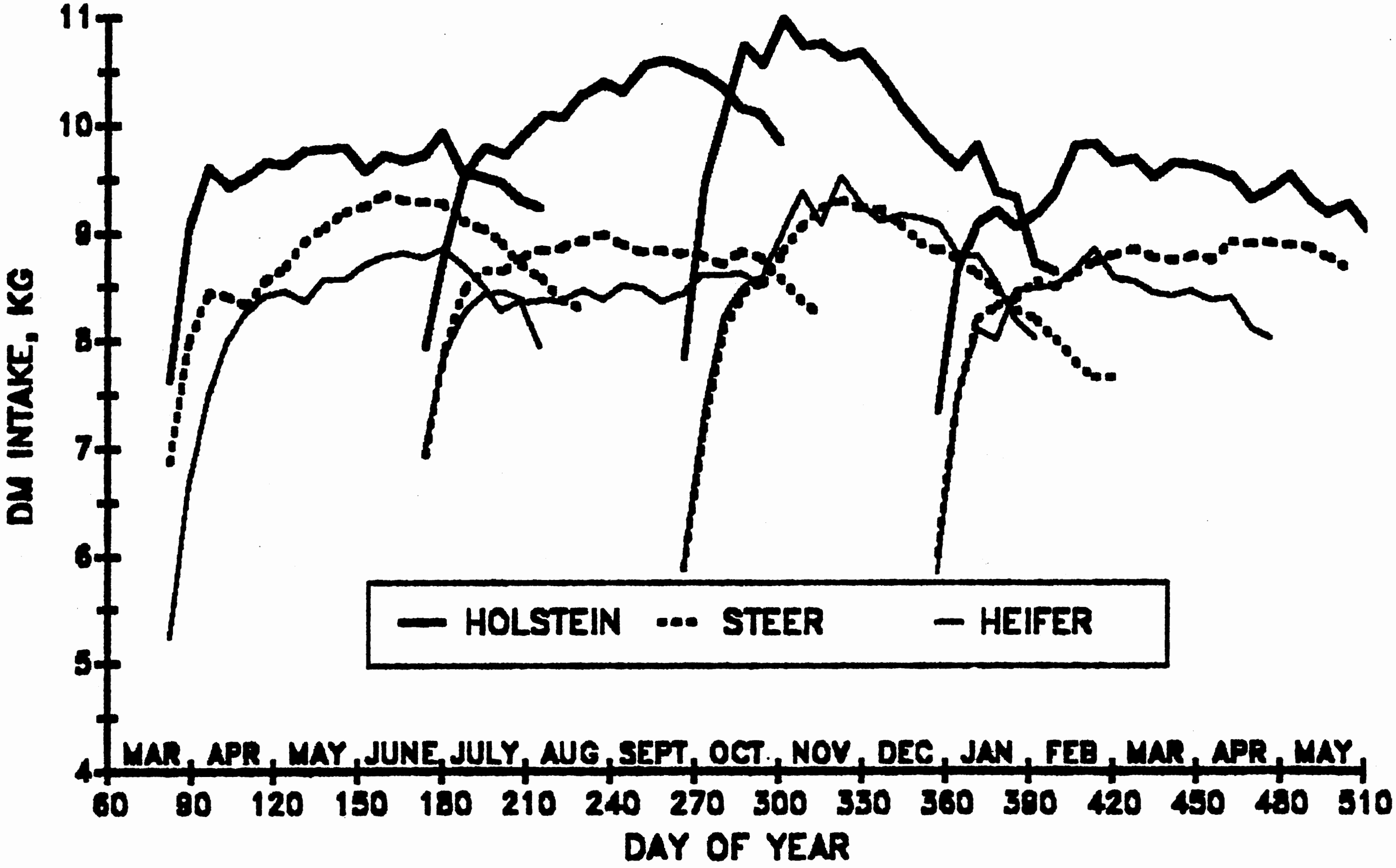

Figure 7. Feed Intake Versus Days on Feed Across Seasons for 273 kg Beef Steers, Beef Heifers and Holstein Steers

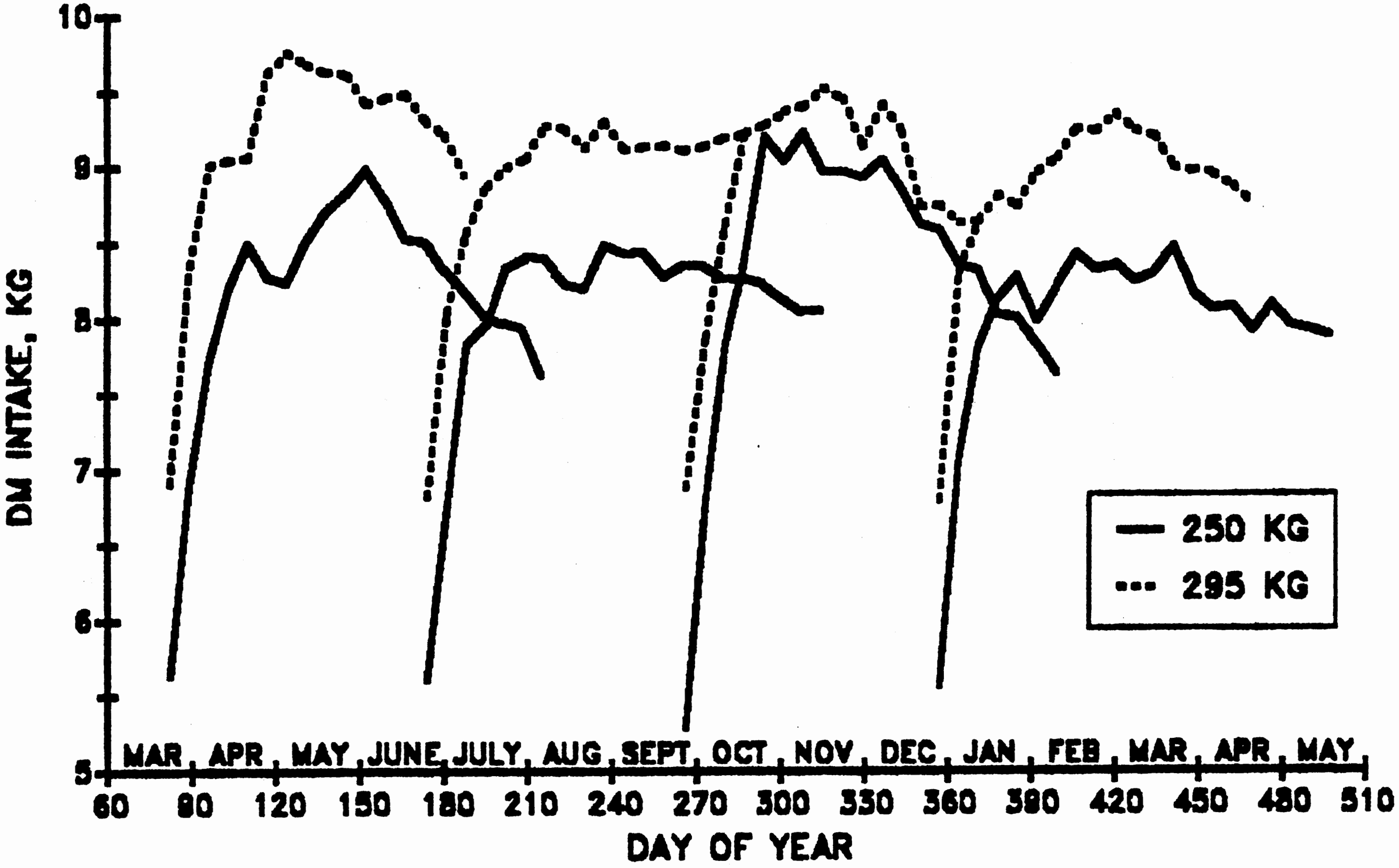

Figure 8. Feed Intake Versus Days on Feed Across Seasons for 250 and 295 kg Beef Heifers

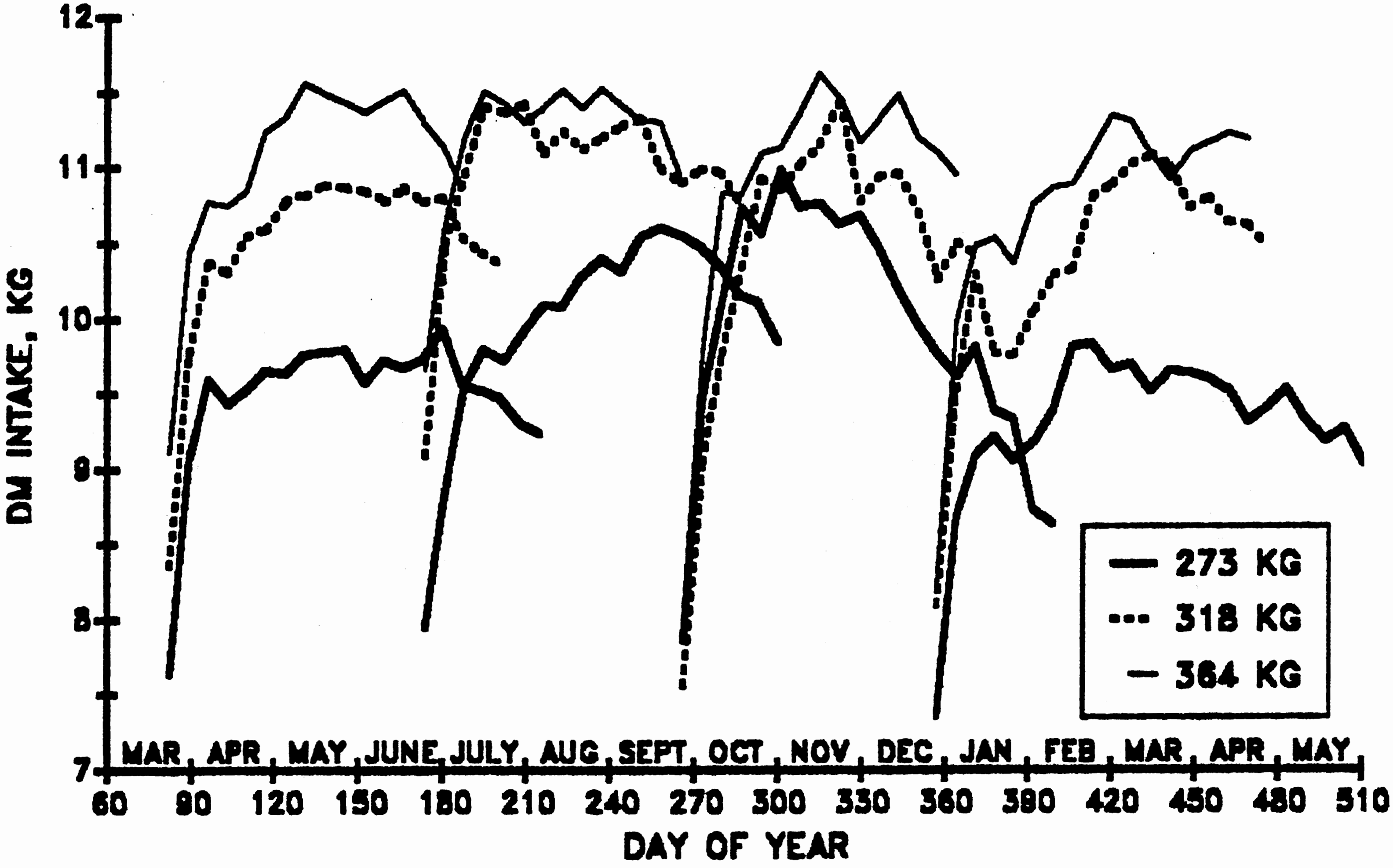

Figure 9. Feed Intake Versus Days on Feed Across Seasons for 273, 318 and 364 kg Holstein Steers

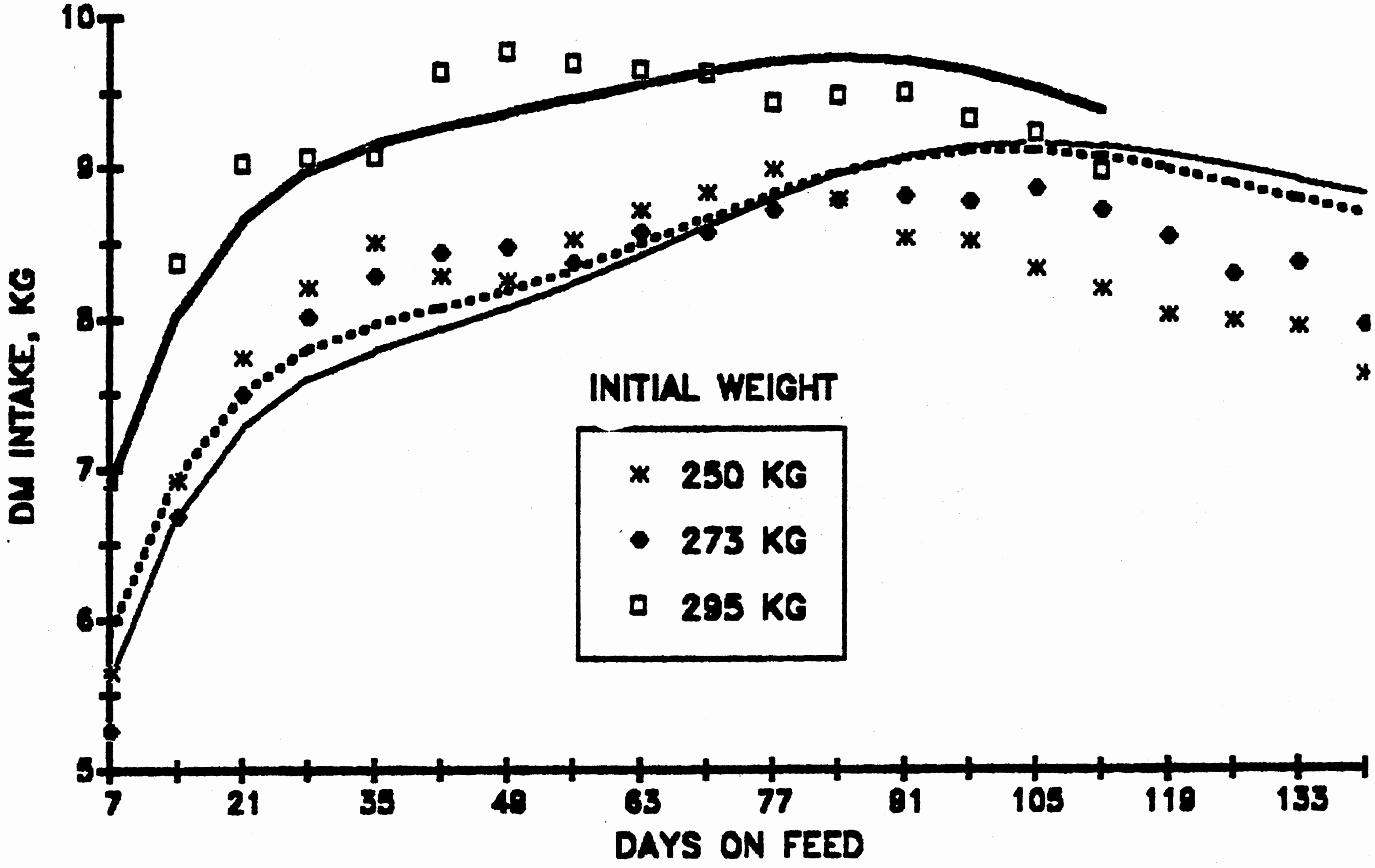

Figure 10. Predicted (Using Steer Equations) and Observed Feed Intakes Versus Days on Feed for Heifers of Various Initial Weights Received January 29 - April 30

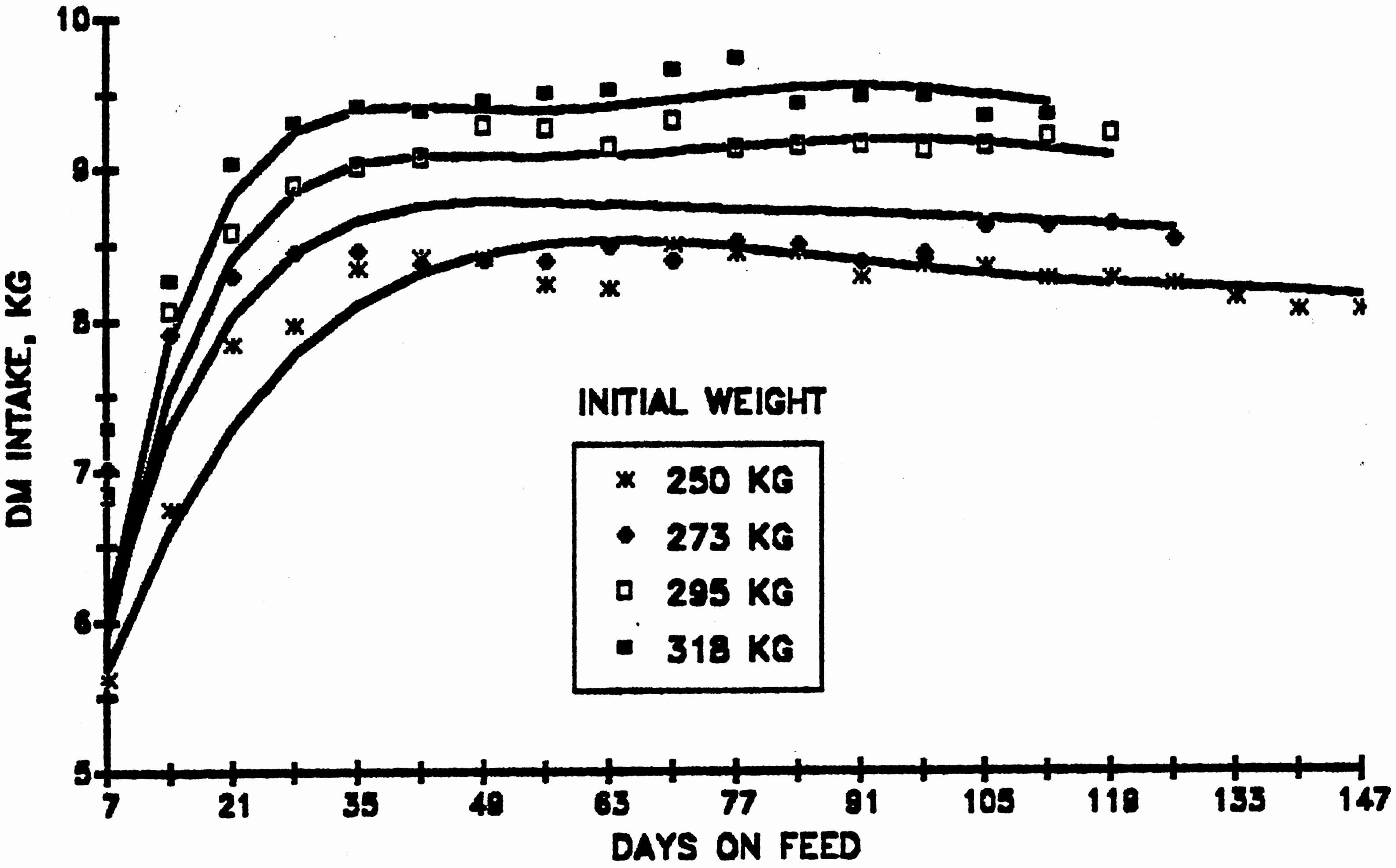

Figure 11. Predicted (Using Steer Equations) and Observed Feed Intakes Versus Days on Feed for Heifers of Various Initial Weights Received May 1 - July 30

