

VERIFICATION OF EQUATIONS TO PREDICT DRY MATTER INTAKE
OF DAIRY HEIFERS

by

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VERIFICATION OF A DRY MATTER INTAKE PREDICTION EQUATION FOR
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(ABSTRACT)

Diets of varying forage base were fed to dairy heifers to test the accuracy of an prediction equation to accurately predict dry matter intake (DMI). Heifers ranging from 120 to 430 kg body weight, were randomly assigned to treatments with forage bases of 1) 100% corn silage, 2) 75% corn silage : 25% alfalfa haylage, 3) 50 % corn silage : 50% alfalfa haylage, or 4) 25% corn silage : 75% alfalfa haylage. Diets were fed for an average of 187 days. Rations were formulated to meet NRC requirements for .68 kg ADG and reformulated monthly. Animals consistently gained an average of .8 kg per day. Statistical analysis showed actual DMI to be significantly less than predicted levels of DMI. The correlation coefficient of actual DMI to predicted DMI was .59. In spite of increased rates of gain, differences due to treatment, ration acid detergent fiber (ADF) and season were not significant. Depressed intake may be the result of metabolic control of intake as ADG approaches .8 kg. This

suggests that current recommendations for TDN may be excessive for dairy heifers reared in confinement.

Application of the prediction equation on five cooperator herds resulted in ADG's ranging from .41 to .96 kg with a mean of .62 kg. when rations were balanced of .68 kg ADG. Relationships between 1) body weight and wither height; 2) body weight and age; and 3) age and wither height were not significantly different from established standards. The variability of these results suggests how management and environmental factors effect successful application of the feeding program.

Key Words: heifer, dry matter intake, gain, acid detergent
fiber

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INTRODUCTION

The success of a dairy operation is influenced by the quality of heifers entering the herd. Quality replacement heifers are the result of conscientious youngstock rearing programs that strive to produce healthy, well-conditioned, reproductively sound animals, capable of calving by 24 months of age and producing large quantities of milk.

Proper nutrition is an essential factor in producing heifers with these qualities. The lifetime profitability of a heifer is influenced by her age at first calving and the amount of milk she is capable of producing once lactation begins. To maximize milk production, it is recommended that heifers be raised on a plane of nutrition that produces steady growth without over-fattening.

With heifers consuming approximately 50% of all feed consumed on a farm, it is important to design a feeding system that considers the economic impact of a heifer feeding program without sacrificing proper nutrition. Nutritionally balanced rations, fed in appropriate amounts, are the basis of a sound feeding program. Proper nutrient concentration can be achieved only with accurate prediction of an animals' dry matter intake.

Recommendations for nutrient requirements, dry matter intake prediction equations and ration formulation programs have been developed for lactating animals. Lack of information prompted the development of a dry matter intake (DMI) prediction equation and establishment of a ration formulation program (Dair4H) for dairy heifers through research conducted by Dr. J.D. Quigley, III at Virginia Tech. Quigley developed prediction equations utilizing corn silage and orchardgrass hay based rations fed to dairy heifers for 28 days.

The objective of this study is to determine if the equation accurately predicts DMI for heifers over a wide range of body weights, consuming rations with varying forage bases. Evaluation will be conducted by application of rations, formulated with the assistance of Dair4H, to heifers reared in a controlled experimental environment and under practical conditions on five cooperating dairy farms.

REVIEW OF LITERATURE

The availability of an adequate number of high quality replacement heifers is essential to the success and improvement of a dairy operation. Sources of youngstock may vary depending on the resources and facilities of an individual farm. Some dairy producers purchase heifers, while others replenish their milking herds with home-grown animals. Regardless of the source of replacements, the purpose of a youngstock program must be to economically provide healthy, well-conditioned, reproductively sound heifers entering the milking herd at 24 to 26 months and capable of producing a large quantity of milk.

Youngstock comprise approximately 50% of animals on the farm. Replacement feeding accounts for 20 to 30% of total feed costs. Success of a youngstock program is judged by the amount of profit an animal produces during her lifetime, relative to cost of rearing. While rearing should be cost-efficient, immediate cost consideration should not compromise the quality of nutrition and care heifers receive. Design of sound feeding, animal health and breeding programs are practices conducive to rearing animals with desirable characteristics. A profitable youngstock program should establish tangible, long term goals for

expected animal performance while recognizing the influence youngstock management has on overall profitability.

DESIRABLE PERFORMANCE:

One measure of the success of a youngstock program is average age at first calving. A calving age of 22.5 to 23.5 months has been determined as optimum for maximizing total lifetime performance (12). However, heifers calving during the 25th month of age produced more profit per day of herd life than those calving earlier (12).

To realize a recommended calving age of 23-26 months, animals must reach breeding age by approximately 14-15 months of age. For first breeding to be appropriate at this age, heifers must have sufficient growth to induce puberty (19). The relationship between body weight and age of puberty is exhibited in research conducted by Gardner et al. (11). Heifers maintained on an elevated plane of nutrition were observed in estrus at 275 kg body weight by 8.3 months of age in comparison to controls fed a standard diet in which first estrus occurred at 288 kg body weight at an average of 10.2 months of age.

Although younger age at puberty makes it possible for heifers to calve as early as 16 months, youngstock programs

that provide steady, uniform rates of gain without over-conditioning are viewed as optimal (33,36). Accelerated rearing frequently leads to fattening which can overshadow any perceived economic benefit from increased lifetime milk yield. Fattening that occurs when heifers are grown rapidly has been observed to result in abnormally developed mammary glands lacking development of secretory tissue. Swanson's studies (34,36) of milk yield in fattened vs. control animals showed a 15% reduction in milk yield during first lactation with disparity between groups remaining during second lactation. He suggested that lower milk production was the result of under-developed mammary secretory tissue (34). Similar studies by Sejrsen et al. (33) comparing heifers fed rations in restricted or ad libitum amounts demonstrated that ad libitum feeding of pre-pubertal animals reduced the amount of mammary secretory tissue. This effect was not observed in post-pubertal animals which were overfed.

The feeding and conditioning of young animals influences health and milk production ability throughout life. In addition to reduced milk yields, over-conditioning is believed to contribute to increased incidence of dystocia, breeding problems, and cost of feeding (11,41).

Feed requirements of heifers are composed of requirements for maintenance and gain. Maintenance requirements of smaller animals comprise a lower percentage of total nutrient requirements. Thus, total nutrient requirements (growth and maintenance) are lower for smaller animals. From birth, calves make very efficient weight gain. Theoretically, calves are monogastrics consuming expensive, high energy liquid diets. These diets provide large quantities of metabolizable energy available for growth. As heifers mature, body composition begins to change with adipose tissue comprising a larger proportion of total gain. Consequently, greater amounts of feed are required to produce a specific amount of body weight gain (35,36).

This information reinforces the importance of maintaining proper rates of gain prior to breeding age. Feeding programs that rear heifers with steady rates of body weight gain contribute to the rearing of heifers able to reach suggested weight by breeding age. Average daily gains of .66 kg for Holsteins and Brown Swiss, .56 kg for Ayrshires and Guernseys and .50 kg for Jerseys should produce sufficient growth for breeding by 14-17 months (10).

Optimum conception is observed in properly conditioned Holstein and Brown Swiss heifers weighing 350-400 kg, Ayrshires and Guernseys weighing 290-330 kg and Jerseys of

250-280 kg. After these goals are achieved, there is no need to delay breeding and first calving. In order to maximize length of productive life, well-conditioned heifers should be bred as soon as they reach breeding weight. It has been observed that heavier heifers have no advantage in milk production ability over lighter heifers of similar age (22,35).

NUTRITION:

Nutrient Requirements of Dairy Replacement Heifers

How adequately heifer nutrient requirements are provided determines rate of growth, body composition, and body weight. Requirements that should be met by rations are 1) energy, 2) protein, 3) minerals, and 4) vitamins.

Energy. The nutrient required in the largest quantity is energy. For dairy cattle, energy is usually provided by inexpensive carbohydrates contained in forages, but can also be derived from proteins and fats. Energy is utilized to maintain body functions like growth, metabolism and reproduction. Requirements for energy will vary with animal size, body weight, rate of growth and level of activity. Thin or emaciated appearance, retarded growth and delayed

onset of puberty are symptoms of inadequate energy consumption in young animals (10,25).

Requirements of energy in youngstock are expressed as digestible energy (DE), total digestible nutrients (TDN), metabolizable energy (ME) or net energy for maintenance (NEm) and net energy for body gain (NEg) (25). DE is closely related to the frequently-used term, TDN. Once energy lost in feces, urine and through the production of methane gas is deducted from the gross energy provided by the feedstuff, energy available for metabolism remains (ME). Once heat lost via digestion and metabolism of feeds consumed is subtracted from ME, net energy of the feed remains. In heifers, net energy is partitioned into energy needed for maintenance of body tissue (NEm) and energy needed for the deposition of tissue (NEg) (6). The TDN system is the most widely used in balancing heifer rations because TDN information is widely available and easily used.

Protein. Protein is needed to provide an adequate supply of amino acids to serve as building blocks for cell and tissue growth. They are the precursors of all body proteins including enzymes, hormones and mucin. Protein can be stored on a short-term basis in the blood, liver and muscle. However, if insufficient dietary protein is provided for an extended period, the deficiency will be exhibited as a

negative effect on appetite, growth, general appearance and health (25).

Fiber. Although not a nutrient requirement, rations should also provide adequate quantities of fiber. It is difficult to balance rations for high producing cows that provide an adequate amount of fiber and energy simultaneously. The absence of milk production greatly reduces the amount of energy heifers must consume, making it easier to maintain adequate levels of fiber in youngstock rations. Adequate levels of fiber, usually supplied by consumption of forage, contribute to rumen health.

Currently, there are three classifications of fiber: 1) crude fiber (CF); 2) acid detergent fiber (ADF); and 3) neutral detergent fiber (NDF). The difference between these three classes is the portion of plant cell wall constituents that they measure. The plant cell wall consists of cellulose, hemicellulose, and lignin. Crude fiber represents all of the cellulose and alkali-insoluble portion of the lignin. ADF contains more of the cell wall structure by also identifying the alkali-soluble portion of lignin in addition to alkali-insoluble lignin and cellulose.

Currently, NDF is considered the best indicator of total plant cell wall structure by quantifying all cell wall constituents previously mentioned (6).

Intake

Availability of nutrients to heifers is regulated by feed intake. Ruminants have complex physiological and psychological mechanisms that regulate energy balance. Energy balance being the difference between the metabolizable energy (ME) of feed eaten and total energy expended. ME requirement is influenced by body weight, maintenance, desired rate of growth, reproductive status, ambient temperature, level of production, and activity level. Even under varying environmental and feeding conditions, growing animals maintain a relatively steady rate of gain by regulation of feed consumption (1). The amount of growth produced is dependent on feed availability and how well the ration fed meets nutrient requirements. Factors limiting the amount of feed an animal can consume are physical limits of the gastrointestinal tract and satiety mechanisms triggered by the consumption of energy.

Metabolic Control

Metabolic regulation of feed intake is related to the energy content of the body. When functioning properly, consumption of energy is balanced by changes in energy output. Though actual control mechanisms are not known, it is widely

accepted that the central nervous system is the origin of physiological response to feed intake and energy balance.

There is evidence that peptides of the central nervous system may be involved in intake regulation. It is believed that opiate peptides promote the initiation of feeding while cholecystinin peptides contribute to satiety (1). The ventromedial and lateral regions of the hypothalamus are also thought to play an important role in the balance of hunger and satiety with certain hormones and neural transmitters forming a complex information system. Disruption of the function of these areas of the hypothalamus by the presence of lesions have been shown to retard information feedback thought to contribute to hyperphagia and aphagia, respectively (1).

