EFFECT OF METHOD OF PROCESSING MILO UPON THE EFFICIENCY OF ENERGY UTILIZATION BY BEEF STEERS AS MEASURED BY RESPIRATION CALORIMETRY AND SLAUGHTER TECHNIQUE

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CHAPTER I

INTRODUCTION

Milo has become increasingly important in recent years as an energy source in high concentrate rations for feedlot cattle. Various methods of processing which might improve the efficiency of utilization of the grain have been studied. The feeding of grains processed by such methods as grinding, pelleting, rolling, popping, steam-flaking, early-harvesting and reconstituting have usually resulted in improved feed efficiency and rate of gain. Methods available for use in evaluating feeds or rations include feeding trials, digestion trials and techniques such as the comparative slaughter technique and respiration calorimetry. Although respiration calorimetry has been in use for many years it has not been used in recent years to evaluate feeds for beef cattle.

The use of net energy for expressing the value of a ration for feedlot cattle has gained much attention in recent years. Respiration calorimetry and the comparative slaughter techniques along with digestion trials provide a means for fractionating the gross energy of a feed into various components (DE, ME, HI, NEm, NEp and NEm+p). Thus, it should be possible to estimate rather accurately the actual usefulness of a ration for specific purposes.

The purpose of this study was to compare the net energy value of reconstituted rolled milo to that of dry rolled milo using respiration

calorimetry and the comparative slaughter technique and to compare the two methods of estimating the net energy value of high energy rations.

CHAPTER II

REVIEW OF LITERATURE

Introduction

Grain sorghum (milo) is the most readily available and widely used grain for fattening cattle in the Southwest. Since many feedlot rations contain as much as 80 to 90% milo, an accurate estimate of the net energy value of milo for feedlot cattle is important. The net energy concept; an expression of the actual usefulness of a ration for specific purposes, has become increasingly important in recent years, especially for feedlot cattle.

Energy metabolism is one of the fundamental vital functions. As any chemical process is related to a definite transformation of energy, energy metabolism could be determined if the complete chemical metabolism is known. However, according to the Law of Hess, only the initial and final chemical states must be known to determine energy balance (Kleiber, 1935). Also, according to Hess' law, direct and indirect calorimetry should give equal results. This is the underlying principle for the use of respiration calorimetry and comparative slaughter technique for the indirect determination of net energy values. The following is a review of respiration calorimetry and comparative slaughter as techniques for measuring net energy and the effect of processing on the utilization of the energy of grain sorghum.

Methods of Processing Grain Sorghum

Processing methods such as grinding, pelleting, rolling, popping, steam-flaking and reconstituting along with early harvesting of grain sorghum have been used in attempting to increase efficiency of utilization. It has long been recognized that efficiency of utilization of grain could be improved by grinding or cracking the grain. Such factors as improved feed efficiency and/or increased rate of gain have been observed for cattle fed milo which had been pelleted, rolled, popped or steam-flaked.

Riggs et al. (1959) reported that steers fed early harvested ground milo (23% moisture) required 12% less dry matter per unit of gain than those fed dry ground milo. Franke et al. (1960) compared early harvested ground milo (31% moisture) to dry ground milo and obtained 10 and 17.6% increases in feed efficiency in two trials of 112 and 140 days, respectively.

Parrett and Riggs (1966) reconstituted milo to 30% moisture by spraying the grain with water while it was being augered into an air-tight structure where it remained for 90 days before feeding. The cattle fed on this reconstituted milo gained only 0.13 lb/day more than those fed on dry grain but required 15% less dry matter per unit of gain. This was the first instance in which moist grain was fed in an all-concentrate diet. Totusek et al. (1967) reconstituted milo to 27% moisture and stored it for 20 days prior to feeding. This resulted in decreased grain intake (7.3%) and a significantly ($P < .05$) increased feed efficiency (8.2%) with no significant change in average daily gain as compared to course ground milo.

Digestion coefficients were 29% higher for dry matter, organic

matter and non-protein organic matter when determined by steers fed reconstituted milo (30% moisture) than when dry grain was fed (McGinty, Breuer and Riggs, 1966). Protein digestibility was 16% higher for the reconstituted grain. Buchanan-Smith, Totusek and Tillman (1968) also reported significantly ($P < .05$) greater digestibility of dry matter, organic matter and non-protein organic matter as well as energy in cattle fed diets containing reconstituted rolled milo than for those containing ground milo. Sheep and cattle did not differ significantly in the digestibility of the reconstituted product.

Numerous feedlot studies have been conducted to evaluate high moisture milo for feedlot cattle. Newsom et al. (1968) reported that the percent increase in feed efficiency paralleled the percent decrease in intake of reconstituted rolled milo and that energy intake seemed to be the governing factor. In contrast, for steam-flaked grain the improvement was in faster rate of gain without decreased intake. Similarly, Riggs and McGinty (1970) found that average daily gain of cattle fed ground, moist grain was equal to that of cattle fed dry grain but total ration dry matter required per unit gain was 11% less for the reconstituted milo. Other studies indicating insignificant differences in rate of gain but large improvements in feed efficiency with reconstituted milo have been reported (White and Totusek, 1969; Wagner and Schneider, 1970; Wagner, Christiansen and Holloway, 1971). Bowers, Riggs and McGinty (1968) reported that feeding reconstituted grain significantly increased daily gain ($P < .07$) and feed efficiency ($P < .02$) over dry ground milo. White et al. (1969) also reported that high moisture harvested-rolled and reconstituted-rolled milo produced non-significant faster rates of gain with a significant ($P < .05$)

improvement in feed efficiency over finely ground milo.