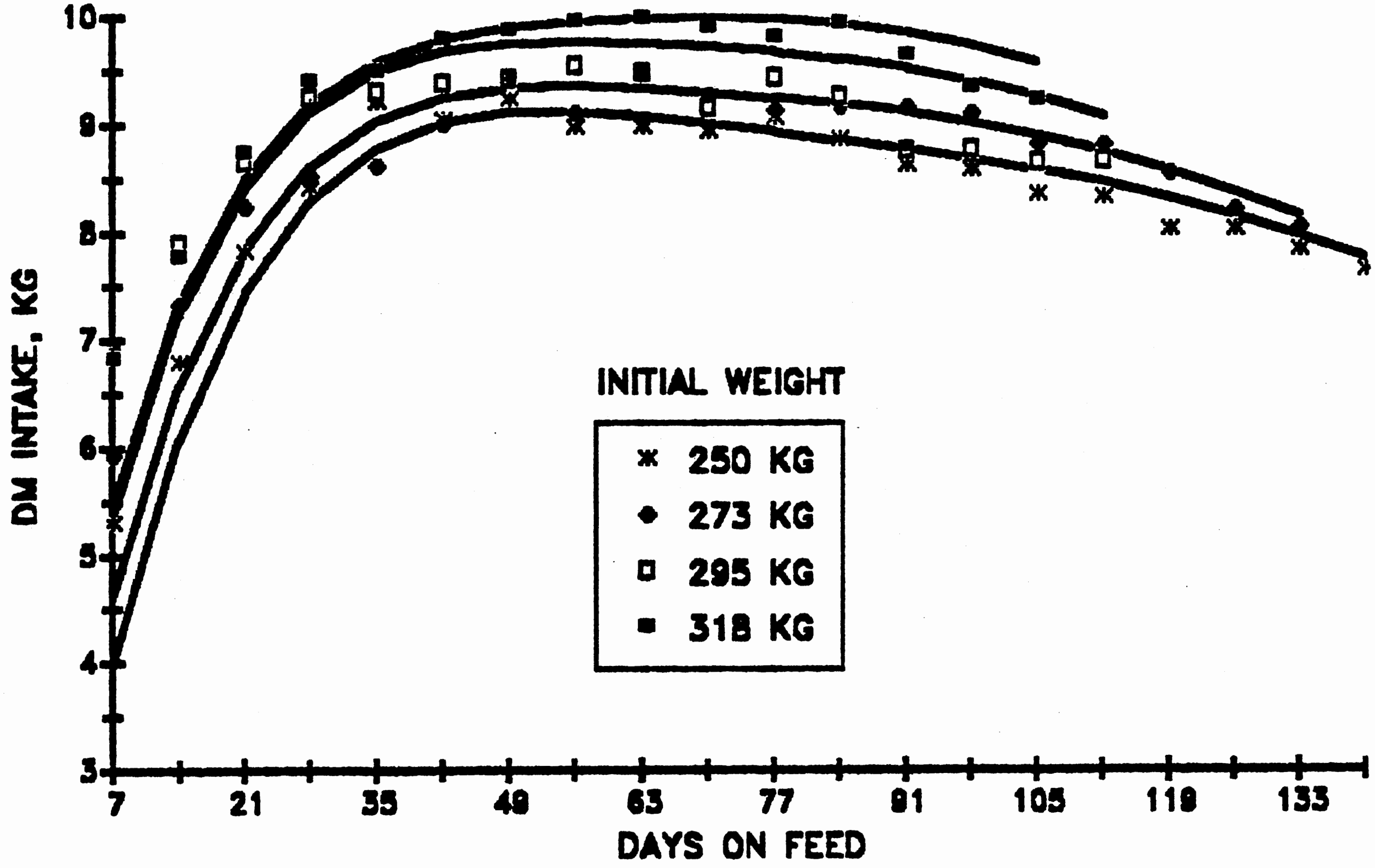

Figure 12. Predicted (Using Steer Equations) and Observed Feed Intakes Versus Days on Feed for Heifers of Various Initial Weights Received July 31 - October 29

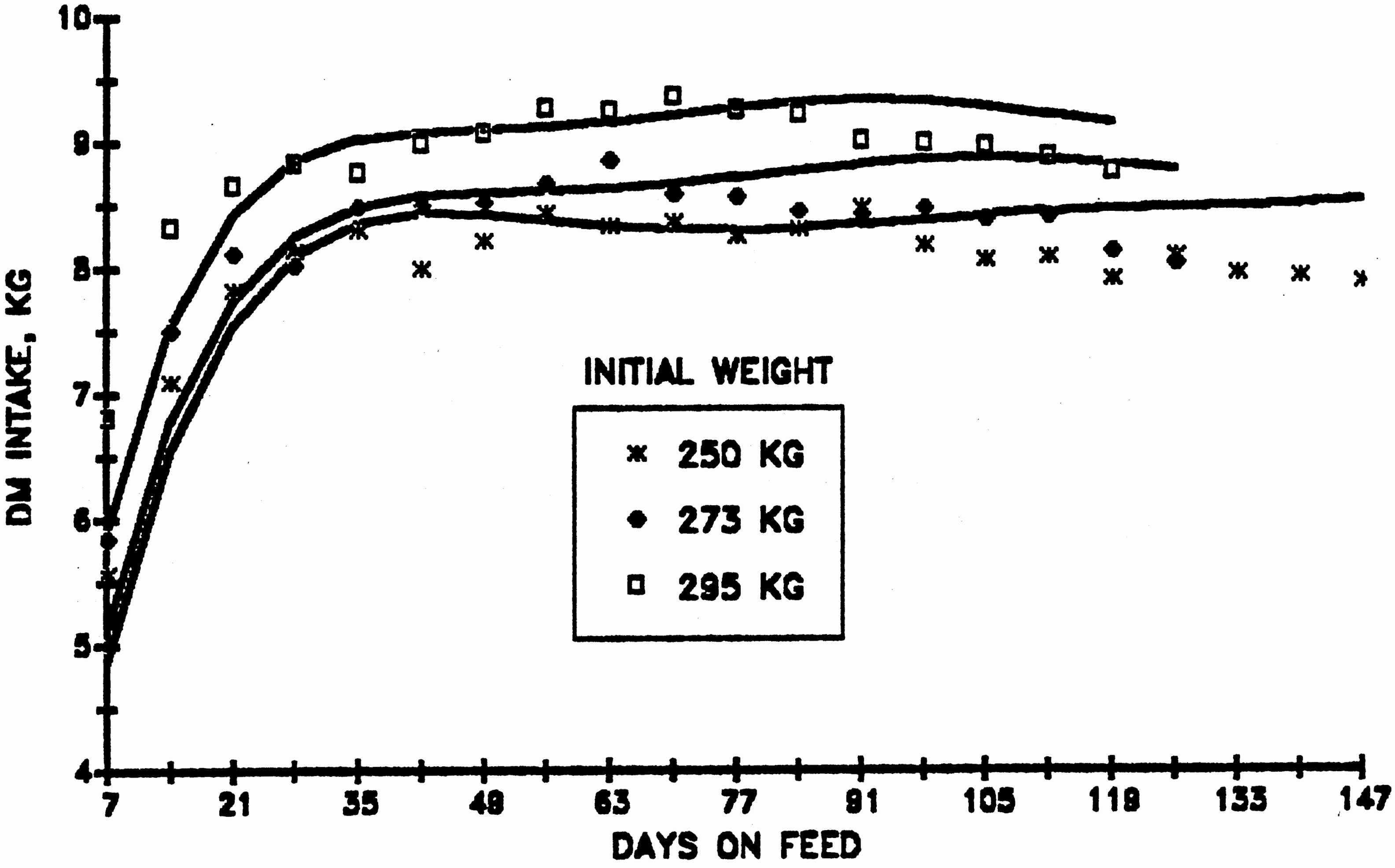

Figure 13. Predicted (Using Steer Equations) and Observed Feed Intakes Versus Days on Feed for Heifers of Various Initial Weights Received October 30 - January 28

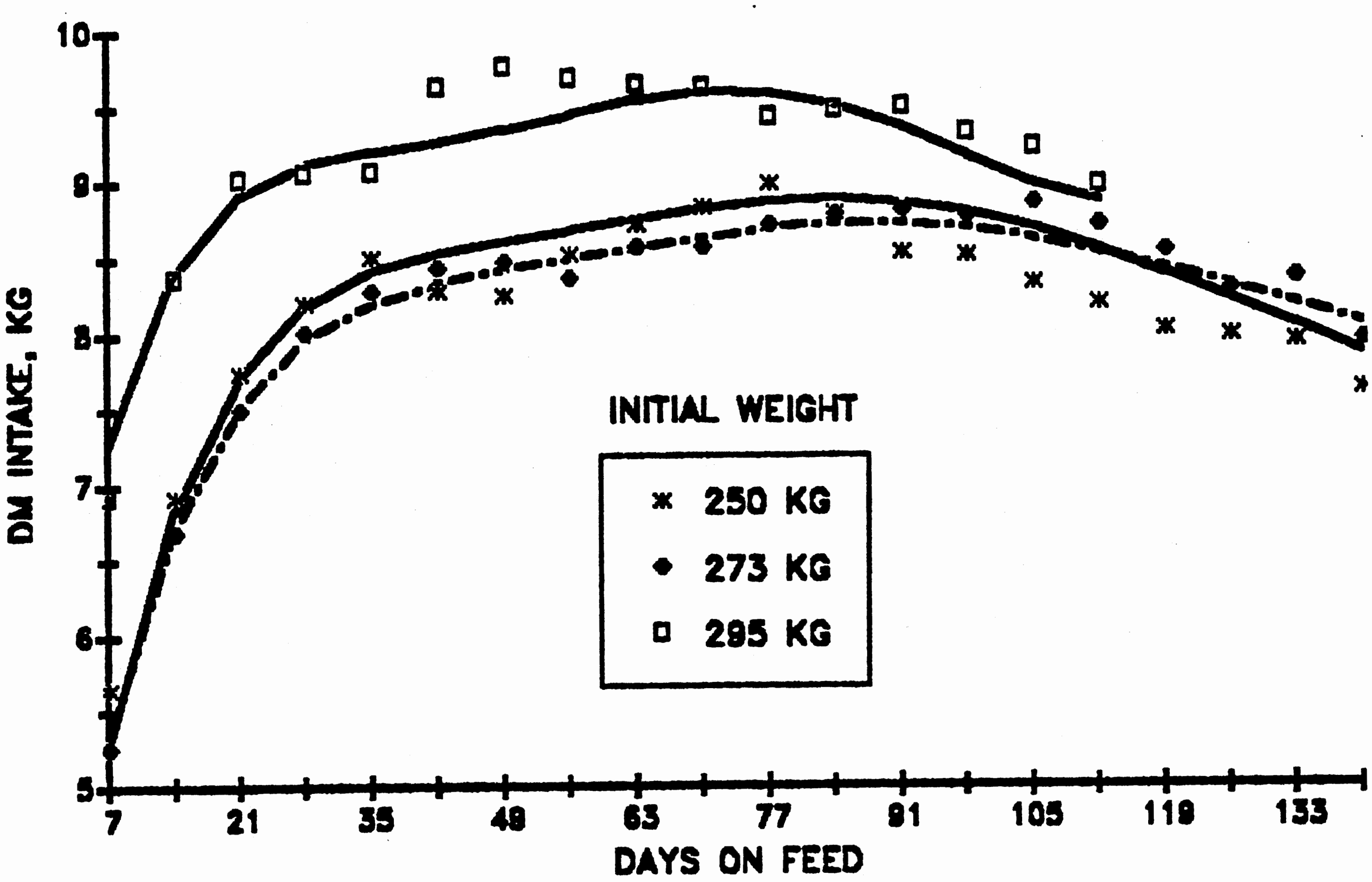

Figure 14. Predicted (Using Heifer Equations) and Observed Feed Intakes Versus Days on Feed for Heifers of Various Initial Weights Received January 29 - April 30

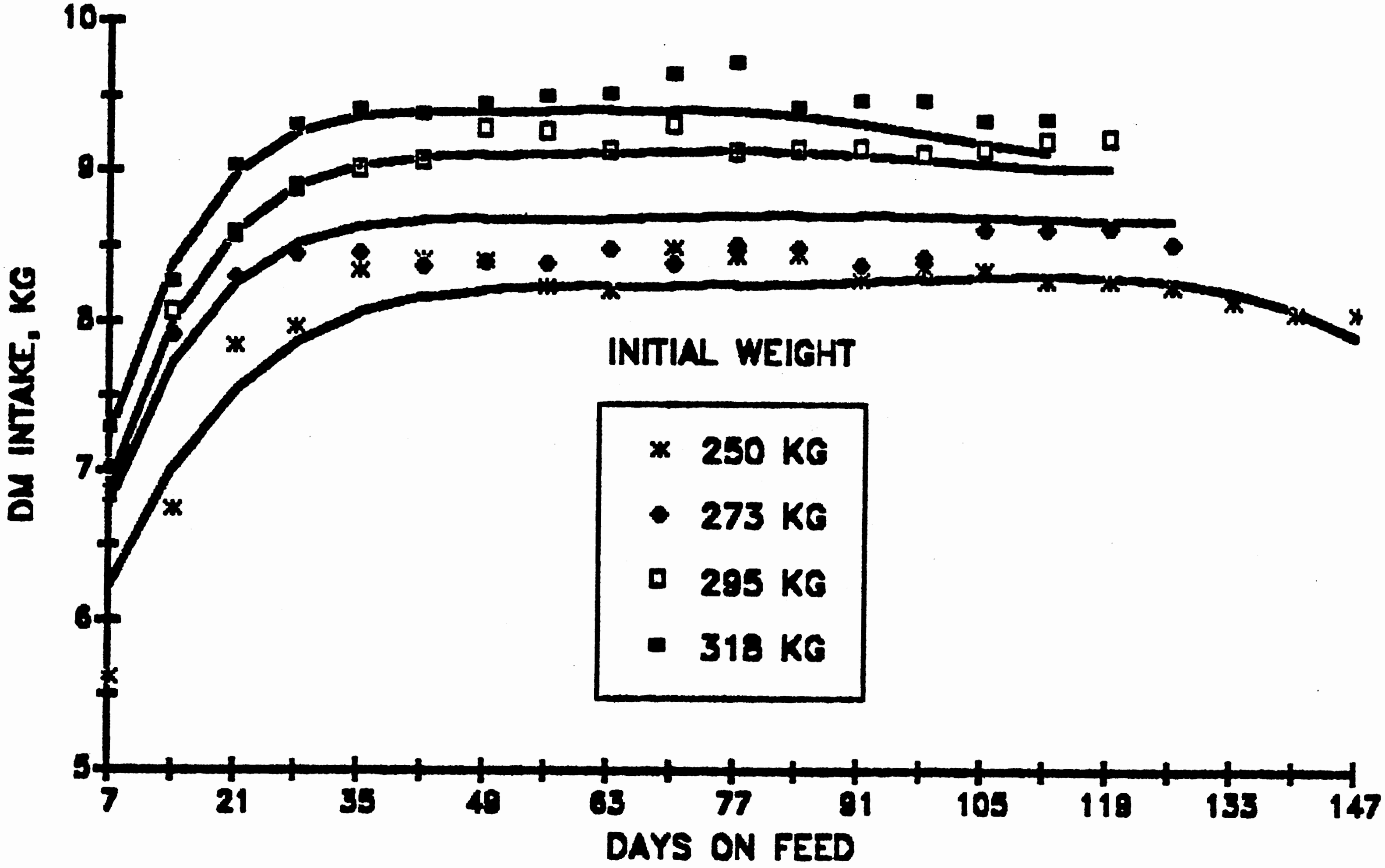

Figure 15. Predicted (Using Heifer Equations) and Observed Feed Intakes Versus Days on Feed for Heifers of Various Initial Weights Received May 1 - July 30