Though chemical pathways responsible for metabolic control of intake are not known, several factors affecting consumption have been identified. It is accepted that metabolic controls work in conjunction with external sensory cues like smell and feed palatability. Initiation of feeding is a combination of the effects of the body's current energy balance and sensory inputs. Once feeding begins, ruminants utilize their senses in preference of feeds. Selection is also affected by energy balance. This is demonstrated through the common observation that a hungry

animal will consume feedstuffs it would find unacceptable if well-fed (1).

Variation of body temperature from thermo-neutrality is not proven to directly control intake. Though blood and skin temperature increase in animals at feeding, once a feeding pattern is established, similar elevations in temperature can be observed at the expected time of feeding even when feed is not provided. Changes in ration intake due to varying environmental temperature are perceived to be an indirect reaction to the regulation of energy balance and not an independent effect (1).

Physical Control

Physical signals of distension from the gastro-intestinal tract are another factor contributing to intake regulation. Though the actual mechanism of physical regulation of voluntary intake is not known, several hypotheses have been proposed. It is believed that distension of the rumen or reticulum regulates meal size. Tension receptors in the ruminant stomach provide neural feed-back that alter feed response. The mechanism of tension reception is linked to the quantity of the volatile fatty acids (VFA), acetate and propionate in the rumen. Intraruminal injections of both VFA's during feeding have resulted in depressed feed intake

in ruminants. Though function of the receptors for the individual VFA's may be different, the result of their action is believed to be similar (1).

Effect of Feedstuff Composition

Metabolic and physical factors limiting intake are affected by quality and composition of the feeds consumed. Feeding patterns vary as palatability, caloric density, percent fiber, digestibility, and moisture content interact to affect consumption.

Digestibility. Physical and metabolic regulation of feed intake changes with percent dry matter digestibility of the ration. As digestibility increases above 67%, physiological factors appearing to regulate intake are metabolic body size and level of production or growth. The factors controlling intake shift as digestibility decreases with body weight, undigested residue per unit body weight per day (reflecting rate of passage), and dry matter digestibility (reflecting fill of the gastro-intestinal tract assuming control). With highly digestible feeds the ruminant depends on metabolic regulation. Intake of rations of lower digestibility is based on physical capacity and rate of passage of slowly digested roughage out of the gastrointestinal tract (8).

Ration Density. Since limits of physical fill influence the amount of feed a ruminant can consume, the effect of feed volume on the regulation of intake is an important consideration. Ration density (kg DM/liter) relates the volume of a feedstuff to the nutritive value it provides (27). Research has been conducted to relate the factors of ration density and ration form to intake. As ration density increases dry matter intake decreases. The mechanism controlling energy balance does not change with varying ration form. Variations in form were reflected as changes in density and the trend of decreased dry matter intake as density increased continued. (2)

Caloric Density. Caloric density (Mcal digestible energy /liter) is an index combining ration digestibility and density. Caloric density is viewed as a more effective indicator of dry matter intake than energy concentration or ration digestibility (24). Lactating animals fed rations with varying levels of caloric density exhibited metabolic control of intake when caloric density rose above 0.68 Mcal DE/l. Physical fill limited intake of rations when density was below this point. Response to ration caloric density mirrors that of ration digestibility. The ruminant utilizes a combination of metabolic and physical factors to maintain energy balance and achieve satiety (4).

Fiber. Neutral detergent fiber is an estimate of the lignin, cellulose, hemi-cellulose and silica in a forage. These four components comprise 90% of the cell wall structure of a plant. The composition of the plant cell wall influences the digestibility of a feed. These structures represent the volume of a feed. Cellulose and hemi-cellulose are components of cell structure vulnerable to rumen fermentation. Degradation of the cell wall exposes cell contents to rumen fluid allowing digestion. Lignin is the portion of the cell wall most resistant to microbial degradation. The percent of lignin present in cell structure varies with plant species and increases as the forage matures. Digestibility of cellulose and hemi-cellulose is decreased by their association with lignin (21). An increased amount of lignin present in cell structure decreases digestibility of the forage. As digestibility of cell structure decreases, the volume forage displaces in the digestive tract increases, resulting in physical limitation of intake (39). This relationship explains why researchers (20,39) have suggested that NDF may serve as the best indicator of intake. However, a recent study (27) found that NDF was no more precise in predicting intake than ADF when rations contained more than 42% NDF. At less than 42% NDF, neither ADF or NDF content were highly correlated with intake. NDF contributes to knowledge of

intake regulation but its acceptability as an overall indicator of intake requires further study.

Moisture Content. Another attribute of feedstuffs that may affect consumption is moisture content. Some dairy producers consider high moisture silages and grains to be easier to preserve, of higher quality and higher yield due to lower harvest losses than dry hay and grain. This, in conjunction with the increased availability of economical, high-moisture by-product feeds, makes consideration of the effect of moisture content on intake important. While adequate moisture in rations (> 60%) reduces separation of ingredients, excessive moisture in rations has been observed to decrease nutrient intake resulting in depressed growth and production. In lactating animals, production may be depressed when rations contain less than 60 to 65% dry matter (18).

Conclusions drawn from feeding trials observing the effects of moisture content on intake vary. But the majority of studies show that dry matter intake increases linearly as the dry matter content of the feed increases (18,23,30). The assumption that intake is solely restricted by an increased concentration of water is incomplete. Studies by Thomas et al. (37) indicated a secondary relationship between the feeding of silage vs. hay. It was observed that

when moisture was added to hay before feeding, intake was not significantly different than hay fed without added moisture. The same observation was made with silage. The opposite was observed when moisture was added in the form of effluent liquid from a silo. Intake was depressed in both ensiled and dry forages. Results indicate that by-products produced during fermentation of high moisture feeds may be responsible for depression of intake rather than moisture content of the feedstuff alone. Regulation of consumption of high-moisture feedstuffs is probably the effect of metabolic control on appetite and not solely a reaction to decreased palatability or limitation of consumption by physical fill (37).

Precise mechanisms controlling intake are not known. What is becoming more apparent is the influence of ration characteristics on the ability of ruminants to consume dry matter. The utilization of feed characteristics such as moisture content, percent NDF and percent TDN aids in estimating the level of intake that growing and lactating animals can maintain. Only through the proper estimation of dry matter intake can feeding become more efficient and economical.

The ability to regulate ration intake lies in the interaction of 1) nutrient digestibility and ration density,

2) the effect of moisture content and by-products of ensiling on intake of feeds, 3) the effects of fiber on intake, and 4) rate of passage. Understanding these relationships is an important part of the development of methods to accurately predict the amount of ration dry matter a ruminant can consume. Accuracy of predicting dry matter intake (DMI) for lactating animals has been addressed, but consistent standards for youngstock are not yet established.

Feeding Systems

The initial diet of replacement heifers consists of nutrient dense liquid feeds; colostrum, whole milk, milk replacer. Once weaned, many heifers are raised on pasture. Thirty years ago the majority of dairy cattle were fed using pasture feeding systems (7). Though fewer feeding systems for mature cattle utilize pasture, young, actively growing pasture can adequately supply nearly all nutrients required except minerals for heifers six months and older (29,32). Pasture has been shown to be a convenient and economical method of rearing heifers when properly managed (16).

Pasture

Poor pasture management is the downfall of many heifer feeding systems. In many instances, heifers receive insufficient nutrients to meet requirements, resulting in depressed weight gain, delayed puberty and a corresponding increased age at first calving (15). For pasture to supply the quantity of feed and the amount of nutrients needed, it should be 1) composed of palatable species of grasses or legumes, 2) fertilized according to soil test, 3) reseeded when appropriate, 4) clipped regularly in order to generate new growth, and 5) grazed under the proper stocking density (14). Continuous evaluation of pasture condition, stocking rate, animal body condition and calving age are practical ways of evaluating the effectiveness of the feeding program.

The potential for problems in pasture systems stems from the inability to accurately predict nutrient intake. When pasture is not in lush growth, heifers should receive some form of supplementation (15). As forage matures it becomes less palatable, more lignified and less digestible.

Availability of protein, vitamins and minerals decreases.

The amount of forage dry matter that a pasture can provide also varies greatly from season to season (10).

Variability of feed quality and feed intake should be considered when animals are grazed. This is the point where

skill and experience of managing pasture feeding systems becomes important.

The importance of adequate supplementation has lead to the use of several types of modified pasture feeding systems. Fence line bunks have been incorporated into feeding systems so that hay, grain and/or silage can be conveniently provided. Pasture also can be supplemented using salt to control intake of concentrates fed ad libitum. Where adequate water is available, concentrate intake can be limited to as little as two lb./head/day by including 20-30% salt in the concentrate mixture (29). Self-feeding protein supplements available in lick tanks or block form can eliminate daily feeding of pastured heifers over six months of age by providing crude protein, usually derived from urea (29). Where appropriate, methods like these can decrease nutrient intake variability and increase efficiency of animal gain.

Availability limits use of pasture for heifers on some farms. It may not be practical to utilize land for pasture for farms near urban areas and in crop producing sectors such as the mid-western United States. This, in conjunction with larger average herd size, has developed a trend toward group housing and feeding. (17).

Confinement Facilities

Though confinement systems require a larger initial investment in facilities than pasture, they can be incorporated into a sound, labor efficient, economical heifer rearing program.

Grouping. Most confinement facilities are designed to house heifers grouped by size. Housing animals of similar size together reduces the range of nutritional requirements. Stratifying by body weight makes it easier to provide a ration that supplies proper nutrition to all animals (13). With feed cost accounting for approximately 50 to 58 percent of the cost of rearing replacements (16), how accurately animals are fed can influence the overall cost of the program.

Grouping also decreases the possibility of problems with dominance. When animals are of equal stature it is less likely that one heifer can consume more than her allotted portion of feed (13). To further decrease the effects of dominance, proper attention should be given to stocking density. Holstein heifers fed total mixed rations (TMR) were observed to require .27m of feedbunk length/head to insure adequate daily gains if feed is available at all times. Animals with less bunk space had reduced average

daily gains and decreased eating time/day (17). It has also been observed that animals fed adequate amounts on a regular basis consume small, frequent meals and are less competitive, promoting fair consumption (38).

Total Mixed Rations. Many confinement facilities utilize total mixed rations (TMR) as a practical and labor saving method of feeding. By definition, a TMR is a "quantitative mixture of all dietary ingredients" (6). Practically, it is a blended mixture of forages, concentrate ingredients, minerals and vitamins.

The purpose of a TMR is to supply various nutrient requirements through the presentation of a single meal and to prevent selective eating. Coppock states (6) that successful TMRs should be 1) mixed well enough to prevent sorting and selective eating, 2) balanced for a specific nutrient content, and 3) fed on an ad libitum basis. The major objective in feeding TMR's for heifers is being able to avoid over-fattening by restricting intake. This is accomplished by adding fiber to the ration to decrease intake. If this is done, every bite an animal consumes should contain a defined amount of ingredients and be nutritively sound. Chandler (5) stressed the importance of accuracy in formulating TMR's through 1) proper determination of the nutrient content of feedstuffs, 2)

correct calculation of rations according to requirements of animals fed, 3) proper weighing of ingredients, and 4) complete blending (5).

Though separate feeding of concentrate and forage is the most common and an effective method of feeding, there are advantages to feeding TMR's to grouped heifers. TMR's can improve the allocation of feeds available on the farm by formulation of rations for heifers with similar nutrient requirements. TMR's make it possible to utilize a variety of feeds through the ability to mask off-flavor or odor of unpalatable feeds, making utilization of poor quality or by-product feeds more feasible (6).