Reconstituting grain sorghum in whole form increased efficiency of utilization 11% while reconstituting in ground form completely failed to increase efficiency as compared to dry ground grain for finishing beef cattle (Penic et al., 1968). They suggested that certain physical pathways of enzyme action for starch hydrolysis exist in the intact grain are disrupted by grinding as a possible explanation for these results. This was supported by White et al. (1969) who reported that reconstituted-ground milo produced 9% better feed efficiency while ground-reconstituted milo produced 3.5% less feed efficiency than dry ground milo. However, these differences were not statistically significant. They suggested that reconstituting in the whole form apparently results in partial germination which converts the starch into simpler carbohydrates which are more available to the rumen microorganisms. Similar results were reported by Martin et al. (1970) who also showed a beneficial effect of increased protein with whole-reconstituted-ground milo but not with ground-reconstituted milo.

Other explanations for the improved feed efficiency of reconstituted milo include a decreased density of the rolled products (Newsom et al., 1968) and distinct differences in particle size (Florence and Riggs, 1968) relative to dry grain. Solubility studies by Florence and Riggs indicated that there was a larger amount of starch available for digestion in the reconstituted grain. Buchanan-Smith et al. (1968) reported an increase in the amount of reducing sugars from about 0.3% in dry grain to 1% in reconstituted grain. Riggs and McGinty (1970) suggested that alterations of the starch molecule and/or alteration of the protein matrix which encapsulates the starch might be responsible

for increased digestibility of the components in reconstituted grain. The more complete physical breakdown of moist grain during rolling or grinding might be a contributing factor also. Buchanan-Smith et al. (1968) suggested that the increase in digestibility of the reconstituted product might be a consequence of physical softening of the endosperm or it might be due to fermentation changes taking place after the water was added. Potter, McNeill and Riggs (1971) found enhanced ruminal conversion of sorghum protein to bacterial protein with reconstituted grain relative to ground grain. This increased the biological value of the grain protein.

Neither water temperature (60 or 120°F) nor storage time (10 or 20 days) significantly altered the effect of reconstituting grain sorghum (Bowers, Riggs and McGinty, 1968; Pantin, Riggs and Bowers, 1969). White and Totusek (1969) found that storage of one day was not sufficient to significantly benefit from reconstitution. Wagner and Schneider (1970) reported that feed efficiency was improved (non-significant) by 3.7, 3.0 and 12.0% over dry rolled milo when whole milo was reconstituted to 30% moisture and stored for 5, 10 and 20 days, respectively. The benefit of increasing moisture level over 30% appears questionable, however 38% moisture milo stored for 10 or 20 days produced equal or greater feed efficiency than 30% moisture milo stored for 10 or 20 days (Wagner, Christiansen and Holloway, 1971).

Schake et al. (1969) evaluated reconstituted milo under commercial feedlot conditions using two lots of 75 steers each for steam-flaked, whole-reconstituted-rolled or dry-rolled-reconstituted grain sorghum. Feed per pound of gain and cost per pound of gain tended to be less for the whole-reconstituted-rolled grain even though

the differences were not statistically significant.

Net Energy of Milo

In the determination of net energy values it is necessary to have a measure of the energy retention brought about by the consumption of a given quantity of feed (Lofgreen, 1965). Two methods by which this may be done are respiration calorimetry and the comparative slaughter technique. The efficiency of energy utilization for maintenance is higher than for production (Kleiber, 1961). Lofgreen and Garrett (1968) stated that net energy for maintenance (NEm) is that quantity of feed needed to maintain the body at energy equilibrium and is equal to the fasting heat production of the animal. They further stated that the net energy of a feed for production (NEp) at different levels of feed intake did not deviate significantly from linearity. Thus NEm and NEp are more nearly constant than the total (NEm+p) and more precisely express the usefulness of the feed.

The net energy of milo is about equal to that of corn (Morrison, 1959). Since the development of the comparative slaughter technique, the procedure has been used in several studies to determine net energy values. Garrett (1965) determined a NEp value for milo of 1.43 Mcal/kg which was slightly higher than the value of 1.31 Mcal/kg determined by Garrett, Lofgreen and Meyer (1964). The NEp for milo tended to be greater than for barley in the two studies (1.31 and 1.23 Mcal/kg, respectively) but the differences were not statistically significant. Newsom (1966) also reported slightly higher NEp values for milo than for barley (1.14 vs. 1.11 Mcal/kg, respectively). Hall et al. (1968) compared milo and corn at different levels of performance. The NEp

values for corn and milo respectively were 1.01 and 0.97 Mcal/kg for the maintenance to intermediate level of feeding, 1.05 and 1.12 for intermediate to high and 1.00 and 1.08 for maintenance to high level of feeding. None of the differences were statistically significant.

Newsom (1966) conducted several studies to compare the effects of method of processing milo on net energy values. In one trial, dry rolled and reconstituted rolled (22% moisture) milo were compared. The milo was added to a premix which contained the necessary ingredients to form balanced mixtures. The NEm+p was 1.50 Mcal/kg for the dry rolled milo ration and 1.61 Mcal/kg for the reconstituted rolled milo ration. The NEm+p values for the milo in the two rations were 1.64 and 1.77 Mcal/kg, respectively for the dry rolled and reconstituted rolled grains. Milo NEp values for the two grains were 1.34 and 1.52 Mcal/kg, respectively. All differences were significant ($P < .01$). Schneider (1968) conducted a similar study and determined the same energy values for dry rolled milo, reconstituted (30% moisture) milo stored for either 5, 10 or 20 days and steeped (38% moisture) milo. The values were lower for the 10-day reconstituted milo than those for the other moisture treatments, which were almost identical. Total ration NEm+p values for the dry rolled and 20-day reconstituted grains were 1.34 and 1.48 Mcal/kg, respectively with the difference being significant ($P < .05$). Milo NEm+p was 1.40 and 1.59 Mcal/kg and milo NEp was 1.13 and 1.35 Mcal/kg, respectively for the two grains. The differences were not statistically significant.