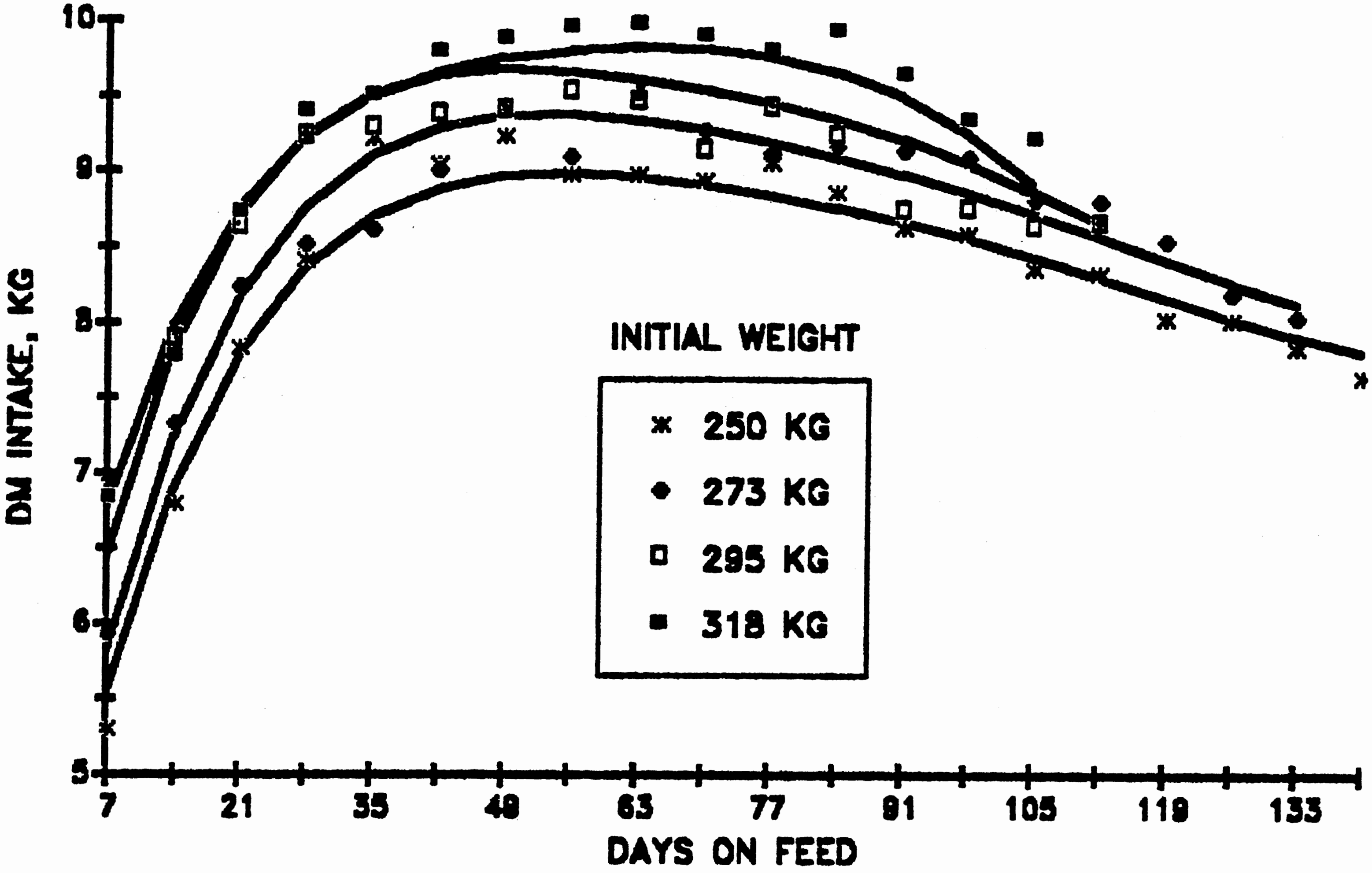

Figure 16. Predicted (Using Heifer Equations) and Observed Feed Intakes Versus Days on Feed for Heifers of Various Initial Weights Received July 31 - October 29

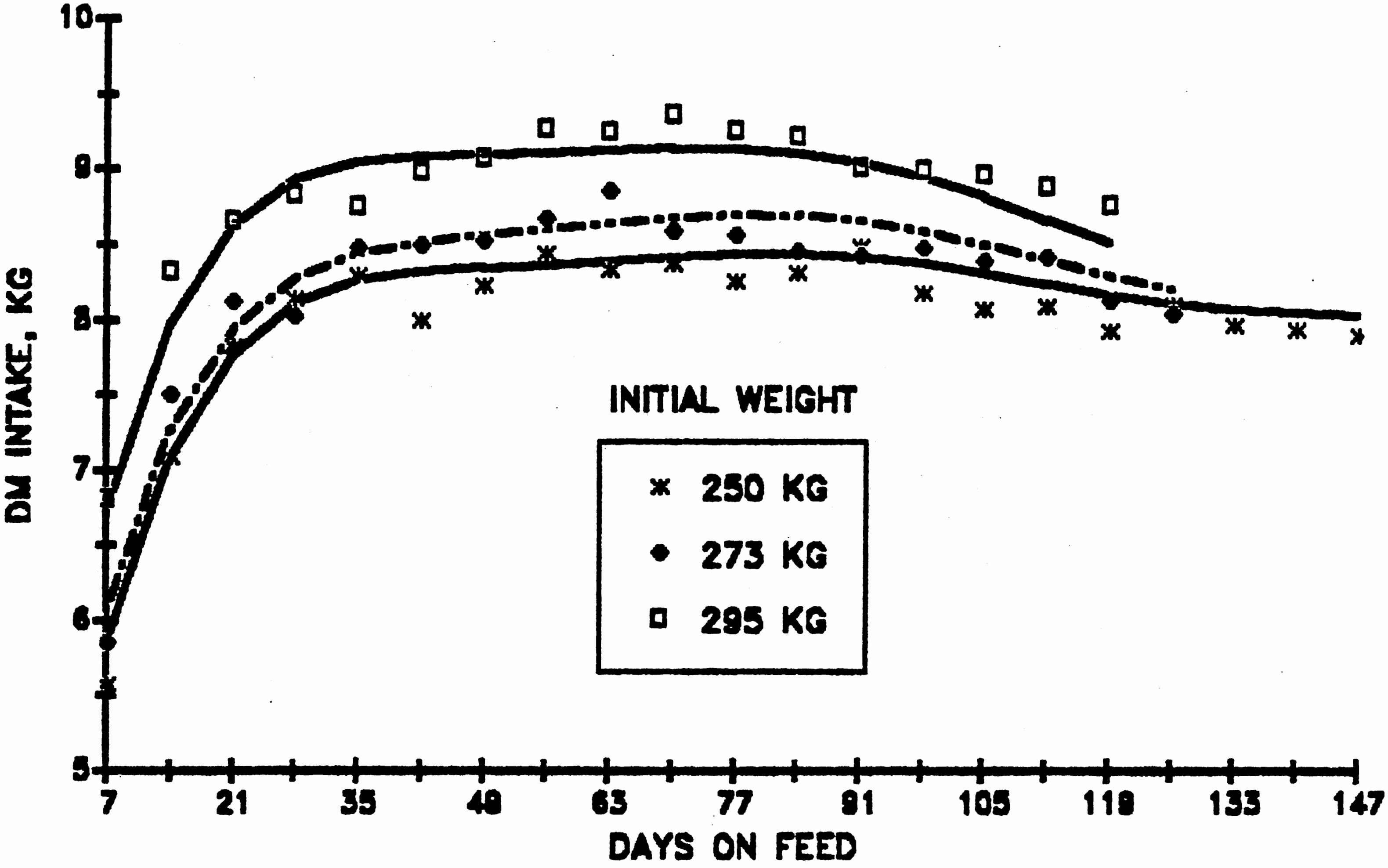

Figure 17. Predicted (Using Heifer Equations) and Observed Feed Intakes Versus Days on Feed for Heifers of Various Initial Weights Received October 30 - January 28

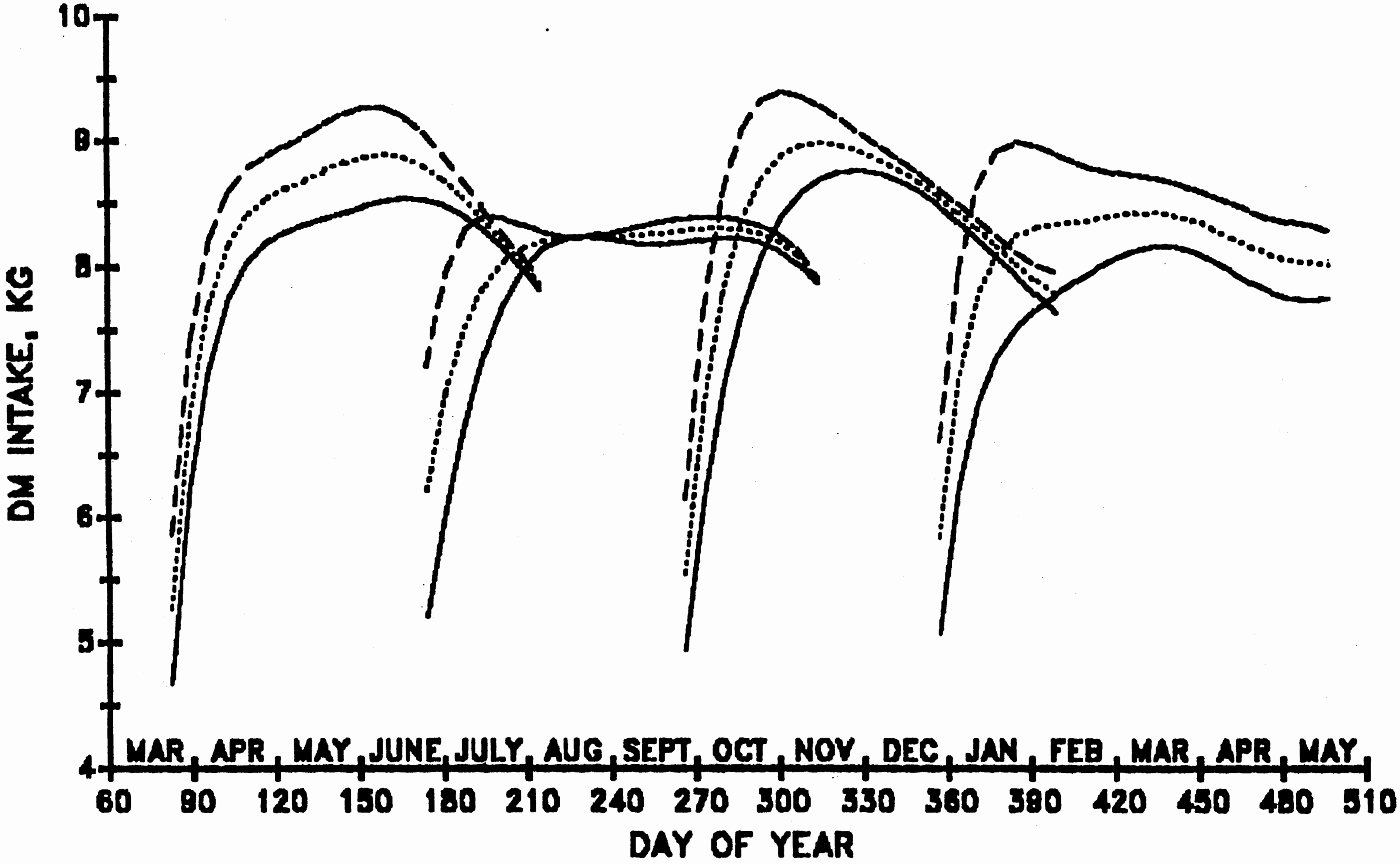

Figure 18. Predicted Feed Intakes Versus Days on Feed, Across Seasons for 250 kg Heifers Eating Below Average, Average or Above Average Over Days 8-28

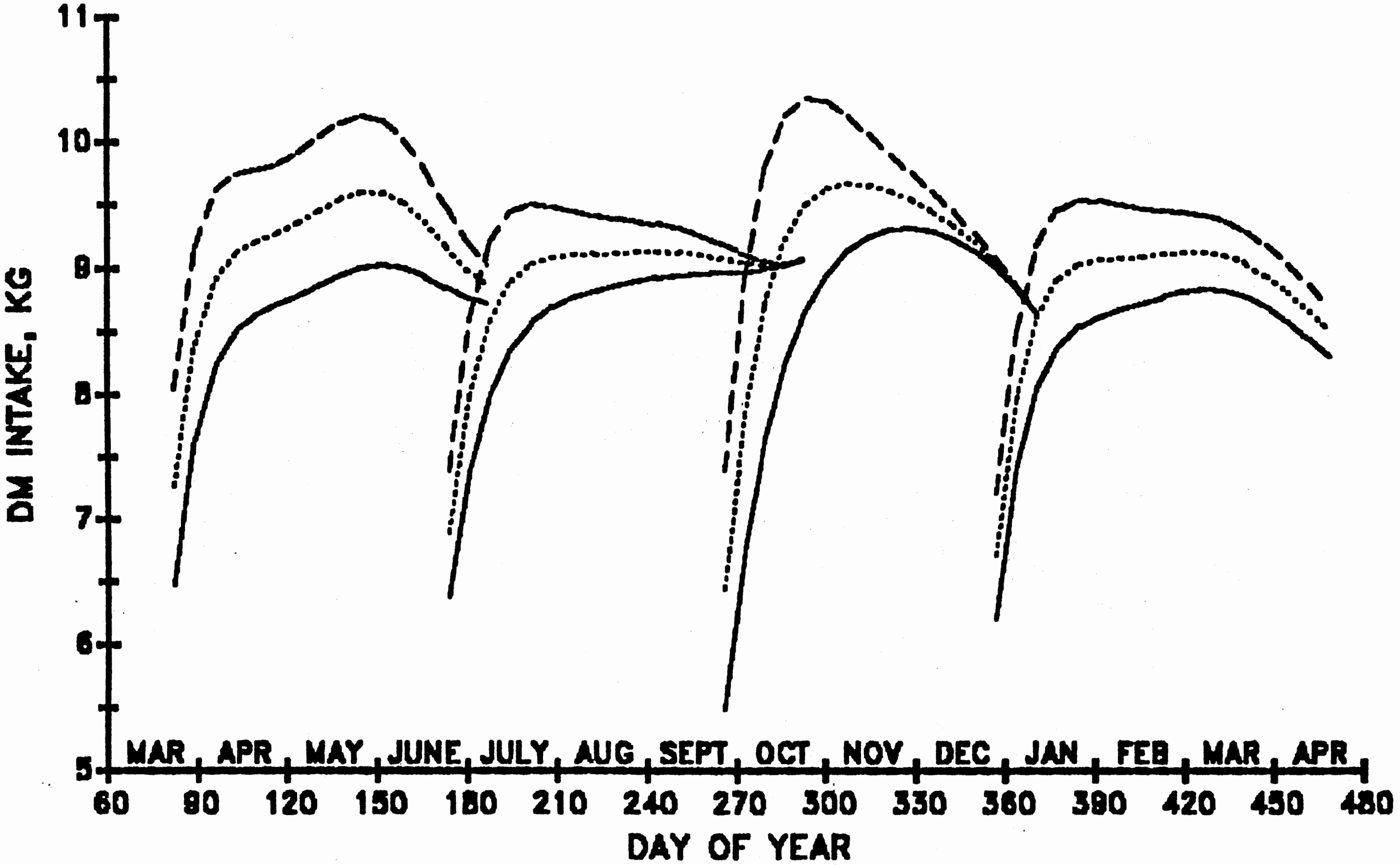

Figure 19. Predicted Feed Intakes Versus Days on Feed Across Seasons for 295 kg Heifers Eating Below Average, Average or Above Average Over Days 8-28

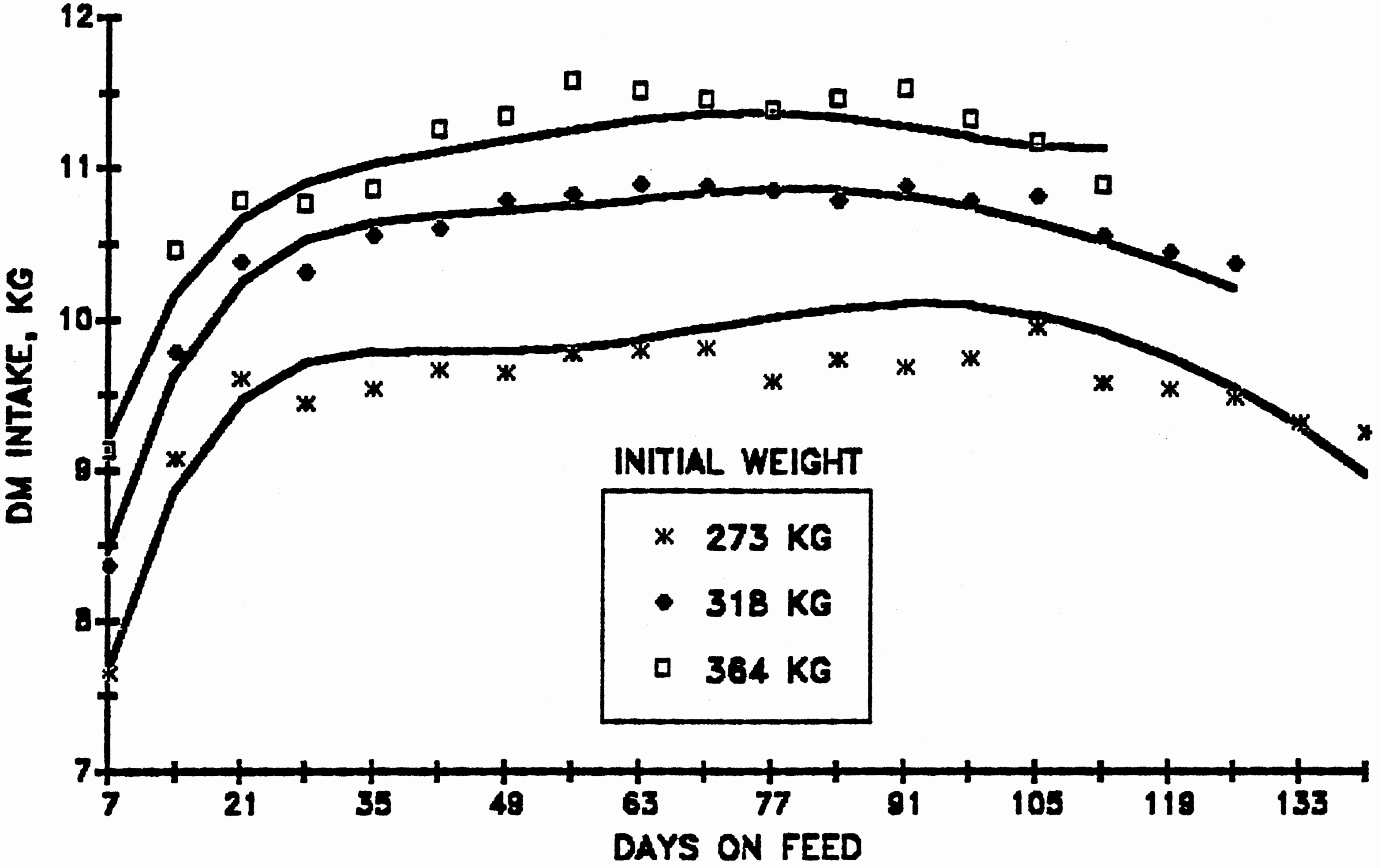

Figure 20. Predicted and Observed Feed Intakes Versus Days on Feed for Holstein Steers of Various Initial Weights Received January 29 - April 30