TMR's have also been observed to have desirable effects on digestion. Regular feeding of TMR's encourages even distribution of feed intake. Animals fed infrequently tend to consume large slugs of feed. Rapid consumption of large amounts of feed, particularly concentrates, can result in fluctuations in rumen pH that are not conducive to continuous rumen function and digesta flow (26,29). The uniformity of feed consumed as a TMR makes it possible to maintain steady conditions in the rumen. A steady rumen environment allows the animal to maximize the benefit of soluble energy sources available in the feed (26).

Though the use of TMR's may be advantageous, many times facilities are not conducive to utilization of TMR's. Heifers reared on pasture located a considerable distance from the farm proper could limit the availability of equipment and feedstuffs for heifers. If a mobile mix wagon is not utilized for the milking herd, purchase of such equipment for youngstock only would be uneconomical. In some cases the structure of current facilities are not designed for convenient use of TMR's, negating any assumed labor saving advantage (6).

Ration Formulation

Ration formulation should seek a balance between economics of the youngstock program and proper nutrition. Cost efficiency and proper nutrition should be achieved with neither variable being sacrificed in lieu of the other.

Discussion of the advantages of TMR feeding systems illustrates the practicality of blended rations for heifers under intensive management conditions. Ration balancing systems for lactating animals (3,42) within depth study of nutrient requirements, prediction of dry matter intake, and the formulation of rations for cows grouped according to milk production. Currently, proper nutrient requirements and optimal levels of dry matter intake for dairy

replacements have not been thoroughly investigated. This lack of information makes it difficult to develop tools to conveniently and accurately balance complete rations for dairy youngstock.

Information on dry matter intake specific to dairy replacements is sparse. As mentioned, in order to insure proper proportions of nutrients in the ration, there must be accurate prediction of the amount of dry matter consumed. Existing intake prediction equations are viewed as outdated and/or incomplete (25,27). Estimates derived by the NRC were developed with data gathered from 1943-1964 using beef and dairy heifers fed under less than ad libitum conditions. Genetic developments in dairy cattle and improvements in rearing facilities may warrant re-evaluation of current prediction of intake. Present equations are also based solely on the body weight of the animal with no consideration given to desired rate of gain, nutrient content of the ration or characteristics of the feeds included.

The influence of many of these factors on voluntary intake was the objective of a study by Dr. James D. Quigley, III (27). To cover the gamut of factors that might influence intake, Quigley measured variables listed in Table 1. The study was conducted in a counter slope facility capable of

Table 1. Independent variables measured during study conducted by Quigley.

Independent variable	Remarks
1. BWT/METBWT	Body weight, kg / metabolic body weight, kg.
2. TDN	Ration total digestible nutrients; % of DM
3. NEM	Net energy maintenance (NEM); Mcal/kg DM. Predicted from ADF.
4. NEG	Net energy gain (NEG); Mcal/kg DM. Predicted from ADF.
5. BULK	Bulk density, g/ml as fed.
6. GAIN	Daily gain, kg.
7. NDF	Ration neutral detergent fiber, % of DM.
8. ADF	Ration acid detergent fiber, % of DM.
9. AMBT	Daily ambient temperature.
10. BWTSQ	Body weight squared.
11. NEMSQ	NEM squared.
12. NEGSQ	NEG squared.
13. BULKSQ	Bulk density squared.
14. GAINSQ	Daily gain squared.
15. NDFSQ	NDF squared.
16. ADFSQ	ADF squared.
17. AMBTSQ	Daily ambient temperature squared.
18. AGE BWT	Age of animal, days * BWT.
19. BWTNEM	BWT * NEM.
20. BWTNEG	BWT * NEG.
21. BWTBUL	BWT * BULK.
22. BWTGAN	BWT * GAIN.
23. BWTADF	BWT * ADF.
24. BWTAMB	BWT * AMBT.
25. NEMNEG	NEM * NEG.
26. NEMBUL	NEM * BULK.
27. NEMGAN	NEM * GAIN.
28. NEMADF	NEM * ADF.
29. NEGGAN	NEG * GAIN.
30. NEGADF	NEG * ADF.
31. NEGAMB	NEG * AMBT.
32. BULGAN	BULK * GAIN.
33. BULAMB	BULK * AMBT.
34. GANADF	GAIN * ADF.
35. GANAMB	GAIN * AMBT.
36. ADFAMB	ADF * AMBT.

Quigley 1985.

housing four groups of heifers. Each pen was equipped with a Pinpointer 4000b capable of recording as fed intake of each heifer. Corn silage-based rations with TDN concentration of 85, 95, 105, and 115% of NRC requirements were chosen to depict nutrient content of rations fed in most practical situations. These rations were fed to groups of animals with average body weights of 136, 227, and 317 kg. These parameters were selected to represent animals when nutritional management, in a practical situation, is least intensive.

Before animals entered the study, they were raised until weaning according to accepted management practices at the V.P.I. & S.U. Dairy Cattle Center. After weaning, heifers became part of a pool of animals maintained at the Dairy Cattle Center's heifer facility. The pool of animals received a corn silage-based ration, balanced for NRC requirements according to body weight and .68 kg ADG. Animals were chosen at random and grouped by body weight to begin the experiment in the counter slope facility. Rations varying in TDN content were randomly assigned to groups.

The four total mixed rations contained appropriate amounts of corn silage, high moisture corn, ground orchardgrass hay, soybean meal and mineral mix. Diets were prepared and fed daily in amounts that would allow 5% refusal to ensure ad

libitum intake.

After a 14-day acclimation period, ambient temperature and actual feed intake were measured daily throughout a four-week trial. The composition of feeds was monitored by daily forage sampling. These measurements resulted in data on the variables in Table 1.

The primary factors affecting intake were 1) concentration of total digestible nutrient (TDN) and 2) body weight of the animals. The result of this research led to development of a simplified prediction equation, $DMI \text{ (kg/day)} = -29.86 + (-.54E-05 * (BWT*BWT)) + (.157 * MBWT) + (2.090 * GAIN) + (-.118 * (GAIN*GAIN)) + (.730 * TDN) + (-.005 * (TDN*TDN)) + (-.001 * BWT * GAIN) + (-.019 * TDN * GAIN)$, which utilized readily available information. The equation provides intake estimates similar to those provided by NRC, yet refined to more accurately predict DMI as desired rate of gain and energy content of the ration varies.

The simplified DMI prediction equation became the basis of a computer program designed to formulate rations for dairy cattle replacements.

Limits of this initial study were 1) the ability of the prediction equation to accurately predict dry matter intake

of diets with different forage base, 2) the accuracy with which the equation could predict DMI of diets fed for more than 28 days, 3) the ability of the equation to predict DMI of animals beyond the weight ranges of the study, and 4) the possibility that NRC recommendations for TDN requirements are excessive for heifers over 250 kg, resulting in average daily gains in excess of .68 kg per day.

Additional research was conducted to investigate if the equation could accurately predict DMI when heifers are fed diets with varying forage base for an extended period of time. A second study was conducted with five cooperator herds in the state of Virginia to establish if the prediction equation can produce desired rates of gain for heifers under the variable conditions of an applied situation.

MATERIALS AND METHODS

This study was designed to verify a dry matter intake (DMI) prediction equation for dairy heifers developed in previous research at Virginia Tech (27). It was desirable to know if the equation could accurately predict intake of heifers in a broad variety of weight groups, consuming diets of varying forage bases fed over an extended period of time. To achieve these objectives, two studies were conducted. The first was conducted at Virginia Tech under controlled conditions, the second with the cooperation of five dairy producers in the state of Virginia.

Pinpointer study

Prior to entering the experiment, heifers were raised under accepted management practices at the Virginia Tech Dairy Cattle Center. This portion of the study was conducted in a facility which resembled the Virginia counterslope heifer barn but was modified to accommodate Pinpointer 4000B devices ¹. These devices enabled monitoring of daily ration intake of individual heifers housed in groups. The barn was divided into four 6.1 meter X 9.8 meter pens, each containing approximately eight heifers.

¹Pinpointer 4000 B. AIS Inc., Cookeville, TN.

Heifers entered the pinpointer facility weighing approximately 120 kg. They were placed in groups according to body weight to minimize variation in initial body weight and therefore nutrient requirements for growth and maintenance. All rations were formulated to meet or exceed N.R.C. recommendations for protein, energy, and minerals for the average body weight of each group for .68 kg average daily gain. Rations were formulated using the Dair4H computer program developed by Quigley (27). The spreadsheet-type program permits the user to formulate rations by the trial-and-error method. The program utilizes the intake equation developed by Quigley (27) and N.R. C. recommendations for protein, energy, and minerals for specified body weights and rates of gain. An example of the screen is shown in figure 4H.

Treatments were as shown in Table 2. Rations containing varying levels of corn silage and alfalfa haylage were chosen to reflect practical diets fed to heifers in the U.S. Rations also contained appropriate levels of high moisture corn, ground orchardgrass hay (avg. length of cut, 3.3 cm.), soybean meal and minerals. Diets were fed as total mixed rations once daily.

Table 2. Classification of Experimental Rations.³

<u>Treatment</u>	<u>% Corn Silage</u>	<u>% Alfalfa Haylage</u>
1	100	0
2	75	25
3	50	50
4	25	75

possible effects of varying forage base on DMI should be illustrated through inclusion of alfalfa haylage. It would be expected that increased concentrations of alfalfa haylage would result in a decrease in percent neutral detergent fiber (NDF) and an increase in intake of these rations as suggested by Mertens (20).

Treatments were randomly assigned to each group of heifers. Each group received the same ration through their stay in the facility. Rations were formulated monthly.

After an acclimation period of 14 days, intake was measure daily. When animals weighted approximately 420 kg., they left the study. Initial weights were taken when heifers came into the study, then every two week thereafter. Ration and ingredient composition was measured weekly. Samples were taken three times per week, stored at 4 C, and composited at the end of each week. Composite samples were submitted for analysis weekly and analyzed for dry matter, percent crude protein, total digestible nutrients and acid detergent fiber. Mineral analysis and neutral detergent fiber were monitored approximately every six weeks.

Experimental

Upon entering the pinpointer facility, heifers were placed into groups of eight, according to body weight to minimize variation in nutrient requirements and intake. Treatments were randomly assigned to groups. Rations were balanced monthly, using Dair4H, according to body weight to result in .68 kg average daily gain. After an acclimation period of 14 days, intake was measured daily until animals weighed approximately 420 kg, at which time animals left the study. Initial weights were taken when heifers came onto study and bimonthly thereafter.

Total mixed ration and ingredients were sampled three times per week, stored at 4 C, and composited at the end of each week. Composite samples were submitted for analysis weekly and analyzed for percent dry matter, crude protein, total digestible nutrients and acid detergent fiber. Mineral analysis and neutral detergent fiber were monitored approximately every six weeks.