Respiration Calorimetry

To establish Hess' equation as correct for the living animal, one

must measure the chemical energy of the food, excreta and body tissue (deposited or degradated) and the heat produced by the animal (Kleiber, 1935). This can be done by either direct or indirect respiration calorimetry. Direct calorimetry is based on the principle that heat evolved increases the temperature of a surrounding medium to yield an estimate of the animals' heat production. Indirect calorimetry is based on the fact that oxygen consumption and carbon dioxide production are closely related with heat production (Brody, 1945). Direct calorimetry involves measurements of the actual heat losses due to radiation, conduction and convection which necessitates very expensive instrumentation. In indirect calorimetry the heat production is calculated from oxygen consumption, carbon dioxide and methane production and urinary nitrogen excreted which required the use of an apparatus for collecting respiration gases. Both methods have been shown to give similar results (Blaxter, 1956).

Indirect calorimetry can be conducted with either an open- or a closed-circuit apparatus. In the open circuit respiration apparatus, outdoor air is passed through the chamber and changes in oxygen, carbon dioxide and methane content as well as volume of air are measured. In the closed circuit system, air is recirculated through the chambers after passing through absorbents to remove carbon dioxide and water vapor. Oxygen is admitted to the system to maintain a constant pressure. Almost all the respiration apparatus in current use for large animals are of the open circuit type (Blaxter, 1962).

The best known respiration calorimeter for animals was built by Atwater and Rosa in 1899 (Kleiber, 1961). Later similar respiration calorimeters were built for small animals by Williams (1912) and for

large animals by Armsby in 1904 (Braman, 1933), Mitchell (1932) and Kleiber (1935). The largest and most modern laboratory currently is operated by the U.S.D.A. at Beltsville, Maryland (Flatt et al., 1958).

Armsby (1913) compared theoretical heat production with that observed by respiration calorimetry and reported that the results of individual trials differed considerably but that errors tended to compensate. In 57 trials the observed differed from computed heat production by only 0.4%. Forbes and co-workers (1928, 1930) used both direct and indirect calorimetry to study energy metabolism in relation to plane of nutrition. Heat production values were quite similar whether determined by direct or indirect methods. The curve of heat production in relation to the plane of nutrition was found to be S shaped. Mitchell et al. (1932), by the use of open circuit respiration calorimetry, found that metabolizable energy (ME) and heat increment (HI) per kg of dry matter consumed increased but net energy (NE) per kg of dry matter decreased as level of feed intake increased from one-fifth full feed to full feed.

Fasting heat production is often used as a base line in energy metabolism studies. Marston (1948) determined fasting heat production of sheep with open circuit respiration calorimeters. He found that heat production varied according to previous plane of nutrition. The fasting heat production values, expressed as kcal/$W^{.73}$/day were 74.5 for sheep previously fed at two times maintenance, 59 for those at one half maintenance and 68 for intermediate levels of feeding. These values were slightly lower than those reported by Flatt and Coppock (1963) for dairy cows. They reported values of 76.2 kcal/$W^{.75}$/day for cows previously fed ad lib, 71.6 for one half maintenance and 73.5 for

maintenance level. The interspecies mean is considered to be 70 kcal/ $W^{.75}$/day (Kleiber, 1961).

The heat increment of a feed can be determined from the heat production (HP) on feed and on fast after each digestion balance experiment (Colovos, 1961). Colovos et al. (1963) determined heat increment by the difference in HP on feed and fast to estimate net energy values of dairy cattle rations.

Information about energy utilization in growth with respect to respiration calorimetry studies is limited. Blaxter (1962) shows that the energetic efficiency of lipogenesis varies with the nature of the diet. The efficinecy of fat synthesis is low (25-30%) when all roughage rations are given but over 60% on all concentrate rations. This agrees with the fact that a high acetic:propionic acid ratio results in lower efficiency of body fat synthesis.

Two serious difficulties are associated with open circuit respiration calorimetry: (1) accurate measurement of the volume of air passing through the chambers and (2) accurate analysis of O_2, CO_2 and CH_4 in the expired air. To obtain an accuracy of 1% in daily O_2-consumption and CO_2-production, gas analysis must be accurate to 0.002 to 0.003% (Van Es, 1968). Modern instruments have minimized these problems. Brouwer (1958) derived formulae for calculating the results of respiration calorimetry studies. Increased speed and reliability of calculations has been accomplished by electronic data processing equipment as described by Flatt and Tabler (1961).

Balance studies provide information as to metabolic processes and effects of specific rations and such studies can be repeated on an individual. This method does necessitate an expensive and laborious

procedure and animals are subjected to unnatural conditions, however, many basic problems related to animal nutrition might be answered by respiration calorimetry studies.

Slaughter Technique

A method of determining net energy that has received considerable attention in recent years is the comparative slaughter technique. The method involves slaughtering comparable animals at the beginning and end of a feeding experiment and determining energy retention by the difference between initial and final body caloric content (Blaxter, 1956). Complete chemical analysis of the body is unnecessary since the entire composition can be estimated with an acceptable degree of accuracy if either the fat or water content is known (Lofgreen and Otagaki, 1960). These can be estimated from measurements of body specific gravity. Pearson, Purchas and Reineke (1968) stated that the rationale for estimating fatness or leanness, or both, from density is based on the assumption that the body is a two component system, the two components being the fat tissue and the fat-free body.

Behnke, Fern and Wilham (1942) measured specific gravity of men and concluded that the amount of fat appeared to be the main factor affecting the specific gravity of healthy men. Messinger and Steele (1949) verified the usefulness of specific gravity as a measure of body fat and water content in man. Rathbun and Pace (1945) determined specific gravity on eviscerated guinea pigs and showed evidence that the body specific gravity increases as the fat content decreases. They derived an equation for estimating the percent fat in the body based on body specific gravity. Da Costa and Clayton (1950) used shaved,

eviscerated rats to evaluate the validity of the specific gravity technique. They concluded that specific gravity was as good an index of water content as it was of fat content and calculated regression lines for estimating body fat and water content from body specific gravity.