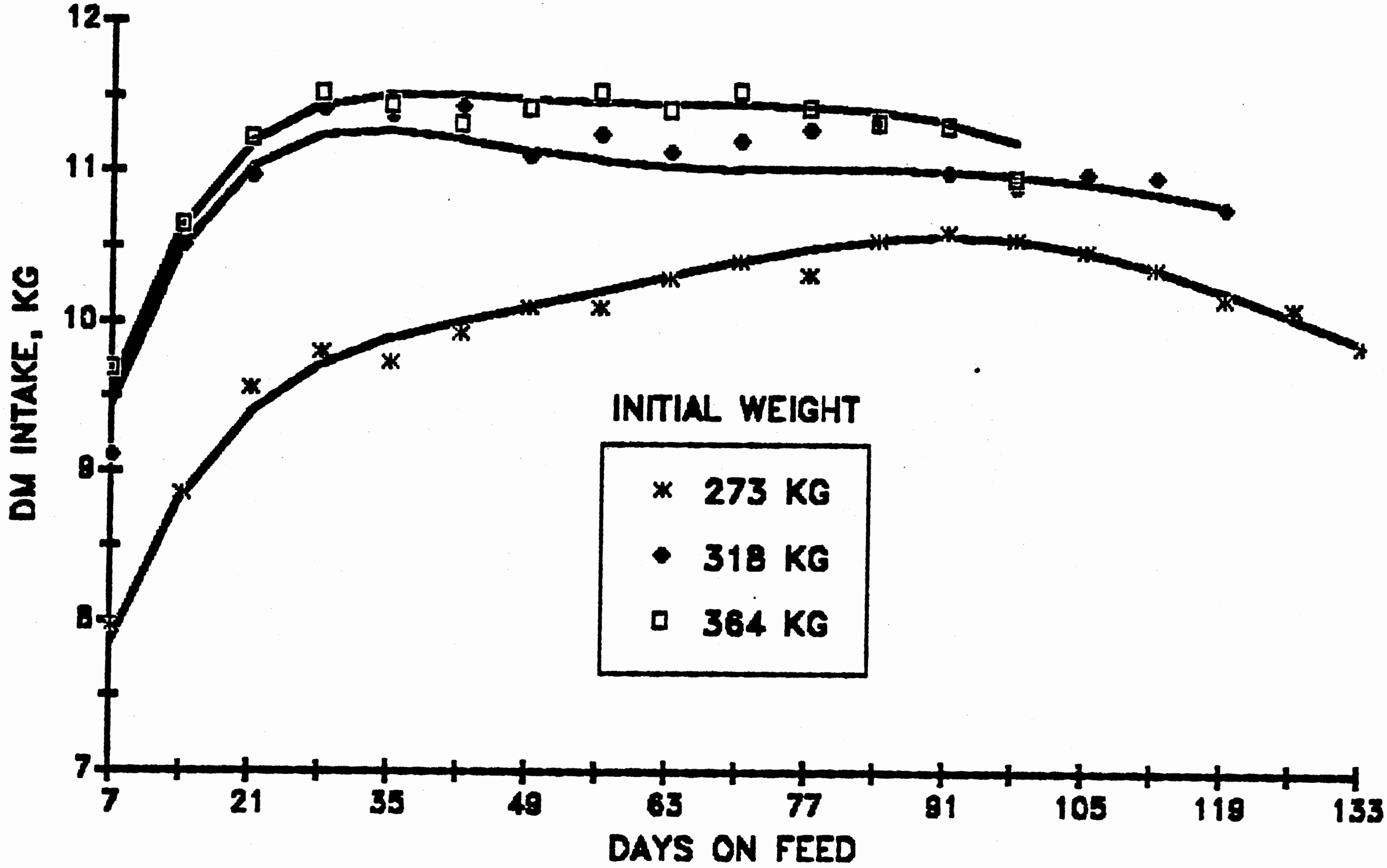

Figure 21. Predicted and Observed Feed Intakes Versus Days on Feed for Holstein Steers of Various Initial Weights Received May 1 - July 30

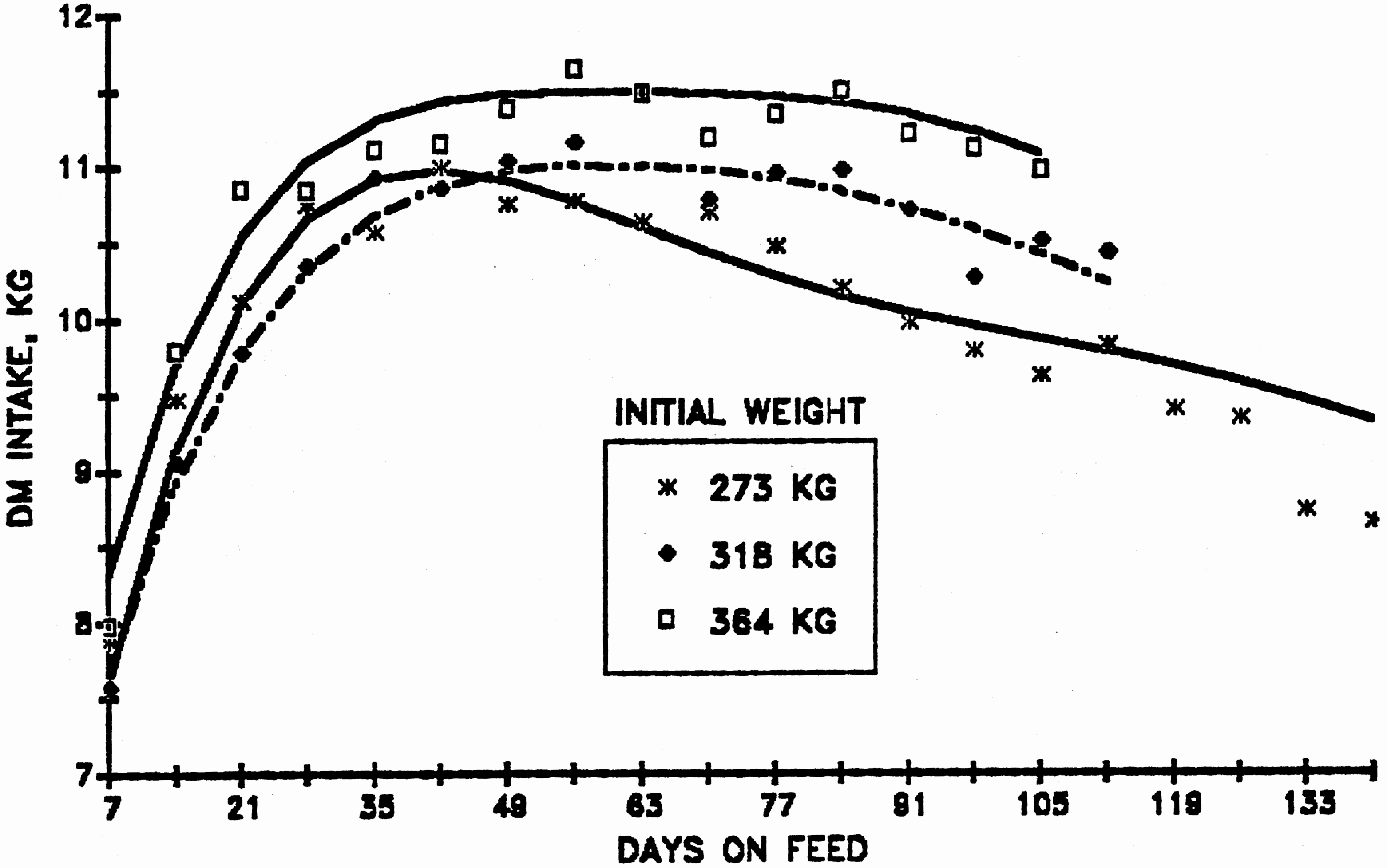

Figure 22. Predicted and Observed Feed Intakes Versus Days on Feed for Holstein Steers of Various Initial Weights Received July 31 - October 29

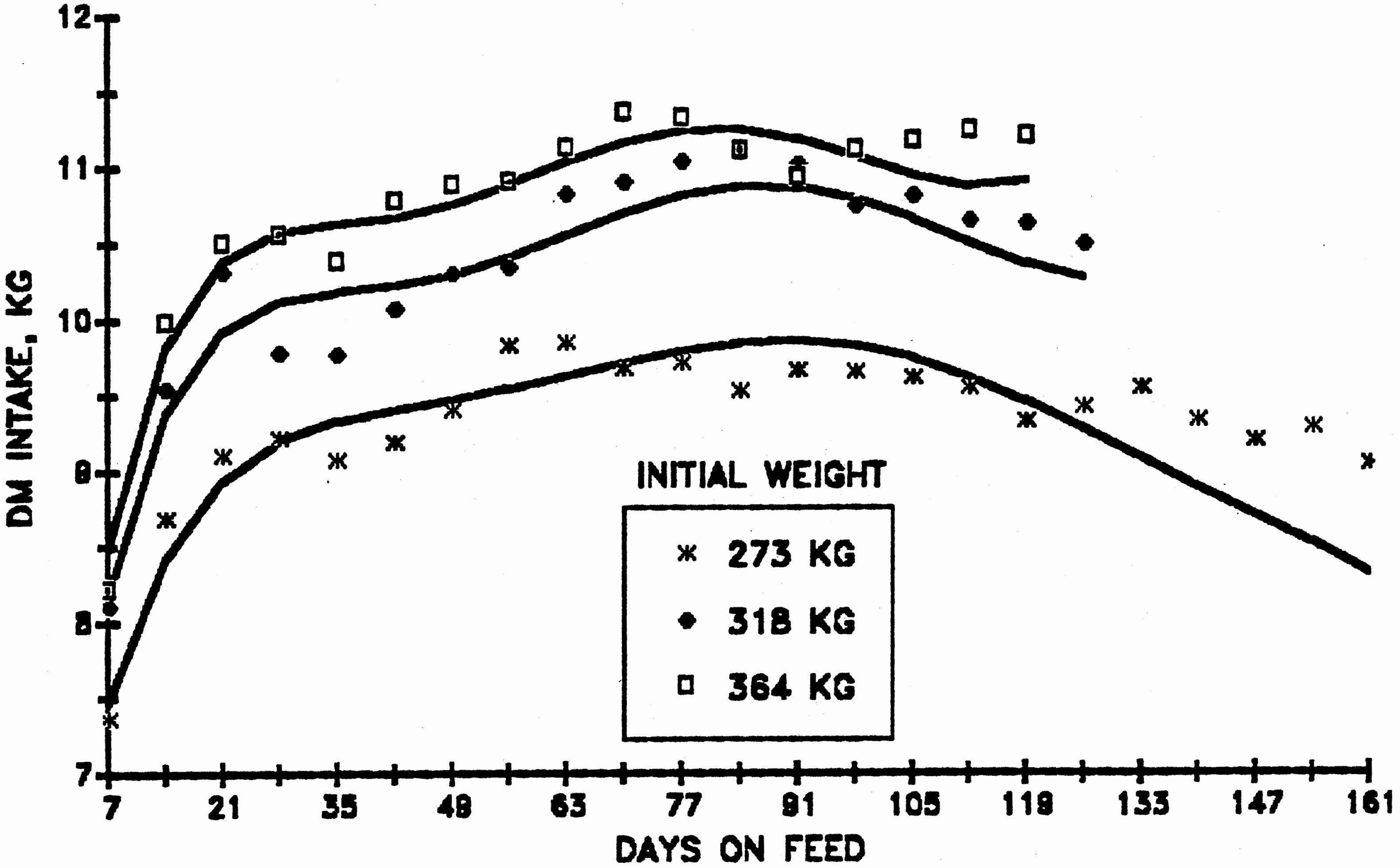

Figure 23. Predicted and Observed Feed Intakes Versus Days on Feed for Holstein Steers of Various Initial Weights Received October 30 - January 28

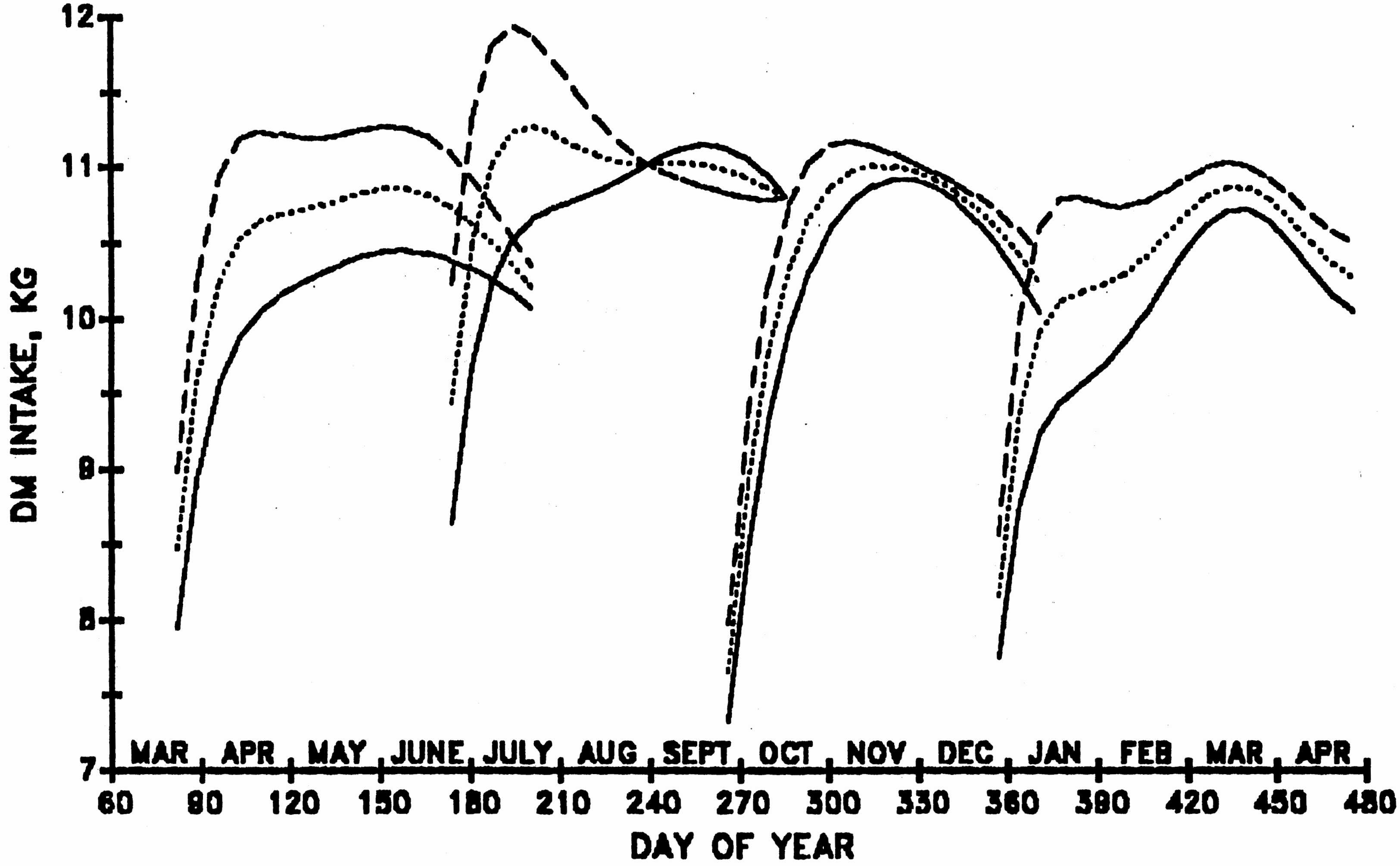

Figure 24. Predicted Feed Intakes Versus Days on Feed Across Seasons for 318 kg Holstein Steers Eating Below Average, Average or Above Average Over Days 8-28