Analysis

Data was obtained on: 1) daily feed intake; 2) bi-weekly body weights; and 3) weekly forage and ingredient analysis. Daily measure of actual feed intake was converted to daily

DMI by multiplying actual intake by the percent dry matter of the ration consumed that week. Daily DMI was averaged weekly to decrease variability in the data and more accurately associate it to weekly analysis of the ration. From body weight data, average daily gain was derived for each animal. Since ration composition was determined weekly and body weight every two weeks, weekly body weights were determined by regression. Average daily gain (ADG) was determined (31) for comparison,

Evaluation of the ability of the equation to predict intake was accomplished by generating a set of predicted data from variables in the actual data. This data set was created by entering the body weight, TDN of the diet and the desired rate of gain (.68 kg.) into the simplified DMI prediction equation:

$$\text{DMI (kg/day)} = -29.86 + (-.54\text{E-}05 * (\text{BWT}*\text{BWT})) + (.157 * \text{MBWT}) + (2.090 * \text{GAIN}) + (-.118 * (\text{GAIN}*\text{GAIN})) + (.730 * \text{TDN}) + (-.005 * (\text{TDN}*\text{TDN})) + (-.001 * \text{BWT} * \text{GAIN}) + (-.019 * \text{TDN} * \text{GAIN}).$$

Actual intake was classified as Method 1 and predicted intake classified as Method 2. The model used to evaluate the prediction equation was:

$$\text{DMI} = \text{Method 2 Treatment 2 Treatment*Method,} \\ \text{Heifer (Treatment), Method*Heifer (Treatment).}$$

Analysis was conducted using SAS GLM ANOVA procedures (31).

$$Y_{ijkl} = \mu + M_i + T_j + MT_{ij} + H_{(j)k} + MH_{i(j)k} + e_{ijkl}$$

Where:

Y_{ijkl} = random variable measured as the l th observation on the k th heifer within the j th treatment on the i th method

μ = population mean

M_i = fixed effect of the i th method

T_j = fixed effect of the j th treatment

MT_{ij} = fixed effect of the interaction of the i th method and j th treatment

$H_{(j)k}$ = random effect of the k th heifer within the j th treatment

$MH_{i(j)k}$ = random effect of the interaction between the i th method and the k th heifer within the j th treatment

e_{ijkl} = random residual

Analysis of the two methods was conducted using (31).

Statistical analysis was performed according to SAS GLM and Regression Procedures (31). Regression analysis was conducted with two models. The first directly compared actual DMI to predicted DMI with the Model Method 1 = Method 2 Dry matter intake.

The second model, Method 1 = Method 2, TRT, Heifer (TRT), considered the influence that heifer and treatment would have on the comparison.

Field Study

Five cooperator herds were chosen to participate in a 12-month field study that would utilize Dair4H to balance rations for their heifers. Criteria for selecting cooperator herds were: 1) raised heifers, from weaning, in confinement; 2) feed heifers, grouped by size; 3) fed a majority of nutrients through total mixed rations; and 4) utilized the DHIA heifer management program.

Preliminary visits were made to each farm to inform participants of study protocol and their responsibilities. Each participant agreed to: 1) allow access to their heifers four times during the study to enable measurement of heifer body weights and wither heights; 2) provide samples of ration ingredients available for heifer rations to be analyzed by the Virginia Tech Forage Testing Lab; 3) feed heifers in confinement facilities rations formulated by using Dair4H; and 4) allow access to their DHIA heifer record keeping system. These agreements were made with the understanding that the researcher would: 1) provide labor and equipment required to weigh and measure heifers; 2) collect and submit the majority of major ingredient samples; and 3) balance and provide recommendations for rations to be fed.

A description of general management procedures in each cooperator herd follows:

Herd 1:

Prior to weaning at six weeks, calves are raised in hutches. Milk replacer or waste milk were fed twice daily. Clean fresh water, calf starter, and the best quality baled orchardgrass hay was always available. Once weaned, calves were placed in small groups of four. Their health was monitored closely until they became accustomed to a new diet of 18% concentrate and orchardgrass hay and learned to feed as a group. When the cooperator felt they were ready or when space was provided, they entered the confinement heifer rearing facility (approximately nine weeks of age).

Heifers were housed in a modified free stall facility. The barn is divided, by gates, into four pens. Each pen was equipped with free stalls, a waterer, and access to an exercise lot. All groups were fed from a covered feed bunk that runs along the front of the barn. An alley in front of the barn allows a mix wagon to be used. A portion of the total ration was fed as a complete mix, usually consisting of corn silage and 16% concentrate fed every other day. The rest of ration requirements were met by feeding long forage separately. The feed bunk was modified to allow feeding of

round baled forage to the oldest group of heifers (approximately 12 months of age) with younger animals fed higher quality baled orchardgrass hay broken in the feed bunk. All groups were provided free choice minerals.

Fermented forage fed was usually corn silage stored in a bunker silo. Corn silage did on occasion, contain some sorghum. Round baled forage fed to heifers was usually stored outside, causing variability of forage quality within and among bales. Baled orchardgrass hay was stored under cover in a three-sided building adjacent to the heifer facility.

Animals were vaccinated and wormed regularly according to a herd health care program established by their veterinarian. Overall appraisal of this heifer management system was very good. The cooperator was very conscientious in all aspects of the dairy operation and realized the importance of proper heifer management.

Herd 2:

Calves were reared in a three-sided building in small pens of one or two depending on availability of space. Calves were usually weaned at 6-8 weeks depending on health. Waste milk was fed twice daily, with milk replacer available if

needed. Orchardgrass hay and calf starter were fed ad libitum from birth. Water was fed only once daily to keep bedding dry. All animals were vaccinated and wormed regularly according to veterinarians recommendation.

Once weaned, calves were housed in a true counter-slope facility designed so that waste water from the parlor would flush the scrape alley. They were grouped by size in pens holding 8 to 14 animals. Each pen had a waterer and one pen was equipped with head locks to assist in handling animals for herd health work. All animals had access to a covered feed bunk that running along the front of the building. A mix wagon was used to feed a total mixed ration to all groups. No long forage was fed in this barn because the wasted forage inhibits proper function of the manure flush system.

Typical rations consisted of corn silage stored in a bunker silo and wet brewers grains stored, uncovered, on a concrete pad and free-choice minerals. Since no long forage was fed in this facility, rations were balanced for 85% recommended DMI in order not to exceed TDN requirements. If heifers had been fed 100% DMI without the contribution of fiber from long forage, the rations would have been too nutrient dense

and may have caused problems with rumen development and over-fattening.

Subjective rating of the overall system would be good.

Herd 3:

Calves were housed in a three-sided building in individual pens. A feed alley and feed storage area and the front portion of the pens are under roof, with each pen extending outdoors. Calves were fed milk replacer twice daily and offered calf starter from birth. Orchardgrass hay was offered at approximately two weeks of age. Again, calves and all other animals were vaccinated regularly.

After weaning, heifers moved to a heifer facility and were grouped by size. Animals were housed in a three-sided building divided into four pens. Each pen was equipped with a waterer and depending on their location in the barn, groups had varying amounts of fescue and orchardgrass pasture available. The largest group of heifers had access to approximately 10 acres of pasture. During the spring this fescue and orchardgrass lot contributes some nutrients to the total ration. At other times of the year, the contribution is minimal considering the stocking rate.

Animals were fed using an uncovered fence line feed bunk that running along the fence row common to the individual pasture areas. Each group also had access to a covered round bale feeder. Minerals were included in the total mixed portion of the ration.

Rations for these heifers usually consisted of corn silage, but ryelage and wheat silage were also fed. All fermented forages were stored in a conventional upright silo. The total mixed portion of the ration was usually completed using soybean meal as a protein source and to carry mineral. Round bales were usually orchardgrass hay; some bales were stored indoors and others stored outdoors covered with black plastic. During the winter several round bales of milo were fed.

The overall rating of this heifer management system would be very good.

Herd 4:

Calves were also raised in hutches, receiving waste milk or milk replacer until weaning at approximately 6 weeks. Calf starter, hay and fresh water was offered at all times and a regular vaccination program was followed.

After weaning, heifers entered a counter-slope facility and were fed 18% CP grain and orchardgrass hay until they reached approximately 120 kg. Larger animals were fed the mixed portion of their ration in a covered feed bunk using a mix wagon. The barn had been modified to allow feeding of round bales in the back of each pen. Again, every pen had access to a waterer and free-choice minerals were fed.

Ingredients at this farm were the most consistent. Rations almost always consisted of corn silage stored in a conventional, upright silo and soybean meal. Round bales were orchardgrass hay; some that had been stored indoors, others outdoors.

Evaluation of this systems level of management would be good.

Herd 5:

Until weaning, animals were reared in groups of eight on mostly waste milk and offered orchardgrass hay and calf starter from birth. Calves were weaned at 6 weeks of age except when in poor health. All calves received recommended calfhood vaccinations and appropriate boosters and worming throughout life.

After weaning, animals were group housed in a modified free stall barn until four months of age. They received 14% crude protein (CP) grain, mixed on the farm, and average quality orchardgrass hay.

At approximately four months, heifers moved into an open span, three sided barn that could be divided into pens. Animals were "usually" grouped by size. The open side of the building was lined by a covered feed bunk modified for feeding of round bales. A portion of the ration was fed daily as a total mix and supplemented with orchardgrass round bales and free-choice minerals. The quality of the round bales varied widely, with quality decreasing significantly into the summer months.

Rations consisted of corn silage or alfalfa haylage stored in conventional silos with the 36% CP milking herd concentrate mix, used as the protein source.

Subjective rating of this farms heifer management system would be average.

Four of the five farms incorporated round baled forage into feeding programs with the fifth farm feeding no long forage. Since Dair4H DMI equation was developed using ground hay, it

was of interest to evaluate performance of heifers fed rations of long forage (hay) and different forage bases.

Observations were made on each of the four farms to estimate the amount of daily as fed intake comprised by round bales. Weight of round bales was estimated using weights measured at the Virginia Tech Dairy Cattle Research Center. Based on an estimate of percent forage wasted and the amount of time it took for a specific number of heifers to finish a round bale, an estimate of intake of long forage was made for different weight groups. These estimates were used in balancing rations. It is accepted that variability in quality and amount of intake of round baled forage in practical situations is a weakness in procedure that could not be overcome.

During subsequent farm visits, made every 6 to 8 weeks, animal movement between groups was noted, composition of new rations to be fed was updated, and samples of available feed ingredients were obtained. Body weights and wither heights were also measured on all animals in confinement during four of those visits.

Ingredient samples were analyzed for percent dry matter, crude protein, acid detergent fiber and total digestible nutrients. These analyses were utilized to balance rations

for individual groups using average body weight for each group. If available ingredients changed during the month, farmers submitted forage samples through DHI supervisors, and ration updates were made by telephone as needed.

Four farms blended and fed suggested rations on a daily basis. One farm fed animals every other day. In all cases, minerals were provided in the blended portion of the diet or in block form.

Analysis

Data was analyzed according to SAS GLM procedures (31). Overall mean of average daily gain was determined with 399 observations of animals that had two or more body weight and wither height measurements during the study. Mean of average daily gain and wither height were also determined by farm.

Birth dates of animals on study were available from DHIA on four of the five farms. Analysis of wither height by age, body weight by age and body weight by wither height were established from this information for comparison to established averages.

RESULTS AND DISCUSSION

Pinpointer Study Results

Primary forage composition of experimental rations is shown in Table 2. Average nutrient composition across all trials is given in Table 3 and average ration composition for each treatment is in Table 4. Rations were balanced to resemble those fed in practical situations. Analysis confirms that ration composition was similar to calculated values.

Average composition of each diet (Table 4) shows that as percent alfalfa haylage DM increased in the ration, percent DM and CP also increased while percent TDN and ADF remained relatively constant. Throughout this study, corn silage and orchardgrass hay were of similar quality to that used by Quigley (27). Alfalfa haylage was above Virginia state average in quality.

Dry matter intake (DMI), body weight (BWT) and average daily gain (ADG) for heifers in all treatments is displayed in Table 5. Overall ADG of .81 kg (Table 5) was greater than the .68 kg of gain rations were balanced for. The mean and standard error (SE) of actual dry matter intake (ADMI), body weight (BWT), and average daily gain (ADG) for heifers by treatment is given in Table 6. ADG exceeded projected ADG

Table 3. Mean, Standard Error (SE), Minimum and Maximum Dry Matter Content (DM), Ration Acid Detergent Fiber (ADF), Total Digestible Nutrients (TDN), and Crude Protein (CP) for all Treatment Rations.