Kraybill, Bitter and Hankins (1952) extended the technique to beef cattle. Thirty head of yearling Hereford steers and heifers were divided equally by sex and line of breeding and fed on different planes of nutrition to produce a wide variation in body fat and water content. Slaughter weight ranged from 500 to 1050 pounds and percent fat ranged from 13.6 to 39.5. They reported a correlation coefficient between body specific gravity and water content of 0.984 and between specific gravity and fat content of 0.956 with these animals. Whole body specific gravity was predictable from carcass specific gravity ($r = 0.9896$, S_{xy}[1] $= \pm 0.0021$). The body water content could then be estimated from whole body specific gravity.

Reid, Wellington and Dunn (1955) obtained data from several sources (139 beef and 117 dairy cattle) to derive equations for estimating the fat and protein content of the whole empty body. A curvilinear equation ($S_{y \cdot x} = 1.061$) for predicting the percent fat and a linear equation ($S_{y \cdot x} = 1.424$) for predicting the percent protein were established. Thus the chemical composition of the whole beef animal can be estimated from carcass specific gravity according to the equations described by Kraybill et al. (1952) and Reid et al. (1955) with an acceptable degree of accuracy.

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[1]Taken from original paper and assumed to mean the standard error of estimate.

Garrett, Meyer and Lofgreen (1959) used the method and found that specific gravity of the dressed animal carcass was the only measurement necessary for the estimation of body composition. They also applied the method to sheep. Rumen fill appeared to be one of the major sources of error since determinations were based on empty-body weight. To correct for this a regression equation was derived to predict empty body weight from the warm carcass weight taken at slaughter (Lofgreen, Hull and Otagaki, 1962). The correlation coefficient was 0.97 and the standard error of estimate was 25 lb of the mean empty body weight of 868 lb.

Lofgreen and Otagaki (1960) explained in detail the development and use of the comparative slaughter technique. The real usefulness of the technique is in its practical application. Net energy for maintenance (NEm) can be obtained by extrapolation of the curve of heat production plotted against ME intake, both expressed as kcal/$W^{.75}$/ day (Garrett et al., 1959). Net energy for production (NEp) can be estimated by the increment method (Lofgreen, Bath and Strong, 1963) and net energy for maintenance plus production (NEm+p) by use of a reference standard (Lofgreen, Bath and Young, 1962).

A complete description of the comparative slaughter technique used at the California Agricultural Experiment Station was reported by Lofgreen (1965). A study to re-evaluate the technique (Garrett and Hinman, 1969) supported the validity of using carcass density to estimate the gross chemical composition of the beef carcass and the empty body. A proposed system for expressing net energy requirements and feed values for growing and finishing beef cattle was presented by Lofgreen and Garrett (1968). The system separates the requirement for

maintenance from that for body gain, expresses the net energy of the feed for these two functions and is adaptable to practice.

This review has shown the development of the net energy system in expressing feed values for feedlot cattle. Reports have been reviewed which suggest that respiration calorimetry and comparative slaughter can be used as techniques for determining net energy values of feeds. The value of grain sorghum (milo) as an energy source for feedlot cattle has been discussed. With these ideas in mind, the following study was undertaken to investigate the effect of reconstituting milo on its net energy value for feedlot cattle and to compare respiration calorimetry and the comparative slaughter technique as methods of determining net energy.

CHAPTER III

MATERIALS AND METHODS

General

Eighteen yearling Hereford steers were selected for uniformity in body conformation and weight and randomly divided into three groups. The steers had been held off feed and water for about 18 hours prior to weighing and allotting. Six steers constituted the initial slaughter group and were slaughtered the following day. All experimental animals were drenched with Thibenzole (3 g/100 lb body wt) and implanted with stilbesterol (2-12 mg implants) before being placed in pens (8 x 13 m) equipped with individual feeding stalls.

One group of six steers was fed a dry rolled milo ration and the other group of six steers a reconstituted rolled milo (38% moisture) ration. Both groups were fed a 90% concentrate mixture. The non-milo ingredients were combined into a premix (Table I) which was added to the milo so that both rations contained 84% milo on a 90% dry matter basis. The reconstituted milo was produced by submerging air-dry milo in water for 24 hours after which the excess water was drained, producing a grain with approximately 38% moisture. The grain was placed in air-tight plastic bags and stored for 20 days. Both the dry and reconstituted milos were rolled through a 12 x 18 inch Ross roller mill prior to being mixed with the premix and fed. Mixtures were prepared daily before the evening feeding.

TABLE I

PREMIX COMPOSITION

Ingredient	Percent
Dehydrated alfalfa meal pellets (17% C.P.)	30.85
Cottonseed hulls	30.85
Soybean meal (44% C.P.)	26.90
Urea (45% Nitrogen)	4.00
Salt	3.70
Bonemeal	3.70
Added per lb of premix:	
Vitamin A	10,000 IU
Aureomycin	1362 mg

Initial Balance Trials

Steers were put in digestion stalls by pairs (one from each treatment group selected at random) according to a pre-planned time table to permit maximal use of the two respiration chambers. A 10-day adjustment period was followed by a 7-day digestion trial for all animals. Feces and urine were collected, weighed, mixed and sampled daily. The urine was acidified with HCl and daily aliquots of both feces and urine were stored in a refrigerator. Upon completion of the 7-day collection period the samples were mixed and subsampled, then stored in a freezer for future analysis. One-half of each fecal sample was dried at 60 C in a forced-air oven, ground through a 1 mm screen in a Wiley mill and stored in a glass jar for future analysis.