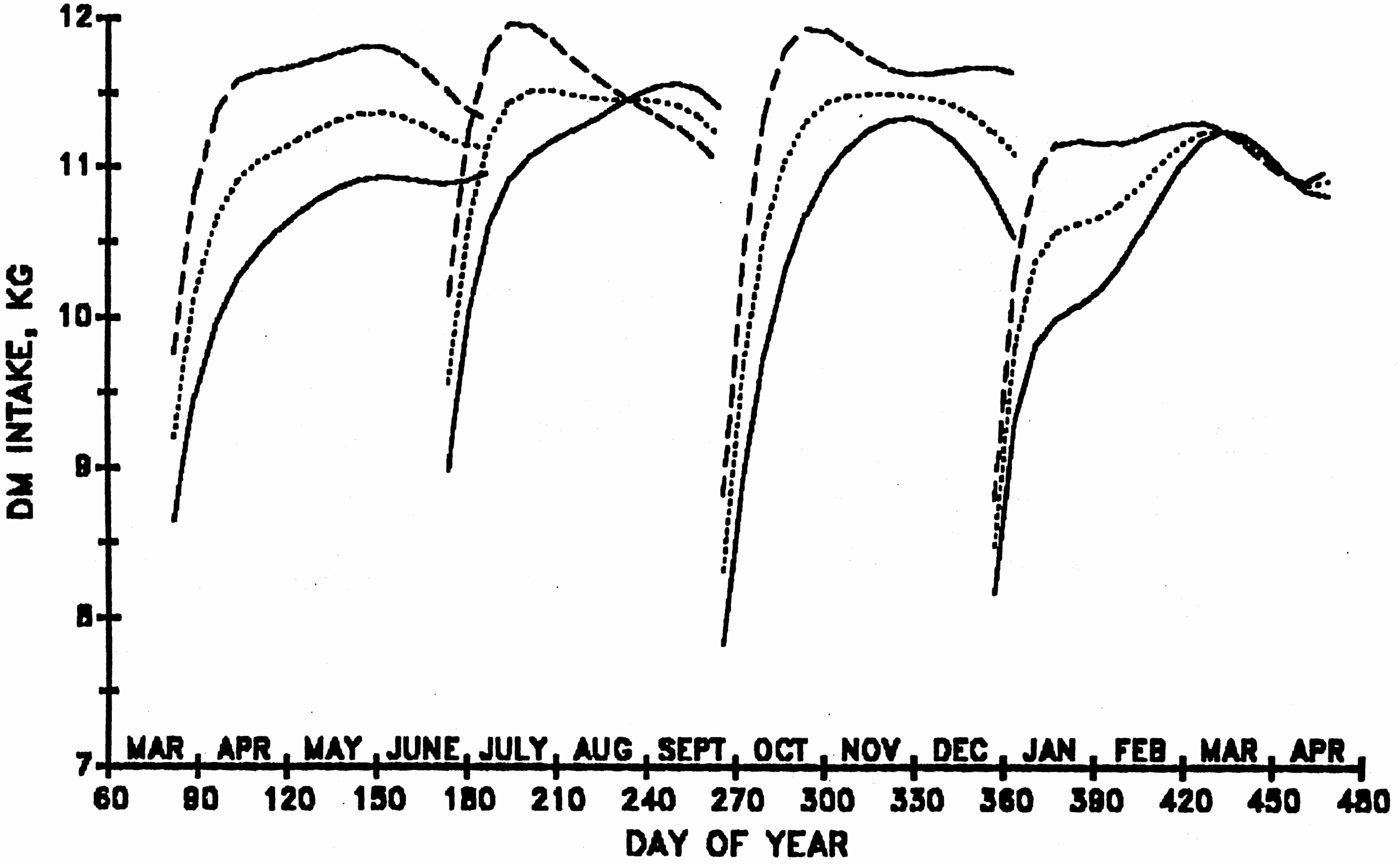

Figure 25. Predicted Feed Intakes Versus Days on Feed Across Seasons for 364 kg Holstein Steers Eating Below Average, Average or Above Average Over Days 8-28

CHAPTER V

EFFECT OF CONTROLLED FEED INTAKE ON PERFORMANCE AND CARCASS CHARACTERISTICS OF FEEDLOT STEERS AND HEIFERS

Summary

Three experiments were conducted to determine the effect of limit feeding on feedlot performance. In experiment 1, 72 yearling steers (374 kg) were fed a high wheat diet either ad libitum or at 85% of ad libitum (controlled). Daily feed intakes over the 149 d trial were 11.98 and 10.13 kg for ad libitum and controlled steers. Efficiency of feed use was improved by 8.9% by controlled feeding (8.80 vs 8.02 kg feed/kg gain). In experiment 2, 80 yearling heifers (329 kg) were fed a high corn diet either ad libitum or at 89% of ad libitum. Daily feed intakes during the 140 d trial averaged 9.68 and 8.59 kg for ad libitum and controlled heifers. Efficiency of feed use was improved by 8.7% (5.96 vs 5.44 kg feed/kg gain) with controlled feeding. In experiment 3, 93 predominantly Hereford yearling steers (293 kg) were fed a high corn diet either ad libitum, 80% of ad libitum for the first 56 days and ad libitum for remainder of trial or were fed to obtain one of two constant daily weight gains (1.50 or 1.35 kg). Daily feed intakes over the 138 d trial were 9.22, 8.38, 8.58 and 7.97 kg/day for ad libitum, 80%, high programmed and low programmed steers, respectively. Daily gains were reduced by 5.9% with controlled feeding (1.53 vs 1.44 kg), whereas feed efficiency was improved by 4% (6.03 vs 5.79 kg feed/kg gain). In all three experiments, the percentage of steers grading choice tended to be reduced with controlled feeding. In experiment 3, improvements in feed efficiency in limit fed steers were not attributable to differences in feed waste, digestibility or maintenance requirements (estimated from liver weight). Benefits from limit feeding may be due to reduced day-to-day fluctuations in feed intake by individual steers.

(Key Words: Cattle, Feedlot, Limit Feeding, Feed Intake, Wheat, Corn.)

Introduction

Several recent studies have reported that feed efficiency of feedlot cattle can be improved by controlling or limiting feed intake. Most of these studies have controlled intake by feeding certain pens of cattle a specific percentage of the feed consumed by pens of cattle with ad libitum access to feed. Restricting feed intake to 92% and 96% of ad libitum improved feed efficiency by 2.5% and 3.2% in a Minnesota trial (Plegge et al., 1985). Plegge et al. (1986), in a follow up study, found improvements of 4.7% and 2.2% in feed conversion with restricted feeding (92% and 96% of ad libitum). Feeding steers at 90% of ad libitum improved conversion ratio by 5.1% (Lofgreen, 1969). In contrast to these studies, others have found that restricted feeding (5 to 17%) resulted in poorer feed use (1 to 7%) and reduced gains (5 to 19%; Davis et al., 1983; Lofgreen et al., 1983; Wagner, 1987). The optimum level of intake appears to be in the range of 90 to 95% of ad libitum. More severe restriction (>10%) depresses gain so severely that feed efficiency is not improved. Benefits with limit feeding seem larger with calves than yearling cattle.

Another new approach to controlled feeding was tested recently by Lofgreen et al. (1987). Three groups of steers were fed either ad libitum or 90% or 80% of ad libitum until the steers reached a weight of 318 kg; at this weight all steers were fed ad libitum until slaughter. Over the 193 day feeding trial, feedlot performance tended to be improved with restricted feeding. Feed efficiency was improved by 5.4% and 4.7% with 90% and 80% of ad libitum feeding during the first portion of the trial. In a similar study, Wagner (1987) restricted feed intake of yearling steers by 15% for the first 56 days of a trial; he noted an 8% poorer feed efficiency.

One additional method of limit feeding (Zinn, 1986) is to limit the amount of feed provided so that cattle will achieve a prescribed daily weight gain. He observed that feed efficiency was improved 4.3% by programming feed intake.

Reducing feed intake should not improve efficiency according to the net energy equations. These equations precisely predict feedlot results of cattle with ad libitum access to feed. However, the above studies indicate that controlled feeding improves efficiency; hence the net energy prediction is inaccurately predicting the direction of the response. Suggested reasons for improved feed efficiency with controlled feeding include reduced feed waste, increased diet digestibility, reduced animal activity, and reduced gut and liver size which in turn reduce the maintenance requirement. The objective of this study was to determine the effect of three different methods of controlled feeding on the performance of feedlot steers and heifers.

The effect of controlled feeding on diet digestibility, passage rate, animal activity, feed waste and liver weight also was measured in experiment 3.

Materials and Methods

Experiment 1

Seventy-two crossbred steers sired by Limousin bulls and out of Hereford/Angus/Brahman cows (0, 1/4 or 1/2 Brahman) were weighed on trial at Goodwell, Oklahoma on April 1, 1986. These steers had grazed winter wheat pasture at El Reno, Oklahoma since November 1985. Prior to the start of the trial, the steers were blocked into three breed groups of 24 head each. Each breed group was further divided into four partially covered pens of six head each with a 2 x 2 factorial of treatments being randomly assigned to each group. Two dietary treatments, hard red winter wheat vs Arkan wheat, were provided either ad libitum or at 85% of ad libitum consumption.

This concentrate ration, consisting of rolled wheat, cottonseed hulls, a pelleted supplement, and molasses (Table 1) was fed twice daily (0700 and 1600) for the entire 149 day trial. Dehydrated alfalfa pellets and cottonseed hulls were used to dilute the ration to 60 percent concentrate to start the cattle on feed. These roughages were decreased sequentially in three steps until the cattle were on their final ration by 28 days on feed. All cattle had ad libitum access to feed for the first 21 days of the study. Amounts of feed offered to cattle being controlled were calculated from amounts consumed by pens with ad libitum access to feed over the past 2 weeks.

Each steer was weighed full on days 28, 56, 84 and 112. On day 140, the steers were weighed by pen because some animals were too large for the individual scales. Steers were trucked 70 miles to Booker, Texas on day 149 of the trial (August 28, 1986) for slaughter, and carcass data were obtained. The data were analyzed using a general linear model (SAS, 1987) with breed type, wheat type and feed treatment (ad libitum vs 85% of ad libitum) as main effects. All two-way interactions were included in the model. No significant interactions between wheat type and feed treatment were observed on any of the criteria evaluated, so only the main effects of feed treatment are reported in this paper.

Experiment 2

Eighty crossbred heifers of the same breed type as the steers used in experiment 1 were weighed on trial at Goodwell on April 10, 1986. These heifers had grazed winter wheat pasture at Goodwell since December 1985. The heifers were blocked into three breed groups of 26 to 28 head each. Each breed group was divided further into two outside pens of either 13 or 14 head, with the two treatments (ad libitum access to feed vs 89% of ad libitum) being randomly assigned within each breed group.

Heifers were fed a whole shelled corn concentrate ration twice daily (0700 and 1300) for the 140 day trial. Roughage content of the diet (dehydrated alfalfa pellets and cottonseed hulls) was decreased sequentially from 40 to 30 to 20 to 10 to 5% over 28 days (Table 2). All cattle had ad libitum access to feed for the first 21 days on feed. Amounts of feed offered to cattle being controlled were calculated from amounts consumed by the ad libitum pens the previous week. Heifers were weighed full at the start of the trial and on days 28, 56, 84 and 112. At day 133, cattle were weighed by pen. These heifers were trucked to Booker, Texas on day 140 of the trial for slaughter. The data were analyzed using a general linear model (SAS, 1987) with breed and feed treatment as main effects.

Experiment 3

Ninety-six crossbred (primarily British crosses) yearling steers which had been wintered on wheat pasture near Dalhart, Texas were trucked to Goodwell, Oklahoma on June 3, 1987. Upon arrival, each animal was individually weighed, ear tagged, implanted with Synovex-S[1], and injected with ivermectin[2] and a BRSV[3] vaccine. These steers were predominantly Herefords (78 head) of small to medium frame size. The steers were divided into twelve pens of eight head each and four treatments were randomly assigned to the pens. The treatments were: 1) controls - fed ad libitum, 2) fed at 80% of ad libitum for first 56 days and ad libitum for remainder of trial, 3) programmed to gain 1.50 kg/day and 4) programmed to gain 1.35 kg/day.

Steers were fed a cracked corn high concentrate ration (Table 3) twice daily (0700 and 1600) for the 138 day trial. Chopped alfalfa hay was used to dilute the ration to 60 percent concentrate to start the cattle on feed. Roughage content of the diet was decreased sequentially in three steps until the cattle were on their final ration by 28 days on feed. For those pens programmed to obtain specific daily weight gains,

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[1] Syntex Animal Health, Inc., Des Moines, IA 50265

[2] Ivomec, MSD Agvet, Rahway, NJ 07065

[3] Norden Laboratories, Inc., Lincoln, NE 685010

daily feed allotments determined in the manner described by Zinn (1986) were increased every two weeks. Amounts of feed offered to cattle being restricted for the first 56 days of the trial were adjusted daily based on the previous day's intakes of pens with ad libitum access to feed.

On days 34 through 40 of the trial, chromic oxide was included in the diet at a level of .2% and on days 40, 42 and 44 fecal grab samples were obtained from 4 to 8 steers per pen. Fecal samples were analyzed for starch, ash, acid-insoluble ash and chromium content. Fecal measurements for day 40 were used to estimate digestibility of the ration and measurements from days 42 and 44 were used to estimate passage rate through the rumen. On days 40 and 41, the steers were observed every 30 minutes for 24 hours (2000 to 1950) to monitor the time spent eating, standing, laying, standing and ruminating, or laying and ruminating.

Cattle weights were off truck weights (shrunk) at the start of the trial but were taken on full-feed on days 28, 56, 84, 112 and 138. Steers were trucked to Holcomb, Kansas on day 139 of the trial (October 22, 1987) for slaughter, and carcass data were obtained. Three steers were removed from the trial for causes not related to the experimental treatments. This trial was analyzed as a completely randomized design using a general linear models procedure (SAS, 1987). Orthogonal comparisons included ad libitum vs the mean of the three limited intake treatments, 80% of ad libitum vs the mean of the high and low programmed steers, and high (1.50 kg gain/day) programmed vs low (1.35 kg/day) programmed rate of gain.

In all three experiments, weights are reported on a full basis while gains and efficiencies were calculated on a shrunk weight (96% of full weight) in an attempt to compensate for digestive tract fill. Gains and efficiencies for each trial were calculated from hot carcass weights assuming that dressing percentage was 62.

Results and Discussion

Experiment 1

Carcass adjusted daily gains of the steers in experiment 1 (Table 4) tended to be reduced by 6.6% with controlled feeding (1.36 vs 1.27 kg/day; P=.22) whereas live weight gains were reduced by 7.4% (P<.01). During the first half of the feeding period, gains were decreased by 12.9% (P<.10) by controlled feeding; this reduction was only 4.5% during the last half of the study. Restriction in feed intake reduced intake over the entire trial to an average of 84.6% of ad libitum (P<.01). Intake was reduced by 8.5% during the first half of the trial and by 18.1% (P<.001) during the second half. Feed efficiency was reduced by 4.8% in the first half of the trial (5.88 vs 6.16 kg feed/kg gain) but improved by 14% (P<.05) during the second half of the trial by controlled feeding. For the entire 149 day trial, feed conversion was improved by 8.9% with controlled feeding (8.80 vs 8.02; P=.14). The estimated ME value of the diet was increased by 6.9% (P=.11) with controlled feeding (2.77 vs 2.96 Mcal/kg). However, the percent of steers grading choice (Table 5) was reduced from 61.1% to 41.7% by controlled feeding (P<.02); this presumably is due partially to their lighter slaughter weight. Although other carcass measurements were not altered, trends indicate fat deposition was reduced by limit feeding.

Experiment 2

Controlled feeding of the heifers in experiment 2 (Table 6) reduced daily gains by 9.6% ($P<.10$) during the first half of the feeding period, but resulted in increased gains (9.9%; $P<.05$) during the second half of the trial. Daily gains over the entire trial were not altered by controlled feeding (1.63 vs 1.58 kg/day). On the average, feed intake was reduced by 11.3% ($P<.01$) over the 140 day trial (9.68 vs 8.59 kg/day), being decreased by 10.3% ($P<.05$) and by 11.4% ($P<.01$) in the first and second halves of the trial, respectively. Although it did not alter feed efficiency during the first half of the trial, controlled feeding improved efficiency by 19.8% ($P<.05$) during the second half of the trial (10.13 vs 8.12 kg feed/kg gain). Efficiency was improved by 8.7% ($P<.10$) over the entire 140 day trial (5.96 vs 5.44). Controlled feeding caused no statistical changes in any of the carcass parameters measured (Table 7) though, as with steers, the percent of heifers grading choice tended to be reduced (38 vs 47%) by controlled feeding and other measurements of fat deposition tended to be lower.

In both of these experiments, feed consumption increased as the feeding period progressed. For typical feedlot cattle, one would expect feed intake to peak and plateau between 60 to 100 days on feed subsequently to declining as cattle approach slaughter weight. It has been suggested that this decline in intake is related to body composition (Hyer et al., 1986) so that when empty body fat reaches a level of about 32%, feed intake decreases. In these trials, perhaps body fat never reached a level of 32%. Fat thickness and percent of animals grading choice were low in both trials.

With both the steers and the heifers in these first two experiments, controlled feeding reduced feed efficiency during the first half of the feeding period but improved efficiency during the second half of the feeding period. This suggests that limiting intake only during the second half of a feeding period might prove most economical. Limiting intake to 85% of ad libitum appears to be too severe because gains were reduced by 7%. Limiting intake to 89% of ad libitum with the heifers improved feed conversion without appreciably reducing gains. Controlled feeding improved feed efficiency and calculated ME with both the high wheat diet and the whole high corn diet.

Results of these first two experiments indicate that controlled feeding of feedlot cattle can improve feed efficiency. Several important questions remain unanswered. First, what is the most desirable method of controlling intake? When should one control intake (early or late in a feeding period)? What is the optimum level of restriction? What type of animals respond best? Experiment 3 was conducted to answer some of these questions.

Experiment 3

The effects of limit feeding on steer performance in experiment 3 are presented in Table 8. Carcass adjusted daily gains tended to be reduced ($P<.10$) with limit feeding (1.53 vs 1.44 kg/day) and liveweight gains were reduced ($P<.05$) by 7.6% (1.31 vs 1.21 kg/day). During the first 56 days of the feeding period, gains were reduced ($P<.01$) by 18.9% with limit feeding (1.48 vs 1.20 kg/day), whereas during the last 82 days there was no difference in gain among the treatment groups. Cattle which were fed at 80% of ad libitum intake during the first 56 days appeared to make compensatory gains during the second half of the trial (1.26 vs 1.16 kg/day for 80% vs ad lib steers). Steers in the high programmed (1.50 kg/day) and low programmed treatment groups (1.35 kg/day) gained only 83.6 and 86.8% of their programmed gains partially because they failed to consume all feed offered during the last half of the trial. Over the 138 day trial, feed intakes were 90.9, 93.0 and 86.5% of ad libitum for 80%, high programmed and low programmed steers, respectively. Over the first 56 days, intake for the 80% steers was 84.2% of ad libitum.

During the first 56 days of the feeding period, feed efficiency was not altered (P>.10) by limit feeding. However, during the second half of the trial feed efficiency tended (P<.10) to be improved (7.2%) with limit feeding (7.96 vs 7.39 kg feed/kg gain). These results are quite similar to those of the first two experiments. Over the entire trial, feed efficiency on a carcass weight basis tended to be improved (P<.10) by 4% with limit feeding (6.03 vs 5.79). The most efficient steers were those programmed to obtain specific weight gains. Dietary net energy values for maintenance (NEm) and gain (NEg) and metabolizable energy values (ME) were calculated from performance by the method described by Hays et al. (1987). Estimated NEm, NEg and ME values were increased (P<.01) by 4.2, 4.3 and 2.9%, respectively, with limit feeding. The estimated NEm and NEg values for the ad libitum fed steers were considerably lower (1.85 and 1.23 Mcal/kg) than those calculated from diet composition (2.08 and 1.34 Mcal/kg).