	<u>N</u>	<u>MEAN</u>	<u>SE</u>	<u>MIN</u>	<u>MAX</u>
DM	178	48.3	.4	38.0	68.0
ADF ^a	177	29.4	.3	13.4	37.8
TDN ^a	178	67.1	.2	61.0	80.0
CP ^a	178	13.0	.2	12.2	18.7

^a Percent of DM.

Table 4. Average Ration Composition by Treatment. Mean and Standard Error (SE) of Dry Matter Content (DM), Crude Protein (CP), Ration Acid Detergent Fiber (ADF) and Total Digestible Nutrients (TDN).

(% Ration DM)								
Treatment	DM		CP		ADF		TDN	
	X	S.E.	X	S.E.	X	S.E.	X	S.E.
1	45.1	.48	11.1	.33	28.9	.54	67.5	.43
2	44.8	.53	12.3	.19	28.8	.41	67.6	.32
3	49.3	.69	13.4	.21	30.5	.61	66.3	.46
4	54.5	.91	15.5	.22	29.6	.83	66.9	.63

Average	48.3	.44	13.0	.17	29.4	.31	67.1	.23

Treatment: Forage base of ration

- 1 100% corn silage
- 2 75 Corn Silage:25 Alfalfa Haylage
- 3 50 Corn Silage:50 Alfalfa Haylage
- 4 25 Corn Silage:75 Alfalfa Haylage

Table 5. Actual Dry Matter Intake (DMI), Body Weight (BW), and Average Daily Gain (ADG) for Heifers in All Treatments.

	<u>N</u>	<u>MEAN</u>	<u>SE</u>	<u>MIN</u>	<u>MAX</u>
ADMI ^a	1811	5.8	.03	.1	23.3
BWI ^a	1830	243.3	1.3	61.4	386.3
ADG ^a	1739	.81	.04	0	1.7

^a Kilograms.

Table 6. Actual Dry Matter Intake (ADMI), Body Weight (BW) and Average Daily Gain (ADG) for Heifers by Treatment.

Treatment	1		2		3		4	
	X	S.E.	X	S.E.	X	S.E.	X	S.E.
DDMI ^a	6.3	.07	6.0	.05	5.7	.06	5.8	.08
BW ^a	255.8	2.4	246.2	2.3	234.1	2.38	233.2	2.9
ADG ^a	.80	.04	.81	.04	.82	.04	.81	.04

^a Kilograms

by approximately .13 kg for all treatments. Average body weight and ADMI was not significantly different.

Animals were healthy throughout the trial with 3 minor cases of pinkeye and a low incidence of ringworm observed.

To allow comparison of actual DMI measures and predicted DMI, actual DMI was identified as Method 1 and predicted DMI as Method 2. SAS GLM ANOVA and correlation coefficient procedures were used to analyze the combination of actual and predicted data. GLM ANOVA was conducted with the model: DMI = Method, Treatment, Method*Treatment, Heifer(Treatment), Method*Heifer(Treatment).

Anova analysis showed that actual DMI (Method 1) was significantly lower than predicted DMI (Method 2). Several possible reasons for the difference could be 1) differences of forage base, 2) changes in the fiber level of rations resulting from inclusion of alfalfa haylage, 3) inability of equations to predict DMI of animals with body weights beyond those used to develop the equation, 4) additive effect of heifers consuming rations for more than 28 days, and 5) the possibility that current NRC requirements for TDN are not accurate for dairy heifers reared in confinement facilities.

Treatments differed in amounts of alfalfa haylage replacing corn silage as the forage base of the rations (Table 2). It should be noted that forage composition in Treatment 1 was similar to that used by Quigley (27) in developing the prediction equation.

It was speculated that including alfalfa would decrease ration NDF content, increasing ration digestibility thereby increasing intake (20). However, intake was not different between treatments or for the treatment by method interaction (Table 7). Least squares means of dry matter intake (kg/day) by treatment shows the similarity of DMI among treatments (Table 6).

There did not appear to be a relationship between season and intake (Table 8). Data did not show depressed levels of intake expected during the summer nor a marked increase in intake during winter months. In the initial study by Quigley (27), variation in intake due to ambient temperature was statistically significant but not of practical significance. It is thought that temperature range in south-west Virginia is not extreme enough to significantly effect DMI.

During winter months, animals in the Pinpointer facility remain dry and are adequately sheltered from wind.

Table 7. Anova Table of Pinpointer Study.

	DF	SS	MS	F
Method	1	79.32	79.32	18.66*
Treatment	3	26.86	8.95	.29
Trt->Method	3	16.37	5.45	1.28
Heifer (Trt)	105	3176.44	30.25	25.32*
Method->Heifer (Trt)	105	446.62	4.25	3.56*
Residual	3607	4309.12	1.19	

*Significantly different (P<.05).

Table 8. Means of Treatment Dry Matter Intake by Season.

Treatment	Season	Means
1	Winter	6.0
	Spring	5.8
	Summer	6.1
	Fall	5.7
2	Winter	5.6
	Spring	6.0
	Summer	6.6
	Fall	4.6
3	Winter	5.8
	Spring	4.6
	Summer	5.4
	Fall	5.8
4	Winter	4.6
	Spring	5.7
	Summer	6.6
	Fall	6.2

Treatment: Forage base of ration

- 1 100% corn silage
- 2 75 Corn Silage:25 Alfalfa Haylage
- 3 50 Corn Silage:50 Alfalfa Haylage
- 4 25 Corn Silage:75 Alfalfa Haylage

Increased intake was observed by Quigley (27) only when temperature was lower than -15 C. During the summer, it was theorized that intake was not depressed because heifers delayed eating until cooler evening hours. Intake variation between seasons may be due to differences in forage quality rather than to effects of environmental temperature and humidity on animals.

Since DMI between treatments was not significantly different, it was questioned if varying levels of ration ADF influenced intake through physical regulatory mechanisms (8,9). Least squares means of ration ADF by treatment were not different ($P < .05$) discounting this hypothesis (Figure 1).

The next variable evaluated was the equation's ability to predict DMI over a range of body weights. Plotting DMI by body weight (Figure 2) illustrates that predicted DMI begins to diverge from actual DMI when body weight is below 180 kg and above 300 kg. Least squares means of DMI by body weight group show a similar trend (Table 9).

Analysis conducted with the complete data set included heifer body weights below and above those used by Quigley to calculate the DMI prediction equation (27) resulted in an R^2 of analysis was .48. It was speculated that if the data set

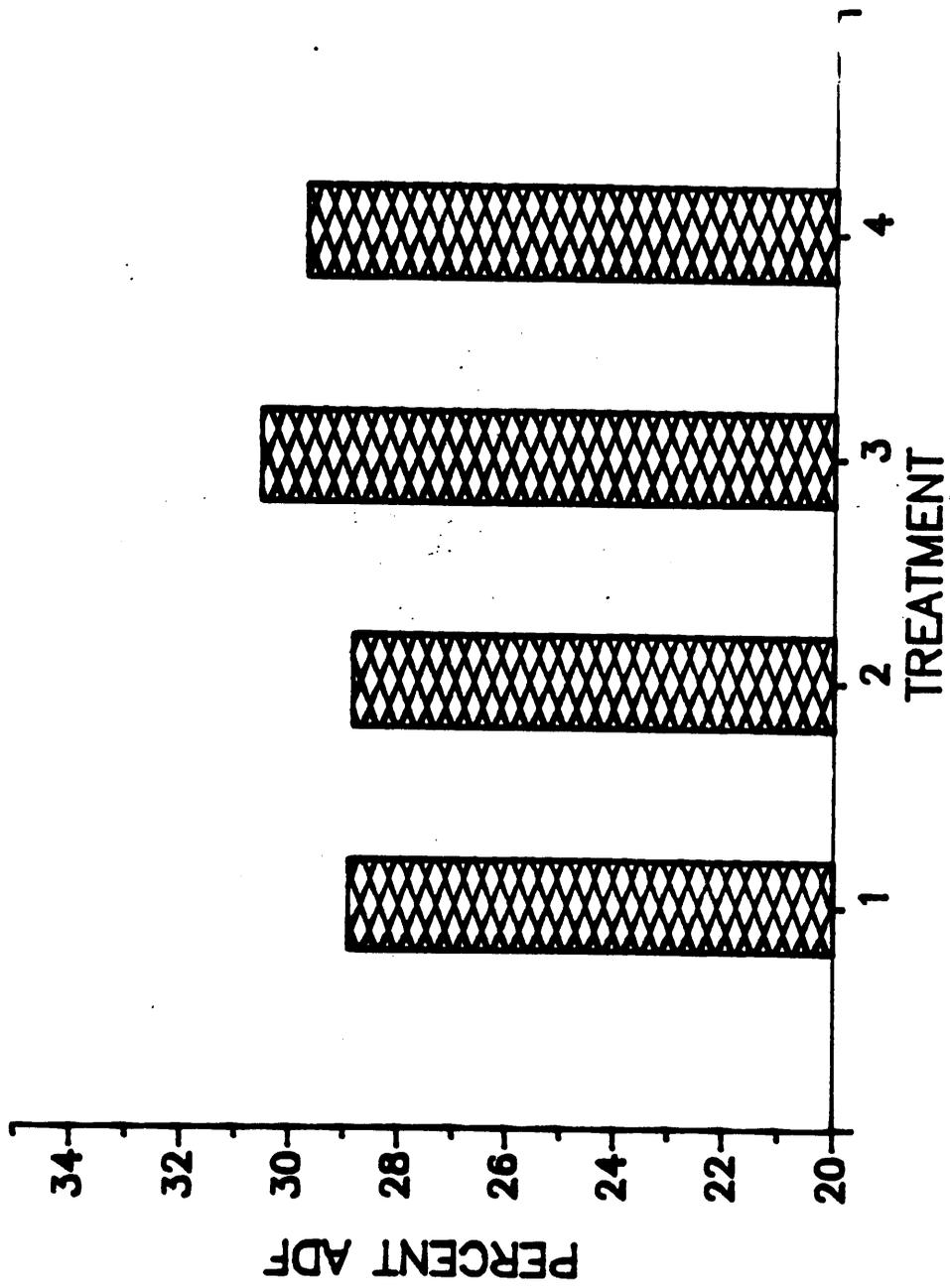


Figure 1. Least Squares Means of Ration ADF by Treatment. Pinpointer Study.