Following the collection period, the steers were placed in open circuit respiration chambers similar to those described by Flatt et al. (1958) for 3 days, the last two of which included two consecutive 24-hour gas collection periods. Operating procedures were as follows: the chambers were sealed at least 12 hr prior to the start of gas collection. Outdoor air was pulled into the chamber and circulated by a fan. The temperature in the chamber was maintained at approximately 18.0 C. Exhaust gas was pulled from the chamber so that the rate of passage of air through the chamber was about 350 liters per minute. Dry gas meters measured the amount of air passing through the chambers and two spirometers constantly sampled the exhaust gas of each chamber.

At the beginning of the first 24-hour period, the gas meters were read, the spirometers were turned on and the chamber air was analyzed for oxygen, carbon dioxide and methane. Beckman instruments were used

for gas analyses.[2] At the end of the 24-hr period (which was also the beginning of the second 24-hr period) the meters were again read and the chamber air analyzed along with the air in the spirometers; which represented the air passing through the chambers for the 24-hr period. The same analyses were made at the end of the second 24-hr period. Barometric pressure, room temperature and exhaust gas wet bulb and dry temperatures were recorded each time.

Heat production was determined from oxygen consumption, carbon dioxide and methane production and urinary nitrogen excretion by the formula developed by Brouwer (1958):

$$T = 3.869\ O_2 + 1.195\ CO_2 - 0.516\ CH_4 - 0.227\ P;$$

where T = heat production (kcal), O_2 = oxygen consumed (liters), CO_2 = carbon dioxide produced (liters), CH_4 = methane produced (liters) and P = protein oxidized (grams urinary nitrogen x 6.25) with the gases being corrected to dry, standard temperature and pressure conditions.

Upon completion of gas collection the animals were placed in holding pens for one day and then fasted for 2 days before being placed back in the chambers for 3 days of additional fasting, the last two of which included two consecutive 24-hr gas collection periods. Chamber operating procedures and gas analyses were the same as described for the balance trial. Fasting heat production was calculated from the amount of oxygen consumed and the caloric value of oxygen based on the respiratory quotient (Carpenter, 1964).

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[2]Model F3 Oxygen Analyzer (magnetic) and Model IR 315 Analyzers for carbon dioxide and methane, Beckman Instrument, Inc., Fullerton, California.

Feedlot Phase

Immediately after completion of the fasting trial the animals were returned to the steer feeding pens where they were fed in individual stalls twice daily. This soon proved to be inadequate in that the steers were unable to consume enough dry matter, especially those being fed the reconstituted milo. Therefore, for the rest of the feeding period, all animals were fed three times daily. At each feeding the animals were allowed 45 to 60 minutes to eat and all feed not consumed was picked up and weighed immediately. Each steer was fed the maximum amount that he would consume in an effort to produce gains comparable to those of ad libitum, group-fed cattle. The animals were weighed at 28-day intervals throughout the feeding period.

Final Balance Trials

As the steers reached a desirable market weight they were again moved to the laboratory and placed in holding pens where they remained for about 7 days. Feed intake was reduced to about 60% of that in the feedlot and feeding was reduced to twice daily. This amount of feed was the maximum that the steers would consume, mainly due to the change in environmental conditions from that in the feeding pens. The steers were then moved to the respiration chambers for an additional 3-day adjustment period followed by a 7-day total excreta collection period, two of which included two consecutive 24-hr gas collections. The chambers were sealed on the evening of the third day of collection and operated as described before with gas collection ending on the morning of the sixth day. Care was taken to assure complete collection of feces and urine. Appropriate corrections were made for each time a compartment

was opened. Heat production was again determined from oxygen consumption, carbon dioxide and methane production and urinary nitrogen excretion. The collection and preparation of feces and urine was the same as during the initial balance trials. The steers were then fasted for 5 days and during the last 2 days gas collections were made from which fasting heat production was calculated as previously described. After completion of the fasting trial the animals were slaughtered at the Meats Laboratory

Rumen VFA Sampling

On the morning following the completion of the energy balance trials rumen fluid samples were obtained via a stomach tube and pump just prior to feeding and at 1, 2 and 4 hr postfeeding. The samples were strained through a double layer of cheesecloth, mixed with mercuric chloride ($HgCl_2$) and stored in a freezer for analysis of volatile fatty acids (Erwin, Marco and Emery, 1961).

Specific Gravity Determination

Initial Body Composition

The initial body composition of the experimental animals was estimated from data on the initial slaughter group. These animals were slaughtered at a commercial packing plant[3] and weights were taken 48 hr later in order to calculate carcass specific gravity according to the

[3]Wilson and Company, Oklahoma City, Oklahoma.

formula

$$\frac{\text{weight in air}}{(\text{weight in air}) - (\text{weight in water})}$$

Empty body weight of the initial slaughter group was estimated by the equation

$$Y = 31.8 + 1.45X$$

where X is warm carcass weight in kilograms (Lofgreen et al., 1962). Specific gravity of the whole empty body was predicted from the equation

$$Y = 0.9955X - 0.0013$$

where X is carcass specific gravity (Kraybill et al., 1952). The water content of the whole empty body was estimated from the equation

$$X = 100\ (4.008 - \frac{3.620}{Y})$$

where Y is empty body specific gravity (Kraybill et al., 1952). Body fat and protein were estimated from equations derived by Reid et al. (1955) as follows:

$$\% \text{ body fat} = 337.88 + 0.2406X - 188.91 \log X$$

where X is the percent body water;

$$\% \text{ protein} = \frac{(80.80 - 0.00078Z)\ 100 - [(\% \text{ water} + \% \text{ fat})]}{100}$$

where Z is the age of the animal in days. The validity and use of these equations has been reviewed (Garrett et al., 1959; Lofgreen and Otagaki, 1960; Lofgreen, 1965; Lofgreen and Garrett, 1968).