Effects of limit feeding on carcass characteristics are presented in Table 9. Dressing percentage tended (P<.10) to be lower for steers fed 80% of ad libitum for the first 56 days than for programmed steers

(65.8 vs 66.6%). The percent of steers grading choice tended to be reduced ($P<.10$) with limit feeding (96 vs 72%) as also was noted in the first two experiments. Final liver weight was not altered by limit feeding in these cattle. However, liver weight expressed as grams per kg of metabolic body size tended to increase with limit feeding (57.3 vs 60.6 $g/kg^{.75}$; $P=.12$). If maintenance requirements are correlated to liver mass, reduced maintenance requirements cannot explain the observed improvements in feed efficiency.

Limit feeding did not alter steer behavior in this group of cattle (Table 10). These steers spent means of 15.5, 6.6 and 54.4% of their time ruminating, eating and lying, respectively. Further discussion of the behavior pattern of these steers is presented the Appendix. Passage rate and diet digestibility also were not altered by limit feeding (Table 11). Hence, reduced animal activity or increased diet digestibility apparently cannot account for the improvement in feed efficiency noted with limit feeding. However, variation in digestibility estimates were large, so some benefit yet may be due to increased digestibility.

Another potential reason for improvements observed in feed efficiency with limit feeding is reduced feed waste. On day 43 of this trial, the concrete bunk pads were cleaned so that feed waste over a 24 hour period could be monitored. No feed waste was observed in any of the pens. Other potential reasons for improvement are reduced animal-to-animal variation and reduced day-to-day variation in feed intake within a pen with limit feeding (Zinn, 1986). Zinn proposed that animals with ad libitum access to feed exhibit wide day-to-day (and within day) fluctuations in feed intake which may result in digestive disturbances and decreased feed utilization. During the 24 hour observation period aggressive eaters and timid eaters were noted in both ad libitum and limit fed pens. Animal-to-animal variation in time at the bunk was not reduced with limit feeding. However, day-to-day variation in pen intake was reduced with programming of feed intakes because steers were fed constant amounts of feed over two week intervals (Figure 1). For steers fed at 80% of ad libitum for the first 56 days, day-to-day variation was not altered because feed allotments were adjusted daily based on intakes of pens with ad libitum access to feed (Figure 2).

In summary, results of these three experiments indicate that limit feeding improves feed efficiency of feedlot steers but reduces rate of gain. Specific reasons for this improvement were not determined. Reduced liver size, reduced animal activity, reduced feed waste or increased diet digestibility were not observed in experiment 3 and cannot explain improvements in feed efficiency. Reduced day-to-day fluctuations in feed intake in programmed steers possibly could account for some of the improvement in feed efficiency.

One major concern with controlled feeding is the reduction in the percentage of cattle grading choice. Typically carcasses grading select receive about $3-7/cwt less than those grading choice. A reduction in the percentage of cattle grading choice was noted in all three experiments (Exp. 1: 61 vs. 42%, Exp. 2: 47 vs 38%, Exp. 3: 96 vs 72%). Similarly, Lofgreen (1969) noted that the percentage of carcasses grading choice was reduced from 92 to 67% in steers fed 86% of ad libitum. Lofgreen et al. (1983) observed that even though limit fed steers (90% of ad libitum) were fed two weeks longer than ad libitum fed steers, their carcasses still had significantly lower marbling scores and quality. However, Wagner (1987) fed restricted steers (83% of ad libitum) an additional 9 days as compared to ad libitum fed steers and reported no difference in percentages of steers grading choice. In an another trial, Wagner (1987) fed restricted steers (94 and 90% of ad libitum) an additional 11 and 20 days, respectively, and detected no difference in the percentages of steers grading choice. However, in neither trial did Wagner detect an improvement in feed efficiency with limit feeding.

Perhaps, the benefits of improved feed efficiency with controlled feeding could be maximized while minimizing the reduction in marbling scores and carcass quality by restricting intake by no more than 5%. Under research conditions, this type of controlled feeding program may be feasible. But under feedlot conditions, such a program would be difficult to implement. Programming gain to a specific rate as tested in experiment 3 and by Zinn (1986) would be the simplest and most feasible method to apply under feedlot conditions and is being used by some yards in California (Zinn, 1987). However, gains for different sets of cattle are difficult to predict. With this method of controlled feeding, under-guessing performance of a set cattle probably is a costly mistake as it is difficult for improved efficiency to fully compensate for lost time.

Several potential advantages of controlling feed intake of finishing cattle in addition to improving feed efficiency have been suggested by Lake (1987b) and Zinn (1987b). These include: 1) improved bunk management, 2) reduced labor for calling feed, 3) greater control over feed inventories, 4) reduced bunk cleaning, 5) reduced feed wastage, 6) reduced feed hauling, 7) less manure needs to be handled and 8) more precision in attaining slaughter dates to meet futures contracts.

TABLE 1. RATION COMPOSITION, DRY MATTER BASIS (EXPERIMENT 1)

	Ration Sequence			
	1	2	3	4[a]
Ingredient	%			
Rolled wheat	51	61	71	81.45
Cottonseed hulls	20	15	10	9.55
Alfalfa, dehy-pellets	20	15	10	-----
Molasses	4	4	4	4
Pelleted supplement	5	5	5	5
	Supplement Composition, % of DM			
Alfalfa meal	2.95			
Cottonseed meal	.50			
Calcium carbonate	.81			
Urea	.40			
Salt	.30			
Rumensin 60 gram	.02			
Vitamin A-30000	.01			
Tylan 40 gram	.01			

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[a] To provide 1.82 Mcal NEm/kg, 1.27 Mcal NEg/kg, .033 g monensin/kg, .01 g tylan/kg, 3300 IU Vit A/kg, 13.5% crude protein, .78% potassium, .50% calcium and .38% phosphorus.

TABLE 2. RATION COMPOSITION, DRY MATTER BASIS (EXPERIMENT 2)

	Ration Sequence				
	1	2	3	4	5[a]
Ingredient			%		
Corn, whole shelled	52.55	62.55	72.55	82.55	87.55
Cottonseed hulls	20	15	10	5	5
Alfalfa, dehy-pellets	20	15	10	5	-----
Pelleted supplement	7.45	7.45	7.45	7.45	7.45

	Supplement Composition, % of DM
Cottonseed meal	2.93
Soybean meal	1.75
Molasses	.28
Calcium carbonate	1.10
Salt	.30
Urea	.45
Potassium chloride	.37
Dicalcium phosphate	.20
Vitamin A-3000	.02
Monensin 60 gram	.03
Tylan 40 gram	.01
Trace mineral	.01

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[a] To provide 2.11 Mcal NEm/kg, 1.36 Mcal NEg/kg, .033 g monensin/kg, .01 g tylan/kg, 3300 IU Vit A/kg, 11.7% crude protein, .65% potassium, .50% calcium and .34% phosphorus.

TABLE 3. RATION COMPOSITION, DRY MATTER BASIS (EXPERIMENT 3)

	Ration Sequence			
Ingredient	1	2	3	4[a]
	%			
Corn, cracked	52.70	62.28	71.87	80.02
Chopped alfalfa	38.36	28.78	19.19	11.04
Cane molasses	3.88	3.88	3.88	3.88
Pelleted supplement[b]	5.06	5.06	5.06	5.06

	Supplement Composition, % of DM
Soybean meal	2.04
Wheat middlings	.64
Meat meal	.60
Calcium carbonate	.53
Dicalcium phosphate	.07
Urea	.49
Salt	.50
Potassium chloride	.04
Bovatec, 68 g/lb	.02
Vitamin A, 30000 IU/g	.01
Vitamin E	.01
Trace minerals	.01
Mineral oil	.10
Total	5.06

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[a] To provide 12.25% protein, .53% calcium, .78% potassium, .33% phosphorus, 2.08 Mcal NEm/kg, 1.34 Mcal NEg/kg and 30 g lasalocid/ton of total feed.

TABLE 4. EFFECT OF CONTROLLED FEEDING ON PERFORMANCE (EXPERIMENT 1)

	Ad libitum	Limit Fed	SEM	P-Level
Number of steers	36	36		
Number of pens	6	6		
Weight, kg				
Initial	375	374	.5	
28 days	428	423	3.0	
56 days	471	461	2.7	
84 days	514	506	3.3	
112 days	551	543	4.0	
140 days	587	572	.8	.01
Daily gains, kg				
0-28	1.29	1.13	.091	
29-56	1.50	1.31	.03	.02
57-84	1.46	1.56	.018	.053
85-112	1.28	1.25	.064	
113-140	1.24	.99	.123	
0-56	1.40	1.22	.041	.09
57-140	1.32	1.26	.032	
0-140, live	1.35	1.25	.005	.003
0-149, carcass	1.36	1.27	.036	
Daily feed, lb DM				
0-28	7.14	6.90	.236	
29-56	9.17	8.05	.177	.05
57-84	13.08	10.32	.068	.001
85-112	14.48	11.92	.109	.004
113-140	15.42	12.95	.064	.001
0-56	8.16	7.47	.191	
57-140	14.33	11.73	.036	.0004
0-140, live	11.86	10.03	.059	.002
0-149, carcass	11.98	10.13	.055	.002
Feed/Gain				
0-28	5.66	6.15	.30	
29-56	6.12	6.21	.25	
57-84	9.07	6.64	.15	.01
85-112	11.43	9.76	.44	
113-140	12.78	14.09	2.09	
0-56	5.88	6.16	.18	
57-140	10.83	9.31	.23	.05
0-140, live	8.78	8.06	.07	.02
0-149, carcass	8.80	8.02	.23	
Net energy, Mcal/kg				
Maintenance	1.65	1.81	.041	.12
Gain	1.07	1.20	.031	.107
Metabolizable energy, Mcal/kg	2.66	2.84	.046	.113

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[a] Based on carcass weight divided by .62, an assumed dressing percent.

TABLE 5. EFFECT OF CONTROLLED FEEDING ON CARCASS PARAMETERS (EXPERIMENT 1)

	Ad libitum	Limit Fed	SEM	P-Level
Carcass wt, kg	358	349	3.8	
Dressing percent	63.5	63.6	.65	
Rib eye area, sq cm	89.42	87.88	1.42	
KHP, %	2.24	2.21	.05	
Fat thickness, cm	.86	.79	.05	
Marbling score[a]	12.53	12.11	.26	
Percent choice	61.1	41.7	2.0	.02
USDA Yield Grade	2.36	2.28	.09	

[a] 12=slight plus, 13=small minus

TABLE 6. EFFECT OF CONTROLLED FEEDING ON PERFORMANCE (EXPERIMENT 2)

	Ad libitum	Limit Fed	SEM	P-Level
Number of heifers	40	40		
Number of pens	6	6		
Weight, kg				
Initial	330	326	.9	.10
28 days	389	389	3.4	
56 days	445	430	1.5	.02
84 days	474	466	1.8	.09
112 days	510	502	1.4	.06
133 days	526	519	2.3	
Daily gains, kg				
0-28	2.02	2.13	.105	
29-56	1.91	1.43	.155	
57-84	.99	1.23	.100	
85-112	1.23	1.23	.068	
113-133	.77	.78	.055	
0-56	1.97	1.78	.041	.08
57-133	1.01	1.11	.018	.054
0-133, live	1.41	1.39	.023	
0-140, carcass[a]	1.63	1.58	.027	
Daily feed, kg DM				
0-28	8.59	8.36	.123	
29-56	9.41	7.78	.200	.03
57-84	8.98	8.50	.091	.06
85-112	10.45	9.01	.036	.001
113-133	11.03	9.35	.027	.001
0-56	9.00	8.07	.150	.05
57-133	10.07	8.92	.045	.003
0-133, live	9.62	8.56	.068	.008
0-140, carcass	9.68	8.59	.068	.008
Feed/Gain				
0-28	4.26	3.94	.25	
29-56	4.94	5.71	.75	
57-84	9.22	7.10	.47	.08
85-112	8.63	7.34	.44	
113-133	15.67	12.25	1.38	
0-56	4.58	4.56	.18	
57-133	10.13	8.12	.31	.05
0-133, live	6.82	6.16	.17	.105
0-140, carcass[a]	5.96	5.44	.13	.105
Net energy, Mcal/kg				
Maintenance	2.00	2.18	.044	.105
Gain	1.32	1.43	.029	.123
Metabolizable energy, Mcal/kg	3.03	3.20	.045	.115

[a] Based on carcass weight divided by .62, an assumed dressing percent.

TABLE 7. EFFECT OF CONTROLLED FEEDING ON CARCASS PARAMETERS (EXPERIMENT 2)

	Ad libitum	Limit Fed	SEM
Carcass wt, kg	338	331	2.1
Dressing percent	66.8	66.5	.45
Rib eye area, sq cm	89.23	87.36	4.06
KHP, %	2.61	2.51	.14
Fat thickness, cm	1.12	1.02	.15
Marbling score[a]	11.9	11.5	.62
Percent choice	47.3	37.7	14.2
USDA Yield Grade	2.52	2.45	.05

[a] 11=average slight, 12=slight plus

TABLE 8. EFFECT OF CONTROLLED FEEDING ON PERFORMANCE (EXPERIMENT 3)

	Ad Libitum	80 %	High Prog	Low Prog	SEM	Contrasts^{e}
No. of Pens	3	3	3	3		
No. of Head	22	24	23	24		
Weight, kg						
Initial	293	293	294	293	0.5	
Day 28	361^{a}	348^{ab}	346^{b}	343^{b}	4.1	AL^{*}
Day 56	391^{a}	373^{bc}	381^{b}	372^{c}	2.6	$\text{AL}^{**},\text{HL}^{**}$
Day 84	427^{a}	416^{b}	424^{a}	414^{b}	2.0	$\text{AL}^{**},\text{HL}^{**}$
Day 112	466^{a}	452^{ab}	459^{ab}	446^{b}	4.5	$\text{AL}^{*},\text{HL}^{+}$
Day 138	493^{a}	481^{ab}	485^{ab}	473^{b}	3.7	$\text{AL}^{*},\text{HL}^{*}$
Daily Gain, kg						
0-28 days	1.93^{a}	1.45^{b}	1.39^{b}	1.27^{b}	.14	AL^{**}
29-56 days	1.03	.87	1.21	1.03	.17	
57-84 days	1.25	1.48	1.44	1.43	.09	AL^{+}
85-112 days	1.33	1.24	1.21	1.10	.13	
113-138 days	.98	1.06	.98	.99	.10	
0-56 days	1.48^{a}	1.16^{b}	1.30^{b}	1.15^{b}	.05	$\text{AL}^{**},\text{HL}^{+}$
57-138 days	1.19	1.26	1.21	1.18	.05	
0-138 days	1.31^{a}	1.22^{ab}	1.25^{ab}	1.17^{b}	.03	$\text{AL}^{*},\text{HL}^{+}$
0-139 days^{d}	1.53	1.41	1.50	1.39	.04	$\text{AL}^{+},\text{HL}^{+}$
DM Intake, kg						
0-28 days	8.80^{a}	7.05^{c}	7.34^{b}	6.69^{d}	.05	$\text{AL}^{**},\text{HL}^{**}$
29-56 days	8.94^{a}	7.26^{d}	8.25^{b}	7.57^{c}	.07	$\text{AL}^{**},80^{**},\text{HL}^{**}$
57-84 days	9.13^{a}	8.63^{b}	8.63^{b}	8.13^{c}	.11	$\text{AL}^{**},80^{+},\text{HL}^{**}$
85-112 days	9.51	9.46	9.33	8.67	.27	
113-138 days	9.79	9.57	9.53	8.87	.27	
0-56 days	8.50^{a}	7.16^{b}	7.80^{ab}	7.13^{b}	.23	$\text{AL}^{**},\text{HL}^{+}$
57-138 days	9.46^{a}	9.21^{a}	9.14^{a}	8.55^{b}	.17	$\text{AL}^{*},\text{HL}^{*}$
0-138 days	9.22^{a}	8.38^{b}	8.58^{b}	7.97^{c}	.10	$\text{AL}^{**},\text{HL}^{**}$

TABLE 8 (CONTINUED)

	Ad Libitum	80 %	High Prog	Low Prog	SEM	Contrasts[e]
Feed/Gain						
0-28 days	4.58	5.07	5.37	5.39	.52	
29-56 days	8.79	9.01	7.28	7.82	1.32	
57-84 days	7.43^{a}	5.92^{b}	6.00^{b}	5.71^{b}	.42	AL**
85-112 days	7.22	8.14	7.76	8.01	.87	
113-138 days	10.24	9.32	9.83	9.06	.89	
0-56 days	5.75	6.20	6.02	6.21	.22	
57-138 days	7.96	7.35	7.54	7.27	.23	AL^{+}
0-138 days	7.06	6.87	6.88	6.84	.09	AL^{+}
0-139 days[d]	6.03	5.93	5.72	5.73	.11	AL^{+}
Net Energy, Mcal/kg						
Maintenance	1.85^{b}	1.93^{a}	1.92^{a}	1.95^{a}	.02	AL**
Gain	1.23^{b}	1.28^{a}	1.28^{a}	1.30^{a}	.01	AL**
Metabolizable energy, Mcal/kg	2.89^{b}	2.97^{a}	2.96^{a}	2.99^{a}	.02	AL**

[abc] Means in the same row with different superscripts differ ($P<.05$).

[d] Based on carcass weight divided by .62, an assumed dressing percent.

[e] AL=Ad lib vs limited, 80=80% vs programmed, HL=High programmed vs low programmed; **($P<.01$), *($P<.05$), $^{+}$($P<.10$).