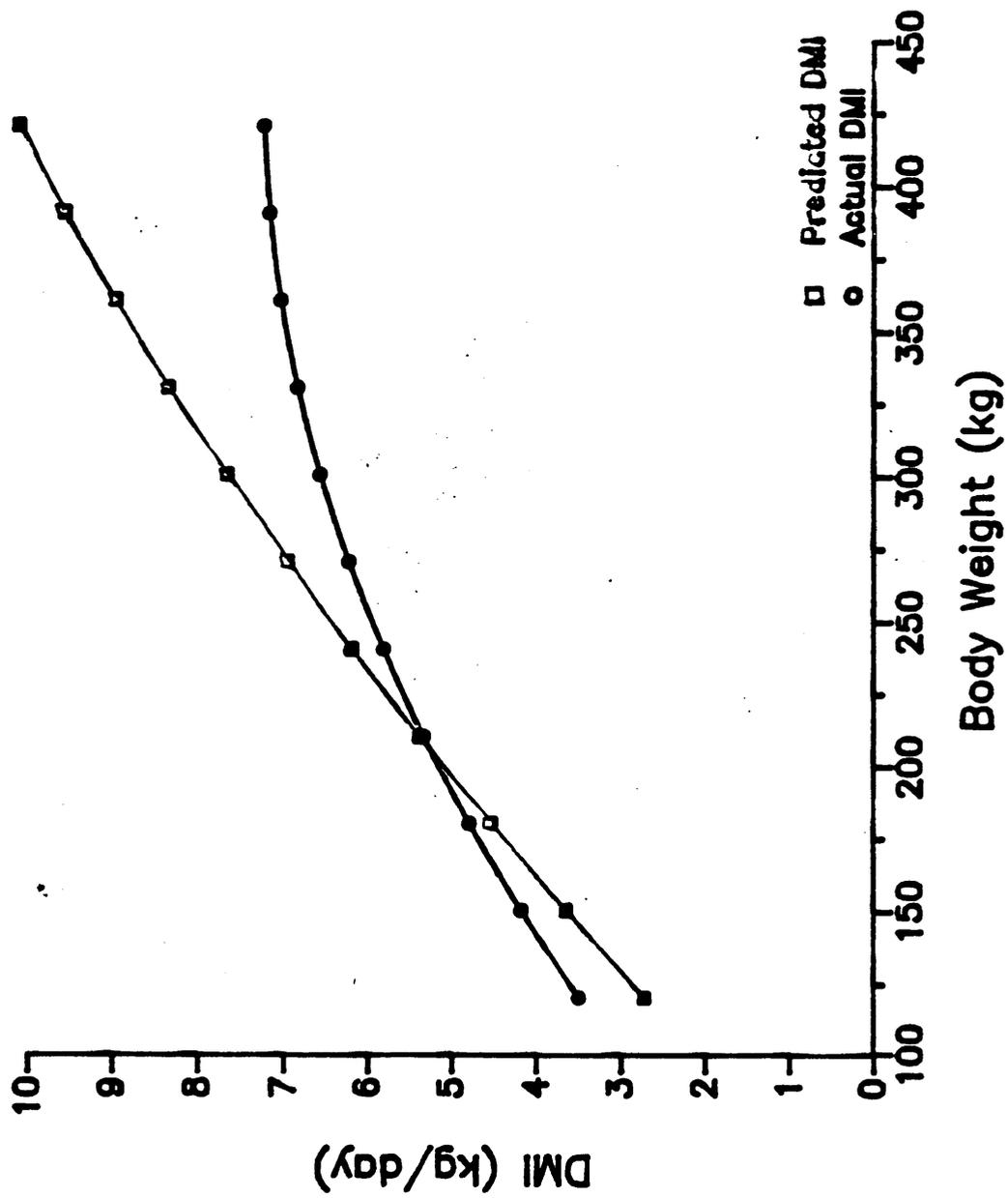


Figure 2. Dry Matter Intake by Body Weight. Pinpointer Study.

Table 9. Least Squares Means of Actual and Predicted Dry Matter Intake by Body Weight Group.

Body Weight Group	Weight Range (kg)	Average Weight (kg)	LS Means (kg/day)	
			Average	Predicted
1	75-125	122	3.5	2.6
2	126-175	161	4.3	4.0
3	176-225	206	5.3	5.3
4	226-275	251	6.0	6.4
5	276-325	294	6.5	7.5
6	326-375	333	7.0	8.4
7	376-425	380	8.3	9.4

was truncated to include only data associated with body weights from 135 to 335 kg, the R^2 of the analysis would improve. Analysis of the truncated data set produced an R^2 of .44; essentially the same as the complete data. It was concluded that the inclusion of body weights outside the range used by Quigley was bit responsible for differences observed between ADMI and PDMI at extremes of body weights.

The difference between actual and predicted intake for animals under 120 kg may be explained by examining the parameters of the experiment conducted by Quigley. The average weight of the lightest group of heifers on the Quigley study was 136 kg (27). Lack of an adequate number of animals under 120 kg, may have contributed to this discrepancy. Length of trial also may have affected intake data for smaller heifers. It was observed that young animals have difficulty adapting to pinpointer feeders. It is possible that a 28-day trial was inadequate to allow complete acclimation of younger heifers and permit collection of data which truly represented ad libitum DMI. If such data was erroneous, the reliability of the DMI prediction equation would be low.

Lack of an adequate number of observations in the initial data set also may have influenced intake differences in animals over 300 kg. The prediction equation was not

developed with data on animals weighing more than 367 kg. As with lighter animals, the equation does not appear to accurately predict DMI for heifers outside the original range of body weights. Other differences between the two studies that might have influenced intake variation for larger animals are levels of TDN fed and additive effects of feeding animals a consistent ration up to as 227 days vs. feeding trials for 28 day as in (27).

The possibility that varying levels of ADF contributed to intake differences is not likely. As stated, there was no significant difference in ADF between treatments fed during the pinpointer study. The overall mean of ADF for rations in this study was 29.4 percent of ration DM (Table 4) as compared to a mean ADF of 29.4 and 30.5 for trials 1 and 2 of studies by Quigley (27). Though measures of NDF were not available in this study, fluctuation in levels of NDF were not considered to significantly effect intake. This is supported by the observation in Quigley's study. NDF remained proportional to ADF with the correlation between NDF and ADF being .82 when NDF was greater than 42% ration DM. NDF in our rations was estimated to be greater than 42%. Quigley also showed that correlation coefficients of DMI to either NDF or ADF were identical, -0.42. For rations with NDF's below 42% ration DM the correlation coefficient of DMI to NDF or ADF in rations is only .03. The later

consideration did not present a concern since heifer rations below 42% NDF are not practical for most heifer feeding situations.

Possible effects of ration TDN content on DMI were investigated. A graph of ration TDN content by body weight (Figure 3) illustrates that heifers over 300 kg consumed less ration TDN than estimated by the equation or recommended by NRC for .68 kg ADG. This suggested that ration TDN concentration was excessive. This is supported by observations of Quigley (27) who observed ADG's of approximately .8 kg (27) for animals fed 100% of NRC TDN recommendations. In this study, ADG ranged from .80 kg for heifers receiving treatment 1 (100% corn silage) .82 kg for those receiving treatment 3 (50% corn silage: 50% alfalfa haylage) (Table 6). ADG's in excess of 1.0 kg have been recorded at other locations with confinement-reared heifers fed TMR's balanced for .68 kg ADG (28). Such levels of gain could be the result of over estimation of energy requirements for confinement-reared heifers.

The ability of the prediction equation to estimate DMI was further evaluated by calculating two correlation coefficients. The first was the correlation coefficient for ADMI and PDMI. The correlation coefficient for ADMI:PDMI

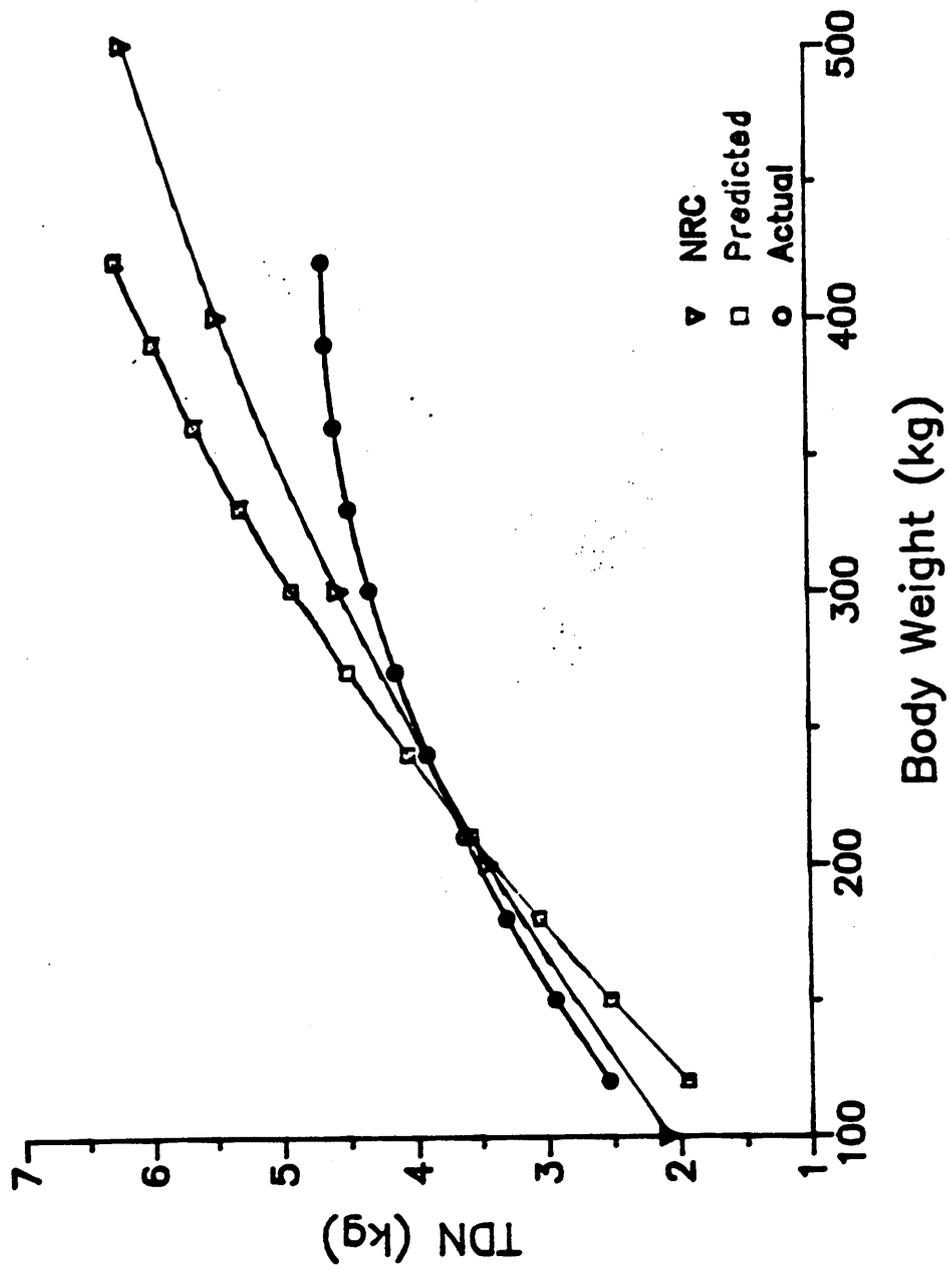


Figure 3. Ration TDN Content by Body Weight. Pinpointer Study.

was .59. In order to account for a larger portion of the variation inherent in the experiment, a multiple correlation was preformed with the model: actual DMI = predicted DMI, treatment, heifer(trt). The multiple correlation coefficient for this analysis was .77. The R² for these two analysis was .35 and .59 respectively. It is felt that these correlation coefficients between ADMI and PDMI could be significantly improved by minor adjustments to the original DMI prediction equation.

Discussion

Current NRC recommendations for TDN were established using dairy and beef heifers under less than ad libitum conditions with no distinction made for animals reared in confinement or in conventional pasture systems (27). My study and those of Quigley's (27) suggest that energy requirements may be lower for heifers reared under intensive management conditions. This, in conjunction with possible additive effects of heifers receiving rations for more than 28 days, is a reasonable explanation of intake differences observed between my study and predicted values.

The discrepancy between actual and predicted DMI seems to be caused by inadequate information on the TDN requirements of growing heifers. Overfeeding energy can contribute to

depression of DMI through metabolic control of intake (8,9). This appears to be a possible factor contributing to the discrepancy between actual and predicted intake.

For heifers under 200 kg, it appears that a lack of data for animals of that size had the most prominent effect. This discrepancy is most likely due to problems in acclimation of small animals to the pinpointer feeding system. Heifers over 350 kg exhibited depressed intake, suggesting that the rations consumed contained more TDN than required for energy balance. When energy balance was met, animals reached satiety with metabolic control depressing feed intake.

The length of time heifers were on study may also have contributed to discrepancies between ADMI and PDMI of heavier animals. During this study animals were reared on the same diet from approximately 120 kg to 420 kg; some animals stayed on study as long as 227 days. The Quigley study (27) fed diets for 28 days, then animals were removed from the trial. The possibility of an additive effect of TDN level over an extended period of time is illustrated by elevated amounts of ADG in the confinement-reared animals .