The initial empty body weights of the experimental animals were

estimated from the ratio of the shrunk weight to empty body weight of the slaughter group. The percent fat and protein of the whole empty body was applied to the initial empty body weight of the experimental animals to estimate the amount of fat and protein present initially.

Final Body Composition and Gain

At the conclusion of the final fasting trials the animals were slaughtered and the empty body weight was estimated from warm carcass weight. Carcass specific gravity was determined and the body fat and protein estimated by the same procedure and equations as those used for determining the initial body composition. The gain in body fat and protein was then determined by subtracting the amount predicted to be present initially from the final estimated amount present. The energy gain was determined by assuming the caloric value of 9367 kcal/kg for fat (Blaxter and Rook, 1953) and 5686 kcal/kg for protein (Garrett, et al., 1959).

Net Energy Determination

Average daily gain in kcal was calculated on a metabolic size ($W^{.75}$; where W is in kg) basis. Fasting heat production expressed as kcal/$W^{.75}$/day was considered as being equal to the maintenance energy requirement (Lofgreen et al., 1963; Lofgreen and Garrett, 1968). These two were added for each steer to obtain a value of the energy used by a steer for maintenance and gain. This value was divided by the average daily intake (kg/$W^{.75}$) to estimate the net energy for maintenance plus production (NEm+p) of the total ration. Net energy for maintenance plus production of the premix was calculated using the values of

Morrison (1959) for each ingredient. The product of this value multiplied by the amount of premix consumed was subtracted from the total to determine the amount of energy for maintenance and gain attributable to the grain portion only. When this value was divided by the amount of grain consumed an estimate of NEm+p of the grain was obtained. Net energy for production (NEp) of the grain was determined by dividing the maintenance and gain between the premix and milo on the basis of the ratio of each in the rations (16% premix and 84% milo). The computer program developed by Newsom (1966) was used to determine NEm+p of the total ration, NEm+p of the grain and NEp of the grain.

Energy gained was determined during each balance trial also. The following formula was used:

$$P = ME - HP$$

where P is the energy for production, ME is metabolizable energy and HP is the heat produced by the animal (Lofgreen, 1965). Thus NEm+p of the total ration could be calculated for each trial. Net energy for maintenance (NEm) and NEp of the total ration were determined as described by Lofgreen (1965). By plotting heat production against metabolizable energy intake, the amount of feed required to meet energy equilibrium was determined. The difference in energy gain between fasting and energy equilibrium gives an estimate of the NEm of the ration. The difference in energy gain between equilibrium and ad libitum gives an estimate of NEp of the ration.

Laboratory Analysis

Feed samples that had been previously dried at 60 C in a forced-air

oven and ground through a 1 mm screen in a Wiley mill were analyzed for dry matter and nitrogen (A.O.A.C., 1960), acid-detergent fiber (Van Soest, 1963) and gross energy by combustion in a Parr oxygen bomb adiabatic calorimeter. The same analyses on air-dried, ground samples yielded almost identical results so the average of all analyses was used to represent the composition of the ration. Dried feces samples were analyzed for gross energy. Wet fecal samples were used for the nitrogen determination. Urine samples were filtered prior to being analyzed for nitrogen and gross energy. In preparation for gross energy determination, urine samples were dried on powdered cellulose at 60 C in a vacuum oven.

Volatile fatty acid analysis of the rumen fluid samples was completed by the procedure of Erwin et al. (1961) with a Bendix Series 2500 Gas Chromatograph.[4]

Soluble carbohydrate (expressed as percent reducing sugar) determinations were made on the dry rolled and reconstituted rolled grain by extraction in 40% isopropyl-alcohol. The procedure used was that of Friedemann et al. (1967) as revised by Johnson[5] (see Appendix Table XIX).

Statistical Analysis

The data were analyzed statistically by the Student's "t" test according to Steel and Torie (1960). The volatile fatty acid data were

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[4]The Bendix Corporation, Ronceverte, W. Va.

[5]R. R. Johnson, Oklahoma Agricultural Experiment Station, Department of Animal Science and Industry, Stillwater, Oklahoma.

analyzed by analysis of variance (see Appendix Table XXVIII for example).

CHAPTER IV

RESULTS AND DISCUSSION

Ingredient composition of the rations (90% DM basis) and the dry matter composition of the rations are shown in Tables II and III, respectively. The proportion of milo to premix required to obtain 84% grain in the two mixtures was 84.5:15.5 for dry rolled (DR) milo and 88.3:11.7 for reconstituted rolled (RR) milo. The reconstituted milo mixture was slightly higher in crude protein and lower in acid detergent fiber than the dry milo mixture but the gross energy content of the two rations was almost identical. Average initial live shrunk weight was 281.7, 279.3 and 282.0 kg for the initial slaughter group, dry milo-fed group and reconstituted milo-fed group, respectively.

The reconstituted grain had significantly ($P < .001$) more reducing sugars than the dry grain. The values were 0.928 and 1.134%, respectively, for the dry and reconstituted form. Buchanan-Smith et al. (1968) also reported an increase in amount of reducing sugars from about 0.3% in dry grain to 1% in reconstituted grain. These results support the suggestions made by other workers that the starch molecule is altered (Riggs and McGinty, 1970) and that there is a larger amount of starch available for digestion (Florence and Riggs, 1968) in the reconstituted grain.