TABLE 9. EFFECT OF CONTROLLED FEEDING ON CARCASS PARAMETERS (EXPERIMENT 3)

	Ad Lib	80 %	High Prog	Low Prog	SEM	Contrasts^e
Carcass wt, kg	314^a	304^{ab}	311^{ab}	302^b	3.3	AL^+, HL^+
Dressing Percent	66.27	65.79	66.8	66.47	.34	80^+
Rib eye area, sq cm	79.04	79.04	78.91	82.52	1.81	
KPH, %	2.02	1.96	1.94	2.08	.11	
Fat thickness, cm	1.37	1.37	1.45	1.24	.13	
Marbling Score^d	14.15^a	12.71^b	13.54^{ab}	12.71^b	.40	AL^*
Percent Choice	95.8^a	62.5^b	78.6^{ab}	75.0^{ab}	9.3	AL^+
USDA Yield Grade	2.95	2.85	2.99	2.57	.21	HL^*
Percent YG 4	0.0^b	0.0^b	13.1^a	0.0^b	3.6	
Cutability, %	50.0	50.2	49.9	50.9	.5	
Liver Abscesses						
Severity^f	2.5	2.1	2.0	2.0	.30	
Incidence, %	38.1	41.7	13.1	41.7	11.2	
Liver Wt, kg	5.81	6.02	6.16	5.92	.17	
Liver Wt, g/BW$^{.75}$	57.3	61.3	61.0	59.5	1.7	

[abc] Means in the same row with different superscripts differ ($P<.05$).

[d] 12=slight plus, 13=small minus, 14=average small

[e] AL=Ad lib vs limited, 80=80% vs programmed, HL=High programmed vs low programmed; **($P<.01$), *($P<.05$), $^+$($P<.10$).

[f] 0=no abscess, 1=one or two small abscesses, 2=moderate abscesses, 3=severe abscesses.

TABLE 10. EFFECT OF CONTROLLED FEEDING ON BEHAVIOR (EXPERIMENT 3)

	Ad Lib	80 %	High Prog	Low Prog	SEM
Time spent, %					
Ruminating	14.32	17.10	14.15	16.32	1.87
Eating	5.57	7.90	5.90	7.12	1.41
Laying	54.03	56.25	54.95	52.17	3.31

TABLE 11. EFFECT OF CONTROLLED FEEDING ON DIET DIGESTIBILITY (EXPERIMENT 3)

	Ad Lib	80 %	High Prog	Low Prog	SEM
Digestibility, %					
Total Diet	71.2	74.6	70.1	71.2	5.09
Starch	89.6	92.2	90.5	91.5	3.96
Passage Rate, %/hr	3.23	2.95	3.32	3.14	.35
Fecal Starch, %					
Day 40, 7/13/87	22.74	18.65	17.22	18.49	3.15
Day 42, 7/15/87	17.34	15.61	19.54	18.20	2.84
Day 44, 7/17/87	22.25	13.05	19.11	17.39	3.44
Mean	21.05	15.82	18.59	17.99	2.19

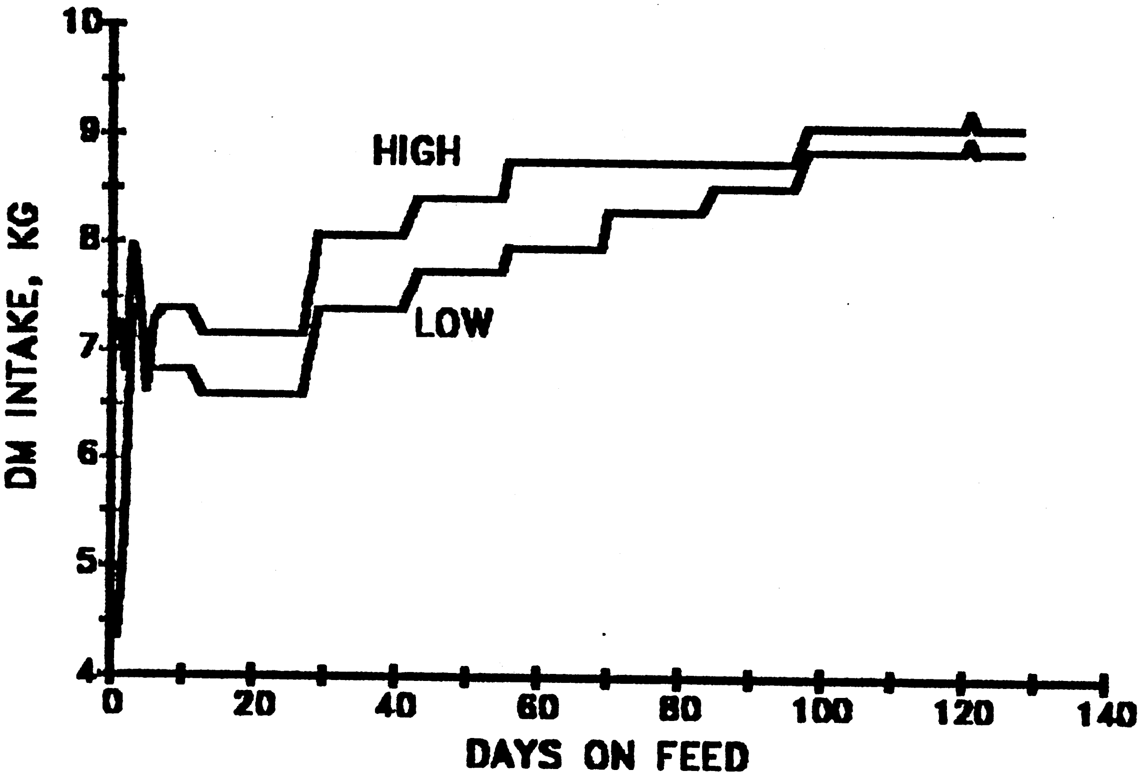

Figure 1. Feed Dry Matter Intake Versus Time on Feed for Steers Programmed to Obtain Specific Weight Gains

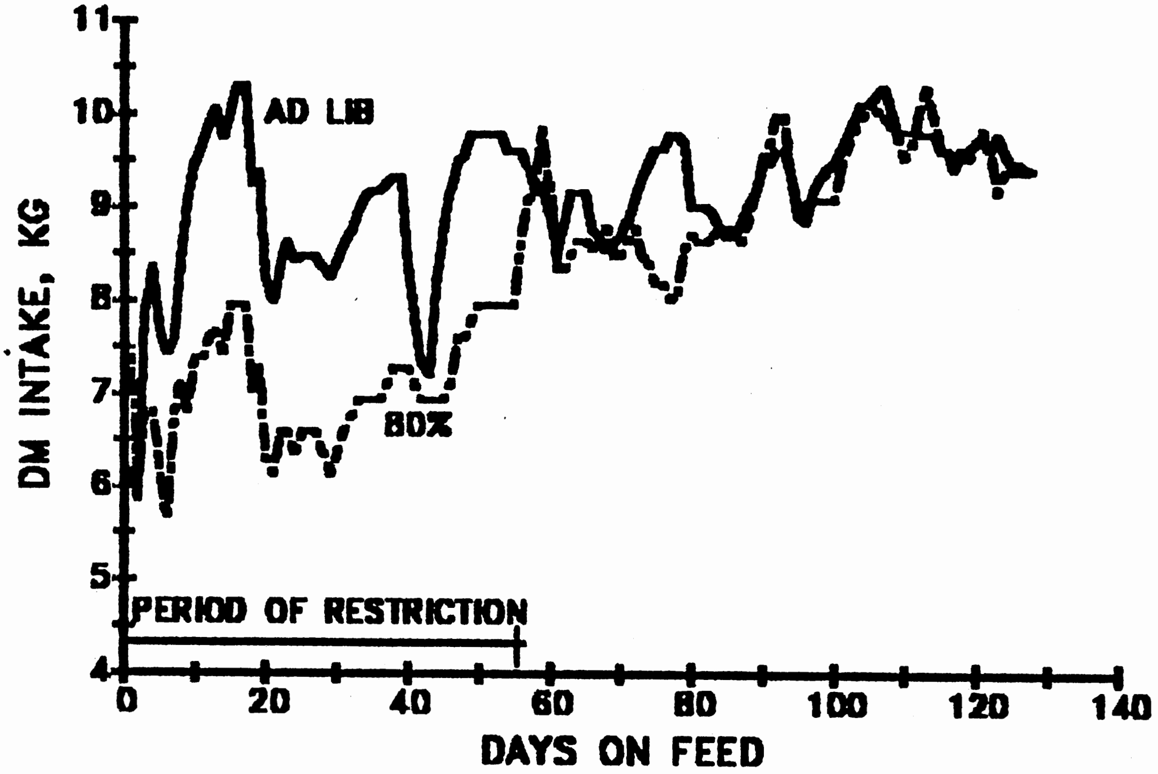

Figure 2. Feed Dry Matter Intake Versus Time on Feed for Ad Libitum Fed Steers and Steers Fed 80% of Ad Libitum for First 56 Days of Trial

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APPENDIX

BEHAVIORAL PATTERNS OF FEEDLOT STEERS

Summary

Ninety-three crossbred yearling steers were observed at 30 min intervals for 24 h on day 40 of a 138 day feeding trial to examine the diurnal patterns and individual differences in eating, ruminating and lying times. These steers spent means of 6.6, 15.5 and 54.4% of their time eating, ruminating, and lying, respectively. Peak eating times occurred at 0650 (47.3% of steers eating) and 1700 (36.8% eating) which corresponds to times of addition of fresh feed with another small peak at 2100 (17.9% eating). Ruminating and lying peaks during the day occurred at times inverse to eating. But for individual animals, those with highest eating times had highest rumination ($P<.02$) and lying times ($P<.08$). Steers which spent more time eating or ruminating tended to gain more rapidly ($P<.10$; $P<.11$). Daily gains increased by 0.01 kg/day for each 1% percent increase in lying time ($r^2=.18$; $P<.01$). Results of this trial suggest that the frequencies of eating, ruminating and lying are correlated with animal performance.

(Key Words: Feedlot Cattle, Behavior Pattern, Diurnal Patterns).

Introduction

The pattern of feeding behavior by cattle is highly repeatable. A review by Hancock (1953) reported that grazing peaks occur at dawn and dusk with the majority of grazing occurring during the day. Diurnal activity patterns of feedlot cattle also have been reported in several studies. Stricklin (1987) in a review of feeding patterns of feedlot cattle in Saskatchewan, Canada (Gonyou and Stricklin, 1981, 1984) reported that cattle exhibited three periods of eating activity during a 24-hour day; major peaks occurred during the morning and afternoon which were associated closely with time of sunrise and sunset. A third period occurred in the middle of the night. Stricklin suggested that cattle divide their day into three 8-hour periods of eating. Ray and Roubicek (1971) reported on the diurnal behavior of feedlot steers in an Arizona feedlot during winter and summer and noted that in both seasons eating activity was greatest immediately following sunrise and prior to sunset. Similar eating patterns were noted in Iowa feedlot trials (Hoffman and Self, 1973), Maryland studies (Putnam and Davis, 1963; Putnam et al., 1967, 1968) and Oklahoma feedlot trials (Arp et al., 1983; Doran, 1985). The objective of this study was to examine the diurnal behavior of feedlot steers and to determine if time spent eating, ruminating and lying were correlated with performance of individual animals.

Materials and Methods

Ninety-six crossbred (primarily British crosses) yearling steers which had been wintered on wheat pasture near Dalhart, Texas were trucked to Goodwell, Oklahoma on June 3, 1987. On arrival, all cattle were individually weighed, ear tagged, implanted with Synovex-S[1], and injected with ivermectin[2] and a BRSV[3] vaccine. These steers were

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[1] Syntex Animal Health, Inc., Des Moines, IA 50265

[2] Ivomec, MSD Agvet, Rahway, NJ 07065

predominantly Herefords (78 head) of small to medium frame size. The steers were divided into twelve pens of eight head each and four feed treatments were assigned randomly to the pens. Steers were fed a cracked corn high concentrate ration twice daily (approximately 0700 and 1600) for the 138 day trial. The ration was 80% cracked corn, 11% chopped alfalfa, 3.9% cane molasses and 5.1% pelleted supplement.

On days 40 and 41 of the trial (July 13 and 14), the behavior of each steer was noted and recorded at 30 min intervals for 24 hours (2000 to 1950, 48 observations per steer) to monitor the amount of time each animal spent eating, standing, lying, standing and ruminating, or lying and ruminating. Ambient temperature peaked at 21 and 26°C, respectively, on these two days. A thunderstorm occurred at 1550 (day 41) which altered normal behavioral patterns. These data were used to examine the diurnal patterns of eating, ruminating and lying. Because eating and ruminating behavior may alter performance (Owens and Ferrell, 1983), performance measurements were regressed against the frequency of eating, ruminating, and lying to examine these relationships.

Results and Discussion

The eating time pattern for these steers is illustrated in Figure 1. Between 2200 and 0600, less than 3.2% of the steers were eating. Eating peaked from 0650 to 0750 with 47.3% of the steers eating at 0650, and again from 1650 to 1700 with 36.8% eating at 1700. These peak eating times coincided with the feeding times (0700 and 1600); the presence of fresh feed stimulated eating. Gonyou and Stricklin (1981) also observed that peak eating times coincided with feeding times. In

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[3] Norden Laboratories, Inc., Lincoln, NE 685010

the period of time between feedings, the percentage of steers eating oscillated between 0 and 17.9%. Another peak in eating occurred at 2100 (sunset) with 17.9% of the steers eating. Similar diurnal eating behavior has been reported by several workers previously (Putnam and Davis, 1963; Putnam et al., 1967, 1968; Ray and Roubicek, 1971; Hoffman and Self, 1973; Arp et al., 1983; Doran, 1985; Stricklin, 1987).

Ruminating incidence (Figure 2) tended to be the inverse of eating. Between 2200 to 0600, 13.7 to 33.7% of the steers were ruminating. Lowest rumination incidence times occurred at 0650 (3.2%), 1700 (0%) and 2150 (2.1%) which correspond with the peak eating times. Doran (1985) noted similar ruminating patterns in feedlot steers.

Lying time (Figure 3) also varied inversely to eating time as was previously noted by Doran (1985). From 2250 to 0600, 56.8 to 100% of the steers were lying down. During the day (0750 to 1500) 31.6 to 88.4% of the steers were lying down which may reflect the warm temperature. From 1550 to 1800, most of the steers were standing; this corresponds to feeding time and occurrence of the thunderstorm. The steers generally were more active during the hours of 1550 to 2150 as temperature decreased.

Correlations between time spent eating, ruminating and lying and steer performance are presented in Table 1. Behavior of the steers grouped by fraction of time spent eating is presented in Table 2. During the 24-hour observation, 82% of the steers spent between 2 and 10% of their time eating. Seven of the steers (7.5%) were never observed to eat; this may be due to chance with steers eating short meals between observation times, timidity of animals so that presence of an observer inhibited eating, or very infrequent meals. Similarly, Doran (1985) noted that 24 of 118 steers were never observed to eat during a 24-hour observation period. As eating time increased, average daily gains for the total trial tended to increase (P<.11). The slope was .01 kg/d increased gain for each 1% increase (14 min) in eating time. Steers eating less than 8% of the time gained an average of 1.43 kg/day, whereas steers eating 8 to 17% of their time gained 1.49 kg/day. Similar trends were noted by Doran (1985). As the steers spent more time eating, the time spent ruminating also increased (P<.01) as did the time spent lying (P<.08). In contrast, Doran (1985) observed no correlation between eating and ruminating time.

During the 48 observation times, all 93 steers were observed to be ruminating two or more times (Tables 3 and 4). Animals which ruminated more frequently tended to reach heavier slaughter weights (P<.19) as was noted previously by Doran (1985). Daily gains also tended to increase with rumination frequency (P<.11) as reported by Owens and Ferrell (1983) and Doran (1985). In this trial, daily gains appeared to plateau once rumination exceeded 17% of the time. As steers spent more time ruminating, time spent lying also increased (P<.003).

Over 83% of the steers spent more than 46% of their time lying down (Tables 5 and 6). Time spent lying was positively correlated with live weight at 56 and 138 days (P<.01). Daily gains for the first half of the trial, last half of the trial and total trial all increased as time spent lying increased (P<.001). Similarly, the NRC (1981) reported that mud, rain or storms (conditions causing lack of suitable bedding area) decrease feed intake by cattle which in turn should decrease performance. Those steers spending less than 57% of their time lying (53 head) gained 1.38 kg/day while those spending greater than 57% of the time lying (40 head) gained 1.56 kg/day. Doran (1985) reported that gains tended to increase as lying time increased up to 71% of the time ($P<.10$).

In summary, these feedlot steers exhibited diurnal behavior as has been noted by other workers. Results also suggest that the frequencies of eating, ruminating and lying were correlated with animal performance, but the mechanisms of the relationships remain to be defined. As frequency of eating, ruminating and lying increased, daily gains also increased. Presumably, increased feed intake would increase all of these factors whereas timidity or nervousness should decrease all three. Altering roughage level or source would be expected to alter eating and rumination time. If greater eating and ruminating times increase both particle size reduction and salivary flow to buffer the rumen and increase ruminal outflow, increases in rumination and eating times may improve efficiency of feed utilization and reduce acidosis. No information on efficiency of feed use of individual animals was available from this study. Selection for rapid eating, as practiced with dairy cattle, would reduce chewing time and potentially decrease digestibility of poorly processed grains. This could explain why shelled corn diets are often poorly utilized by Holstein steers. Whether feed supply, roughage level, feeding frequency or feed additives alter patterns or total time spent feeding and ruminating time needs study. No effect of limit feeding on these measurements was apparent here though Doran (1985) suggested that supplemental potassium tended to increase rumination time.

TABLE 1. CORRELATIONS BETWEEN STEER ACTIVITY AND PERFORMANCE

	Time Spent		
	Eating	Ruminating	Lying
Live weight:			
Initial	.004	-.013	-.012
56 d	.126	.068	.290
138 d	.154	.138	$.434^{**}$
Daily gain:			
0-56 d	.156	.097	$.377^{**}$
57-138 d	.102	.153	$.376^{**}$
0-138 d	.166	.158	$.481^{**}$
0-139 d[a]	.171	.168	$.419^{**}$
Time spent:			
Eating	1.000	$.261^{*}$	$.187^{+}$
Ruminating	$.261^{*}$	1.000	$.301^{**}$
Lying	$.187^{+}$	$.301^{**}$	1.000

[a] Based on carcass weight divided by .62, an assumed dressing percent.