Further study of TDN requirements for heifers raised in confinement is necessary. The use of metabolism chambers or total collection studies is needed to evaluate the energy

requirements of dairy heifers. Establishment of more accurate estimates of energy requirements would make it possible to fine tune the predictive ability of the current equation making Dair4H a more valuable ration formulation tool.

Obviously, there is no single test that can validate the ability of this equation to predict DMI. Current literature does not provide similar data that can be used as a point of comparison for evaluation of these results. The ability of this equation is dependent on its continued use and revision as its independent variables are investigated.

Field Study

Results

This portion of the experiment was to evaluate the effectiveness of rations recommended by Dair4H in feeding heifers under practical conditions. Five cooperator herds with similar heifer rearing programs participated in the study.

Utilizing the heifers available and ration ingredients chosen by the cooperator, rations were balanced for all five herds to produce .68 kg ADG. On all farms, the mixed portion of the rations fed from the mix wagon were balanced to meet the nutrient requirements of the largest group of animals. Energy content of rations for smaller animals was adjusted by topdressing the amount of mixed ration fed with a recommended amount of grain.

Initially, the study was designed to evaluate the DMI prediction equation (27) under practical conditions. Farms were to record the amount of total mixed rations (TMR) fed using mix wagon scales. Estimates of consumption of long hay were to be obtained based on disappearance. DMI was to be determined from the amount of feed refused, measured once

every two weeks. Tubs and a set of scales were supplied to each farm so that feed refusal could be measured.

Each farmer agreed to overfeed the total mixed portion of the ration by 20-30% the day before weigh-backs were to be taken in order to create refusal.

Herd 2 was the first to overfeed by approximately 20% to produce refusal. After the first over-feeding, there was no refusal. The next day, rations were overfed by approximately 35%. This level did not produce refusal. Animals in this herd were normally fed for 85% of recommended DMI to prevent rations from being too nutrient dense since no long forage was fed. On the occasion that feed was increased, animals consumed all that was offered. Animals had not reached the point of metabolic control, which is more long term in developing (24).

The same reaction was observed on the other four farms, but for a different reason. When the total mixed portion of the rations were fed for refusal, heifers continued to consume all that was offered. It is speculated that on this occasion heifers chose to eat all of the mixed ration, substituting this increased amount for their usual consumption of long hay.

It was not practical to request that cooperators continue to feed elevated amounts until refusal was produced. In conjunction with the increased expense, feed availability on most of the farms was stressed by drought conditions.

Since DMI could not be estimated, the ability of DairyH to produce appropriate rations was evaluated by animal performance. When ADG of heifers from all herds was evaluated as a complete data set, ADG was .62 kg (Table 10) and body weight by age was similar to those recommended by NRC (25). Overall ADG by herd ranged from .41 kg to .96 kg (Table 10).

In addition to body weight, heifer wither height was measured on each farm. Four of the five herds were also enrolled in the Dairy Herd Improvement Association (DHIA) heifer program. This provided age for the majority of the heifers on study for those four herds.

To further evaluate heifer performance, the relationship of 1) height to age; 2) body weight to height, and 3) body weight to age; were compared to previously published averages. Since the average daily gain across all herds was .62kg (Table 10), it was expected that the relationships

Table 10. Average Amounts of Gain by Herd

Herd	N	Gain (kg/day)	
		\bar{X}	S.E.
1	73	.60	.04
2	102	.48	.09
3	78	.70	.02
4	76	.96	.02
5	77	.41	.03
Total	406	.62	.02

produced by the data should be similar to those already established (10,25). Average age, body weight and wither heights for each herd is summarized in Table 11. It is the relationship of this raw data that is the bases for Figures 4, 5 and 6.

Height by age (Figure 4) was not significantly different from those previously reported by Etgen et al. (10). When graphed, animals on this study appeared to be slightly shorter than expected with the comparison having an R^2 of .68. In contrast, the height by body weight (Figure 5) comparison appeared above that reported by Etgen (10). The R^2 of height by body weight was .80.

The most important of the three comparisons was to determine if rations were providing adequate nutrition to produce properly conditioned heifers, capable of breeding by approximately fifteen months of age. The relationship of body weight to age (Figure 6) in this study indicates trends higher than those established by NRC (25), though again not significantly different. With an R^2 of .76 it is relatively certain, that across all farms, were providing adequate nutrition to rear well conditioned heifers, capable of calving by 25 months of age.

Comparison of all three of these relationships indicates that though the majority of the animals were capable of

Table 11. Mean of Age, Body Weight (BWT) and Wither Height (WH) for Heifers by Herd.

Herd	1		2		3		4		5	
	N	X	N	X	N	X	N	X	N	X
Age ^a	178	289	0	--	175	402	165	272	191	311
BWT ^b	182	246	172	247	187	344	181	240	198	254
WH ^c	180	106	172	109	113	117	181	107	198	109

^aDays, birth dates unavailable for herd 2.

^bKilograms

^cCentimeters.

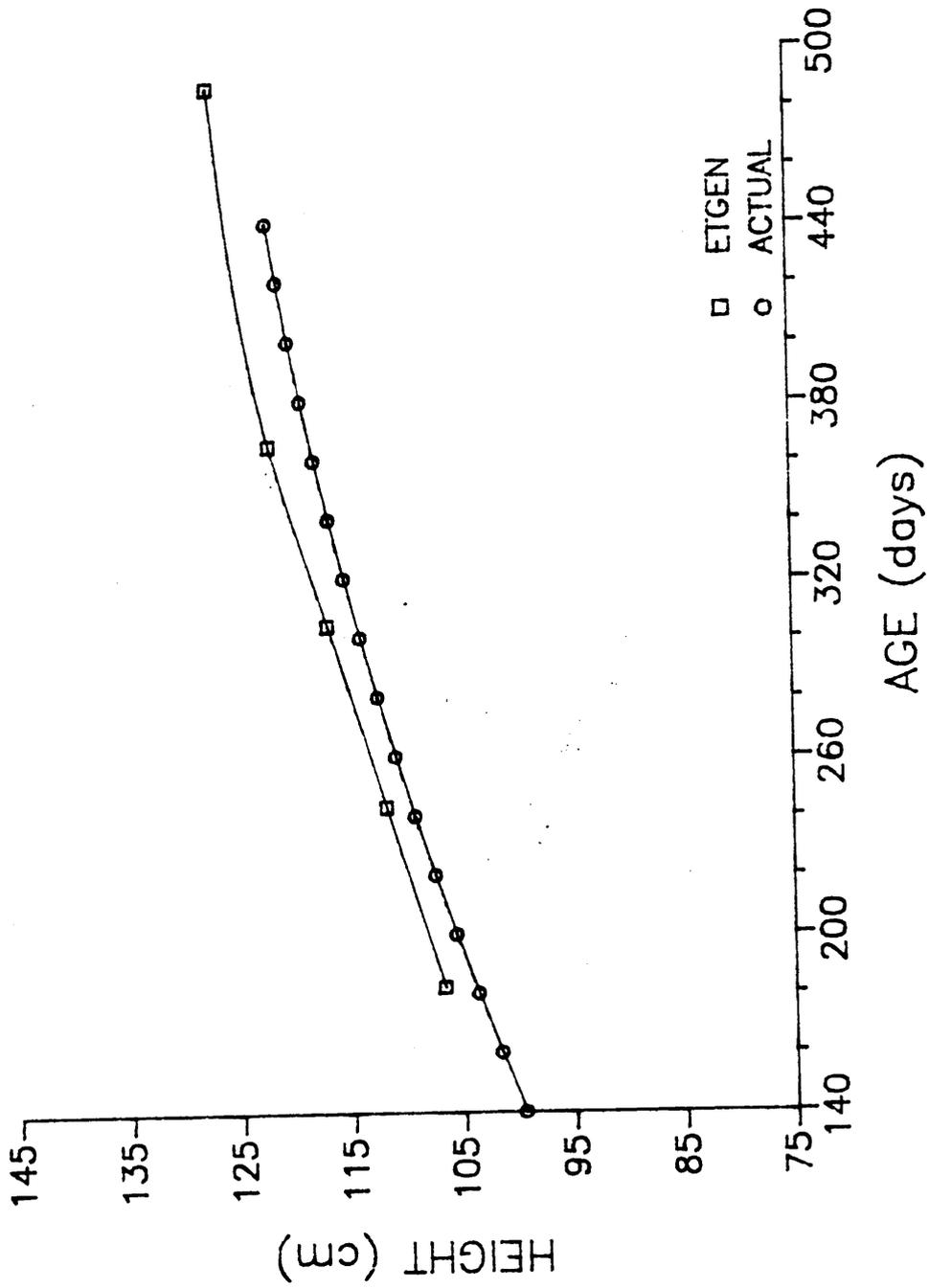


Figure 4. Height by Age Comparison. Field Study.

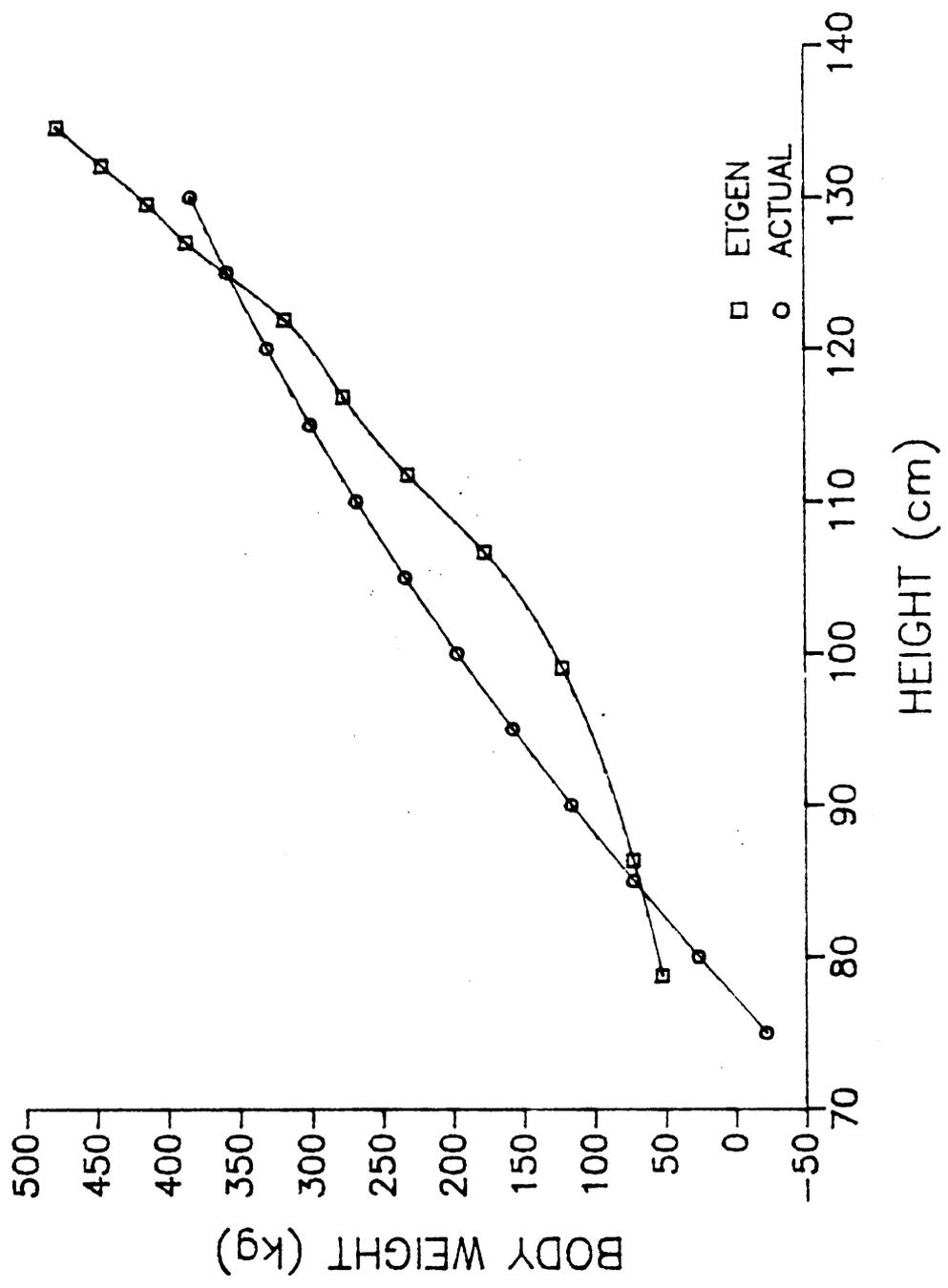


Figure 5. Body Weight by Height Comparison. Field Study.