TABLE II

INGREDIENT COMPOSITION OF THE RATIONS

	(%)
Rolled grain sorghum	84.0
Dehydrated alfalfa meal pellets (17% CP)	4.93
Cottonseed hulls	4.93
Soybean meal (44% CP)	4.30
Urea (45% nitrogen)	0.64
Salt	0.60
Bonemeal	0.60
Added per lb of ration:	
Vitamin A 1600 IU	
Aureomycin 5 mg	

TABLE III

COMPOSITION OF RATION DRY MATTER

Item	Dry milo mix	Reconstituted milo mix
Crude protein (%)	14.20	14.57
Acid detergent fiber (%)	10.16	9.52
Gross energy (Mcal/kg)	4.47	4.50

Respiration Calorimetry

Fasting Heat Production

Fasting heat production can be considered as being equal to the net energy required for maintenance at no activity. The values obtained at the beginning and end of this study are shown in Table IV. Although the differences in fasting heat production between the two groups were not statistically significant in either trial, values were lower in trial 2 than in trial 1 for both groups with the dry rolled milo group showing the greatest difference between trials. The over-all average fasting heat production in trial 1 was in very close agreement with the value of 77 kcal/$W^{.75}$ suggested by Lofgreen and Garrett (1968). However, the average in trial 2 (66.2 kcal/$W^{.75}$/day) was significantly ($P < .001$) lower indicating that net energy required for maintenance is not a constant. This is in agreement with work done by Ritzman and Colovos (1943) with dairy heifers. They reported a fasting heat production of 80-85 kcal/$W^{.75}$ for 24-30 month old dairy heifers compared to 172 kcal/$W^{.75}$ for the same heifers at eight days of age. The average fasting heat production represents an estimate of the mean net energy requirement for maintenance during the feedlot period.

Energy Balance Trial 1

Average weight of the steers in the dry milo fed-group was 15.9 kg more than that of the steers in the reconstituted milo fed group (312.8 vs. 296.9 kg, respectively). Weights were taken after completion of the energy balance trials so that all animals were treated equally even though the length of time since allotment varied. Average weights

TABLE IV

FASTING HEAT PRODUCTION

Trial No.	DR milo[a]	RR milo[b]	Difference	SE[c]
		(kcal/W$^{.75}$/day)		
Trial 1	80.07	74.01	6.06	3.37
Trial 2	67.45	64.96	2.49	4.08
Average	73.76	70.17	3.59	1.72
Trial difference	12.62	10.41	2.21	3.04

[a]Average of six steers for each trial.

[b]Average of six steers for trial 1 and five steers for trial 2, average and trial difference.

[c]Standard error of the difference.

of the two groups at time of allotting were 279.3 kg for the dry milo-fed steers and 282.0 kg for the reconstituted milo-fed steers. All steers were maintained on the dry rolled milo ration between the time of allotting and initiation of the adjustment period for trial 1. Changing the ration on the one group caused decreased intake for two to three days which apparently reduced gains for a short period of time.

Dry matter contents of the two rations were 88.4 and 64.9%, respectively, for the dry and reconstituted milo rations. Dry matter consumption was significantly ($P < .001$) less for the cattle on the reconstituted milo than for those fed dry milo. Since the gross energy content of the two rations was almost the same (Table III), the gross energy (GE) intake also was significantly ($P < .001$) less for the reconstituted milo fed group. These results are shown in Table V.

Since dry matter intake was significantly different, all comparisons were made on the basis of dry matter consumed. Energy balance results are shown in Table VI. Average energy losses and utilization expressed as Mcal/day are reported in Appendix Table XX.

The digestible energy content of the reconstituted milo ration was significantly ($P < .01$) higher than that of the dry milo ration. This suggests that the benefit from reconstituting milo is primarily due to increased digestibility. Increased nutrient digestion coefficients for reconstituted grain have been reported (McGinty *et al.*, 1966; Buchanan-Smith *et al.*, 1968; Riggs and McGinty, 1970). Some reasons given for this increased digestibility include physical softening of the grain, increased size of the grain after rolling, alterations in the starch molecule and alterations in the protein matrix which surrounds the starch.

TABLE V

ANIMAL WEIGHT AND DAILY FEED INTAKE - TRIAL 1[a]

Item	DR milo	RR milo	Difference	SE[b]
Weight (kg)	312.8	296.9	15.9	
DM (kg)	6.074	4.143	1.931***	0.26
GE (kcal/$W^{.75}$)	368.1	277.5	90.6***	19.64

[a]Each mean is the average of six steers.

[b]Standard error of the difference.

***$P < .001$.

TABLE VI

ENERGY UTILIZATION - TRIAL 1[a]

Energy fraction	DR milo	RR milo	Difference	SE[b]
		(Mcal/kg DM daily)		
GE	4.504	4.552		
DE	3.311	3.640	0.329**	0.075
ME	2.679	2.837	0.158	0.097
HI	0.693	0.697	0.004	0.610
NEm+p	1.986	2.140	0.154	0.142

[a]Each mean is the average of six steers.

[b]Standard error of the difference.

**P< .01.

There was no difference in the heat increment of the two rations. Although ME and NEm+p tended to be higher for the RR milo ration than for the DR milo ration the differences were not statistically significant. This is in agreement with numerous reports in the literature that rate of gain is not improved by reconstituting milo. The improvement apparently is due to increased efficiency of grain utilization.

These values were also expressed as kcal/$W^{.75}$/kg dry matter intake daily (Table VII). Again digestible energy was the only measurement in which a significant difference was obtained. Removing the effect of size probably was insignificant since the average weight of the two groups did not differ significantly.

Energy Balance Trial 2

One steer in the reconstituted milo fed group died of bloat during the feedlot phase of the study leaving only five steers for that treatment group in trial 2. The steer was a chronic bloater and his death was not attributed to the milo processing treatment.

Animal weight, dry matter intake and gross energy intake for the two groups of animals in trial 2 are shown in Table VIII. Dry matter intake was again significantly ($P < .01$) lower for the reconstituted milo-fed group which resulted in significantly ($P < .05$) less gross energy intake than for the dry milo-fed group. Because of this difference all comparisons again were made on the basis of dry matter consumed. Energy balance results for trial 2 are shown in Table IX.