$^{+}$(P<.10), *(P<.05), **(P<.01)

TABLE 2. PERFORMANCE OF STEERS VERSUS PERCENTAGE OF TIME SPENT EATING

	Percentage of time spent eating										
Item	0	2	4	6	8	10	13	15	17	Linear Slope	Prob.
No. of steers	7	14	11	17	22	12	7	2	1		
Live wt, kg:											
Initial	294	290	291	295	298	290	290	284	305	0.0	.970
56 d	372	373	375	382	384	388	371	365	399	0.7	.228
138 d	473	470	475	492	489	494	467	484	499	1.2	.140
Daily gain, kg:											
0-56 d	1.12	1.21	1.23	1.29	1.26	1.48	1.18	1.18	1.40	0.012	.136
57-138 d	1.18	1.14	1.16	1.28	1.22	1.24	1.12	1.40	1.17	0.005	.328
0-138 d	1.16	1.17	1.19	1.29	1.24	1.34	1.15	1.31	1.26	0.008	.112
0-139 d[a]	1.39	1.38	1.41	1.50	1.47	1.59	1.34	1.51	1.60	0.010	.101
Time spent, %:											
Ruminating	13.4	12.4	16.3	14.2	17.6	16.0	19.3	17.7	20.8	0.461	.012
Lying	47.6	49.4	59.5	54.0	55.5	58.5	52.7	55.2	52.1	0.470	.073

[a] Based on carcass weight divided by .62, an assumed dressing percent.

TABLE 3. PERFORMANCE OF STEERS VERSUS PERCENTAGE OF TIME SPENT RUMINATING (PART 1)

	Percentage of time spent ruminating										
Item	4	6	8	10	13	15	17	19	21	23	25
No. of steers	4	2	10	13	11	10	12	7	9	2	6
Live wt, kg:											
Initial	284	305	299	296	283	296	290	290	298	305	303
56 d	361	383	382	380	372	387	384	361	387	400	382
138 d	460	465	482	482	485	484	488	458	495	499	488
Daily gain, kg:											
0-56 d	1.13	1.11	1.20	1.23	1.32	1.34	1.41	1.00	1.31	1.42	1.14
57-138 d	1.15	0.96	1.18	1.19	1.33	1.14	1.22	1.14	1.26	1.15	1.25
0-138 d	1.14	1.02	1.19	1.21	1.33	1.22	1.30	1.08	1.28	1.26	1.20
0-139 d[a]	1.36	1.25	1.40	1.42	1.51	1.50	1.53	1.27	1.52	1.56	1.40
Time spent, %:											
Eating	5.2	1.0	5.6	6.4	5.3	7.5	7.6	6.5	9.0	2.1	6.9
Lying	46.4	52.1	50.2	54.0	52.8	53.5	56.2	53.9	55.6	57.3	57.3

[a] Based on carcass weight divided by .62, an assumed dressing percent.

TABLE 4. PERFORMANCE OF STEERS VERSUS PERCENTAGE OF TIME SPENT RUMINATING (PART 2)

	Percentage of time spent ruminating					
Item	27	29	33	38	Linear Slope	Prob.
No. of steers	4	3	1	1		
Live wt, kg:						
Initial	289	282	308	265	0.0	.902
56 d	379	378	386	366	0.2	.519
138 d	488	489	496	480	0.6	.186
Daily gain, kg:						
0-56 d	1.33	1.44	1.11	1.55	0.005	.355
57-138 d	1.28	1.29	1.29	1.33	0.005	.144
0-138 d	1.30	1.35	1.22	1.42	0.005	.130
0-139 d[a]	1.48	1.58	1.50	1.72	0.005	.108
Time spent, %:						
Eating	9.4	7.6	8.3	12.5	0.148	.012
Lying	58.3	63.9	60.4	62.5	0.431	.003

[a] Based on carcass weight divided by .62, an assumed dressing percent.

TABLE 5. PERFORMANCE OF STEERS VERSUS PERCENTAGE OF TIME SPENT LYING (PART 1)

	Percentage of time spent lying										
Item	19	21	25	33	38	42	44	46	48	50	52
No. of steers	1	1	1	2	1	4	1	4	7	3	8
Live wt, kg:											
Initial	282	289	264	300	317	289	281	301	298	283	300
56 d	329	353	322	386	378	373	354	380	381	362	385
138 d	418	460	386	477	470	466	448	475	483	470	482
Daily gain, kg:											
0-56 d	0.61	0.89	0.80	1.26	0.81	1.23	1.05	1.15	1.21	1.15	1.25
57-138 d	1.04	1.26	0.75	1.05	1.09	1.09	1.10	1.10	1.20	1.25	1.14
0-138 d	0.87	1.11	0.77	1.14	0.97	1.15	1.08	1.12	1.20	1.21	1.18
0-139 d[a]	1.12	1.35	0.96	1.41	1.14	1.37	1.35	1.35	1.40	1.40	1.40
Time spent, %:											
Eating	2.1	0.0	6.3	1.0	6.3	8.9	2.1	6.8	6.5	8.3	7.6
Ruminating	4.2	12.5	10.4	9.4	8.3	13.5	14.6	16.7	11.9	14.6	18.8

[a] Based on carcass weight divided by .62, an assumed dressing percent.

TABLE 6. PERFORMANCE OF STEERS VERSUS PERCENTAGE OF TIME SPENT LYING (PART 2)

	Percentage of time spent lying									
Item	54	56	58	60	63	65	67	77	Linear Slope	Prob.
No. of steers	6	14	13	8	5	11	2	1		
Live wt, kg:										
Initial	287	300	292	298	275	290	295	293	0	.907
56 d	372	380	385	387	381	384	388	364	0.7	.005
138 d	470	484	493	485	498	501	491	477	1.3	.0001
Daily gain, kg:										
0-56 d	1.25	1.16	1.38	1.32	1.62	1.41	1.38	1.01	0.012	.0002
57-138 d	1.15	1.21	1.26	1.14	1.36	1.38	1.21	1.32	0.008	.0002
0-138 d	1.19	1.20	1.31	1.21	1.47	1.39	1.28	1.20	0.010	.0001
0-139 d[a]	1.42	1.40	1.54	1.46	1.75	1.60	1.53	1.32	0.009	.0001
Time spent, %:										
Eating	7.6	6.5	5.8	6.3	8.8	7.6	8.3	4.2	0.074	.073
Ruminating	12.2	15.9	14.7	18.2.	22.1	19.1	13.5	10.4	0.211	.003

[a] Based on carcass weight divided by .62, an assumed dressing percent.

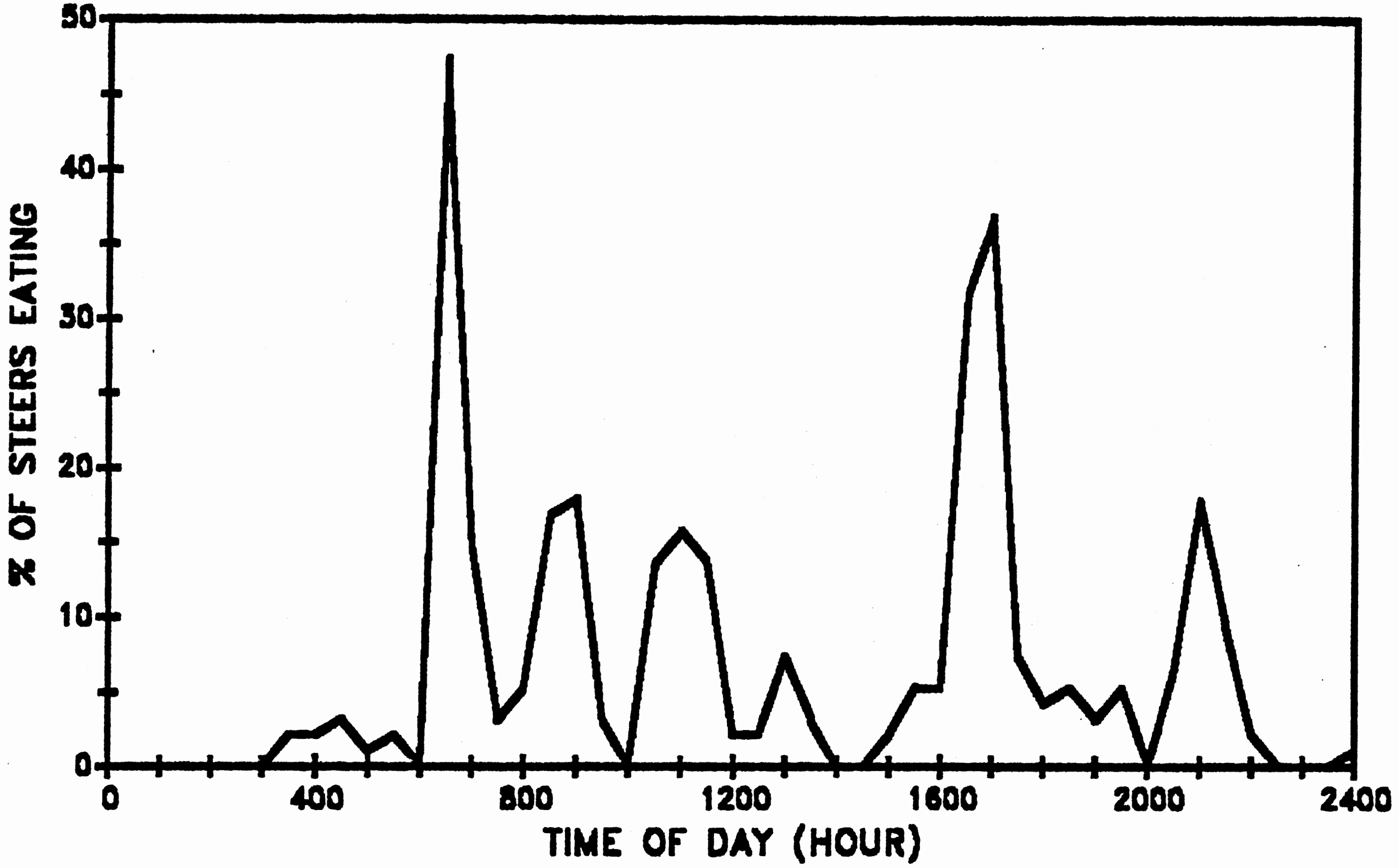

Figure 1. Eating Pattern of Feedlot Steers

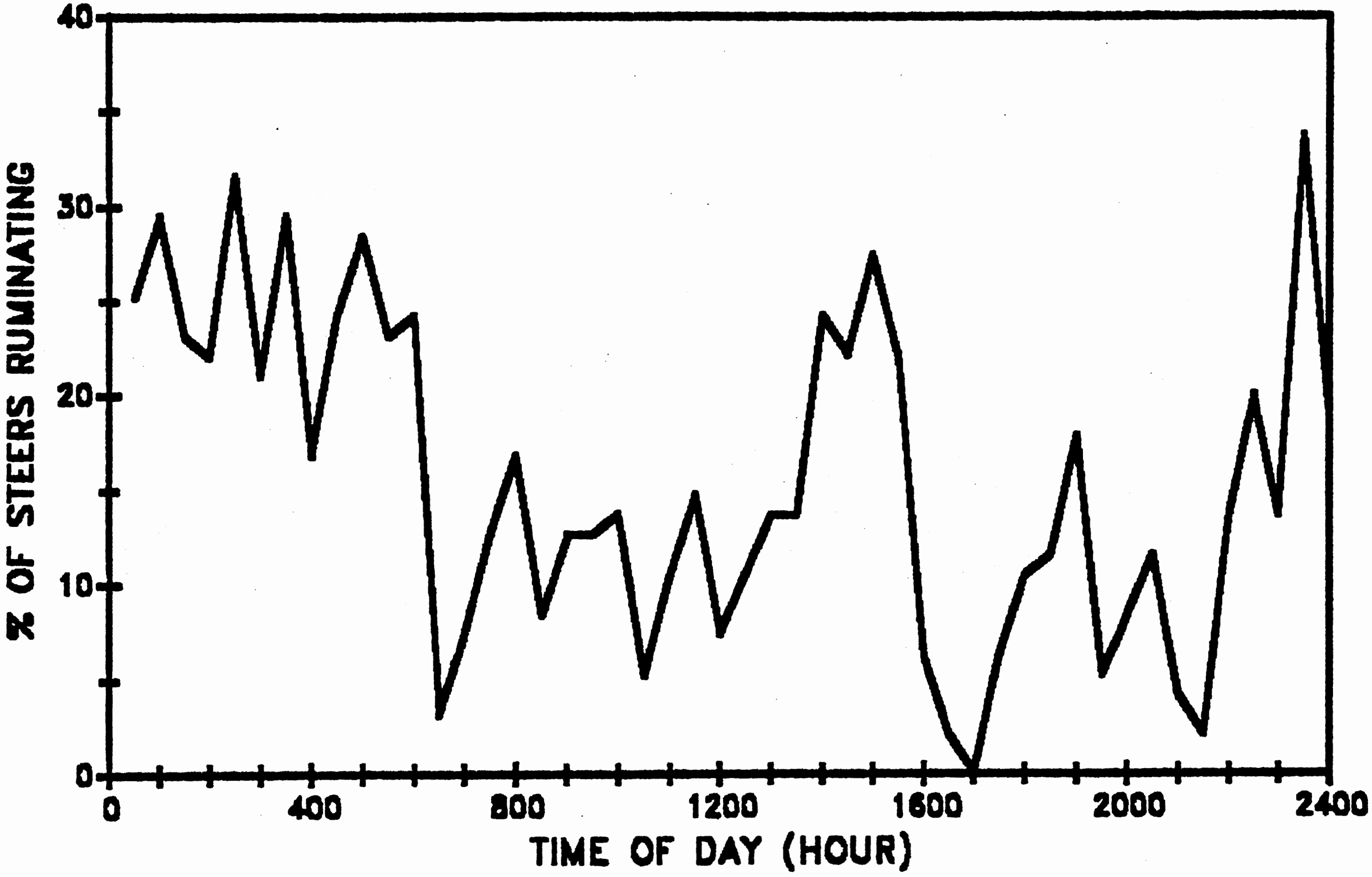

Figure 2. Ruminating Pattern of Feedlot Steers

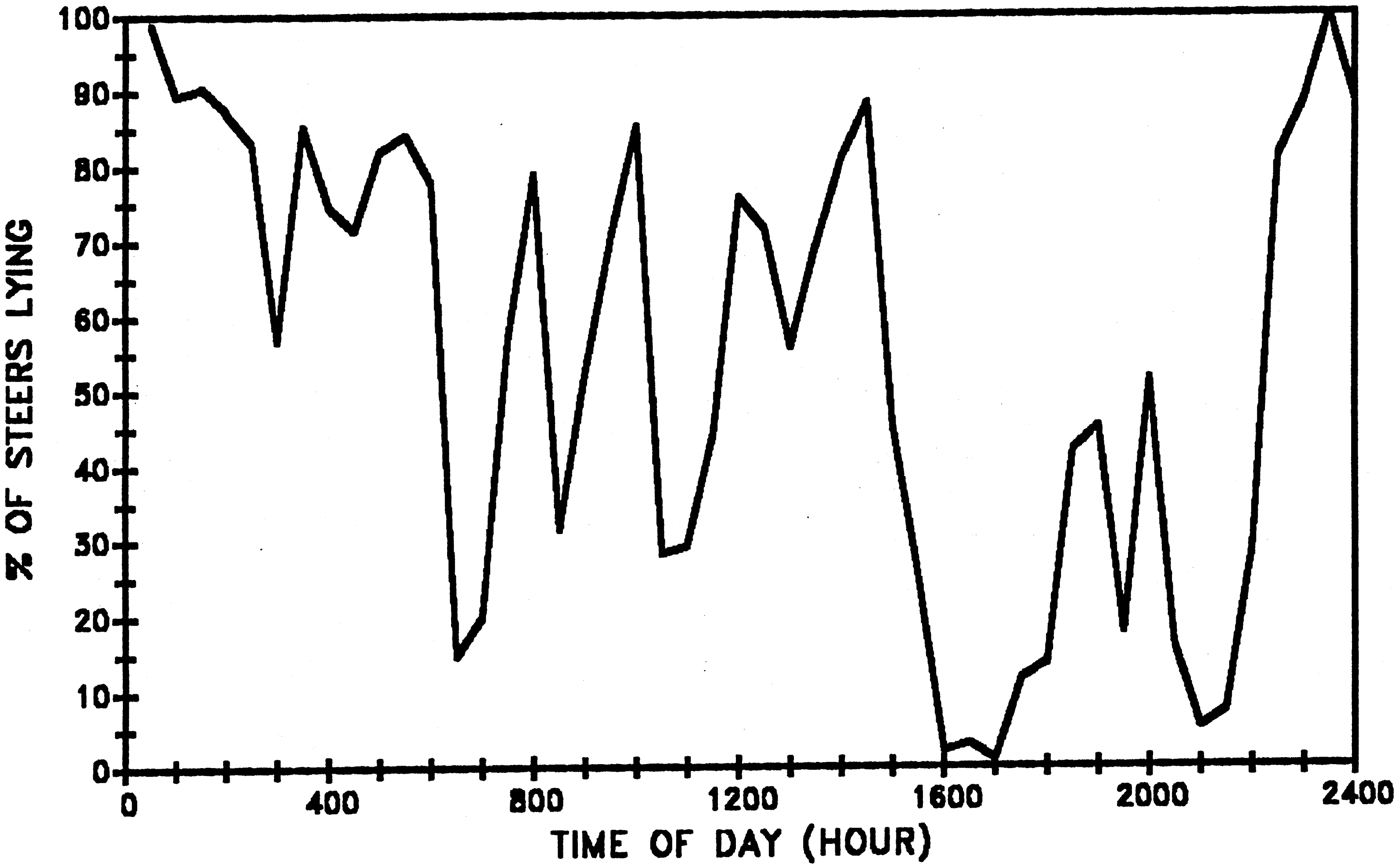

Figure 3. Lying Pattern of Feedlot Steers

VITA

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Candiate for the Degree of

Doctor of Philosophy

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