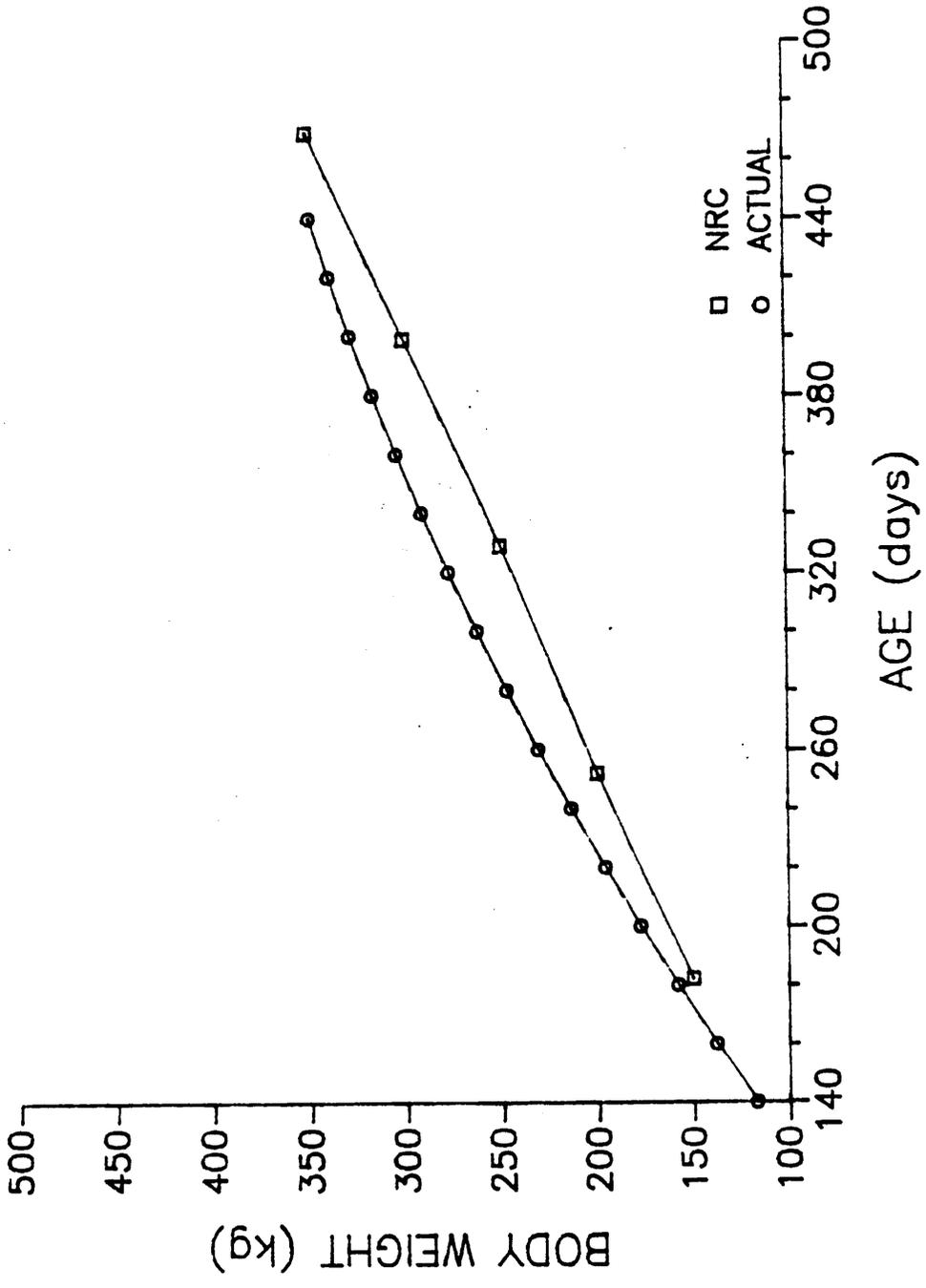


Figure 6. Body Weight by Age Comparison. Field Study.

calving by 25 months of age, they were slightly shorter and heavier than expected.

Discussion

There is an obvious difference between the rates of gain in this study and those produced by animals fed in the Pinpointer facility. Animals fed in the pinpointer had ADG's ranging from .80 to .82 kg. Animals fed under field conditions averaged .41 to .96 kg. The most obvious difference between the two studies was variability and quality of ration ingredients. Heifers on the pinpointer trial received consistent rations throughout rearing. On all farms, corn silage was the primary forage base during most of the study. But, on occasion, corn silage was replaced by alfalfa haylage, ryelage, or wheat silage. Protein sources were soybean meal, wet brewers grains, and commercially mixed dairy protein supplements varying from 18 to 32% CP. Round bales varied in quality within and between farms depending on the original quality of the forage and where and how long the bales had been stored.

Pinpointer animals remained in the same groups throughout the study. Once an order of dominance was established, individuals in groups were not moved. In practical conditions, groups changed when animals were moved from one

facility to another. On several occasions groups were accidentally disrupted while facilities were cleaned or when animals destroyed gates.

In every case, ingredients for heifer rations were chosen that would not detract from the quality of the milking herd ration. Heifer rations usually consisted of the poorest quality forages on the farm, the most heavily weathered round bales or moldy corn silage from the face of the bunker silo. This resulted in rations that were constantly changing and consisted of ingredients with a more variable nutrient content.

While animals at the Virginia Tech Dairy Cattle Center are raised under consistent management conditions, there was variability in calf rearing systems among farms. It is likely that this affected the condition of youngstock entering the confinement facility. It was obvious that heifers on farms with superior rearing programs entered the confinement facility in better condition than others. This factor would influence initial weight, but should not have continued to effect growth rates if animals were properly fed.

It is speculated that the fluctuation of ADG in the field is attributed to the variability of different management.

factors on each farm. This is supported by observation of the variables age, body weight and wither height. When evaluated overall, the feeding regimens produced desirable animals, even though optimum daily gain was not achieved on each farm.

The highest ADG's occurred in herd 3 and 4 (Table 10). Both farms had sound calf rearing programs. Through observation it is speculated that the animals in herd 3 entered the confinement facility in better condition than those in herd 4. Animals in herd 4 were housed in a conventional counter-slope facility, and had very little physical activity. In contrast, heifers in herd 3 had access to varying amounts of pasture. It is likely that increased exercise contributed to lower ADG of herd 3 heifers.

The heifer rearing system of Herd 1 that resulted in .6 kg ADG, is very similar to Herds 3 and 4. Herd 1 also provides exercise lots for heifers and has a successful calf rearing program. The difference that may have resulted in decreased ADG was that Herd 1 fed heifers on study every other day in contrast to other farms that fed animals daily. The acceptable level of ADG suggests that every-other-day feeding is probably not detrimental, but that greater rates of gain might have resulted if heifers had received rations daily.

During summer months, consideration is given to secondary fermentation that may occur in the feed bunk, resulting in decreased palatability of rations. Though this level of ADG is acceptable, it is likely that when compared to the first two herds, this feeding program may not have encouraged ad libitum intake of the energy dense, total mixed portion of the ration. Thereby, forcing animals to consume more round baled forage that did not contribute as much nutritionally to achieve satiety.

Herds 2 and 5 exhibited the lowest rates of gain. Farm number 2 reared animals in a conventional counter-slope facility in total confinement, but did not feed any long forage. Rations on this farm usually consisted of corn silage and wet brewers grain. This cooperator did not have the capability of feeding long hay. Because of the energy content of these feedstuffs, rations were balanced for 85% of predicted dry matter intake. If animals had been fed 100% of their dry matter intake without the contribution of fiber from long forage, their energy consumption would have been excessive. Lack of long forage in combination with decreased DMI and a less than optimal calf rearing system are considered to contribute to this depressed rate of gain.

The rate of gain seen in herd 5 is the lowest (Table 10) and was considered to be mostly environmental. This farm had the worst heifer rearing system of the group, and this was obvious by the condition of heifers when they entered the facility. The cooperator was very willing to follow ration recommendations but did not always group heifers according to body weight, resulting in increased competition for feed, causing some of the smaller heifers to be fed less nutrient dense rations than needed. During five months of the study, three groups of heifers ran together because of a broken waterer. This large group contained 32 animals with a range of weight from 165 to 265 kg. It is also speculated that one waterer may have been inadequate to supply enough water for 32 heifers.

Variability of ration ingredients made it difficult to compare diets between farms. As stated earlier, due to drought conditions, heifers usually received the worst quality forage on the farm. Moldy corn silage or badly weathered round baled forage was fed sporadically. Though analysis of ingredients and balancing of rations was done monthly, diets sometimes changed from week to week, depending of the availability of forage.

Though exact diets can not be reported, rations were constantly updated either during scheduled visits or over

the telephone. Rations were balanced using Dair4H to meet nutrient requirements according to: 1) the average body weight of a specific group of animals and 2) a desired rate of gain of .68 kg.

The variability of ADG's observed in the five cooperator herds suggests environmental limitations that any heifer feeding system would experience. Most practical heifer feeding systems do not utilize true total mixed rations. In many cases, some form of high fiber/low energy feed is fed in addition to the energy dense, blended portion of the ration. In this field study, estimates had to be made of the amount of long forage heifers would consume in addition to the blended portion of the diet.

The effects of separately fed, high fiber forage on intake is currently being investigated in a controlled environment. This information is needed to determine how much the feeding of long forage affects energy intake. In addition, the possibility that current NRC recommendations overestimate energy requirements for dairy heifers warrants further investigation.

Summary

Under controlled conditions of the Pinpointer facility, heifers consuming Dair4H rations consumed less dry matter than predicted. It is unlikely that alfalfa haylage as a percent of fermented feeds effected DMI since intake was similar regardless of the percent of alfalfa fed. It was concluded that depressed intake was the result of animals being fed rations with excessive energy concentrations. The assumption that NRC energy recommendations exceed nutrient requirements is supported by the observation that even with depressed DMI, animals gained in excess of the .68 kg average daily gain rations were balanced for.

Under practical situations, Dair4H rations produce varying levels of ADG that appear to be influenced by the level of heifer management.

Information resulting from investigation of heifer TDN requirements and the effects of separately fed long forage on ration consumption should enhance the prediction of DMI, thereby improving Dair4H ration recommendations. Dair4H has the potential of becoming a viable management tool that will allow farmers to accurately and economically rear healthy, well-conditioned heifers. As with any other management

tools, Dair4H alone will not instantly improve a heifer feeding program. The effectiveness of Dair4H will be determined by the current level of heifer management, accuracy of information put into the program, and how well those recommendations are followed.

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