As in trial 1, the digestible energy content was significantly ($P < .05$) higher for the reconstituted milo ration than for the dry milo ration. Metabolizable energy was also higher for the reconstituted

TABLE VII

ENERGY UTILIZATION ADJUSTED FOR WEIGHT AND INTAKE - TRIAL 1[a]

Energy fraction	DR milo	RR milo	Difference	SE[b]
		(kcal/$W^{.75}$/kg DM daily)		
GE	60.65	63.69	3.04	1.45
DE	44.60	50.97	6.37**	1.54
ME	36.11	39.72	3.61	1.71
HI	9.32	9.72	0.40	0.74
NEm+p	26.79	30.00	3.21	2.27

[a]Each mean is the average of six steers.

[b]Standard error of the difference.

**$P < .01$.

TABLE VIII

ANIMAL WEIGHT AND DAILY FEED INTAKE - TRIAL 2

Item	DR milo[a]	RR milo[b]	Difference	SE[c]
Weight (kg)	433.5	429.6	3.9	
DM (kg)	6.290	4.801	1.489**	0.45
GE ($kcal/W^{.75}$)	292.5	226.6	65.9*	22.59

[a]Average of six steers.

[b]Average of five steers.

[c]Standard error of the difference.

*$P < .05$.

**$P < .01$.

TABLE IX

ENERGY UTILIZATION - TRIAL 2

Energy fraction	DR milo[a]	RR milo[b]	Difference	SE[c]
		(Mcal/kg DM daily)		
GE	4.432	4.448		
DE	3.241	3.408	0.204*	0.092
ME	2.575	2.784	0.209**	0.057
HI	0.678	0.864	0.186**	0.056
NEm+p	1.897	1.920	0.023	0.072

[a]Average of six steers.

[b]Average of five steers.

[c]Standard error of the difference.

*$P < .05$.

**$P < .01$.

milo ration ($P < .01$). This suggests that utilization as well as digestibility is improved by reconstituting the grain. The percent of gross energy that was lost in urine and methane was greater during trial 1 but less during trial 2 for the RR milo group than for the DR milo group (Table X). Most of the energy losses were higher for the RR milo when expressed as a percent of GE intake because daily intake was significantly less for that ration than the DR milo ration. Possibly, the 10-day adjustment period prior to trial 1 was not long enough to allow for adequate adjustment to the reconstituted milo.

The heat increment of the RR milo ration was significantly ($P < .01$) greater than that of the DR milo ration. Therefore, the net energy (NEm+p) content of the two rations did not differ significantly although there tended to be a slight advantage for the RR milo ration over the DR milo ration (1.920 vs. 1.897 Mcal/kg DM, respectively).

When energy utilization was expressed as kcal/$W^{.75}$/kg of dry matter consumed (Table XI) the difference in digestible energy between the two rations was not statistically significant. However, the metabolizable energy content did differ significantly ($P < .05$) which supports the idea that utilization of the grain is improved by reconstituting. However, HI was significantly ($P < .001$) greater for the RR milo ration and again the higher NEm+p value (20.42) was not statistically significantly greater than that for the DR milo ration (20.00). Average energy losses and utilization expressed as Mcal/day are reported in Appendix Table XXI. Energy utilization expressed as a percent of gross energy for both trials is shown in Appendix Table XXII.

TABLE X

ENERGY LOSSES

Energy loss	Trial 1		Trial 2	
	DR milo	RR milo	DR milo	RR milo
	(% of GE/day)			
Fecal energy	26.50	19.98	26.60	23.49
Urine energy	10.88	13.96	9.79	8.85
CH_4 energy	3.15	3.61	5.58	4.91
Heat increment	15.40	15.42	15.28	19.56
Total heat production	37.16	43.36	38.37	48.65

TABLE XI

ENERGY UTILIZATION ADJUSTED FOR WEIGHT AND INTAKE - TRIAL 2

Energy fraction	DR milo[a]	RR milo[b]	Difference	SE[c]
		(kcal/$W^{.75}$/kg DM daily)		
GE	46.67	47.33	0.66	1.32
DE	34.13	36.29	2.16	1.56
ME	27.12	29.60	2.48*	0.87
HI	7.12	9.18	2.06***	0.54
NEm+p	20.00	20.42	0.42	0.96

[a]Average of six steers.

[b]Average of five steers.

[c]Standard error of the difference.

*$P < .05$.

***$P < .001$.

Net Energy

A plot of metabolizable energy intake against heat production, expressed as kcal/$W^{.75}$/day, was used to determine energy equilibrium for each animal. The point representing the heat production of an animal at ad libitum intake was connected with a straight line to the point representing the heat production at zero feed intake (fasting heat production). The point on the line where heat production is equal to ME intake represents energy equilibrium for that animal; i.e., the amount of ME intake (kcal/$W^{.75}$/day) required to maintain energy balance for that animal. The plots representing the averages for each group in both trials are shown in Figure 1. Average energy equilibrium in trial 1 was 109 and 98 kcal/$W^{.75}$/day for the DR milo and RR milo groups, respectively. In trial 2 the values were 92 and 94 kcal/$W^{.75}$/day, respectively for the two groups. The average metabolizable energy for the two groups was 2.679 and 2.837 in trial 1 (Table VI) and 2.575 and 2.784 in trial 2 (Table IX) Mcal/kg of dry matter, respectively. Thus, the amount of dry matter required to maintain energy equilibrium for the DR milo and RR milo groups was 40.5 and 34.5 grams/$W^{.75}$/day, respectively in trial 1 and 35.0 and 34.0 grams/$W^{.75}$/day, respectively in trial 2.

Thus there are two important portions of the plot: (1) heat production associated with level of ME intake from zero to energy equilibrium and (2) heat production associated with level of ME intake from energy equilibrium to ad libitum. The difference in energy balance between fasting and energy equilibrium divided by the difference in dry matter intake between fasting and energy equilibrium gives a measure of the net energy value of the feed for maintenance

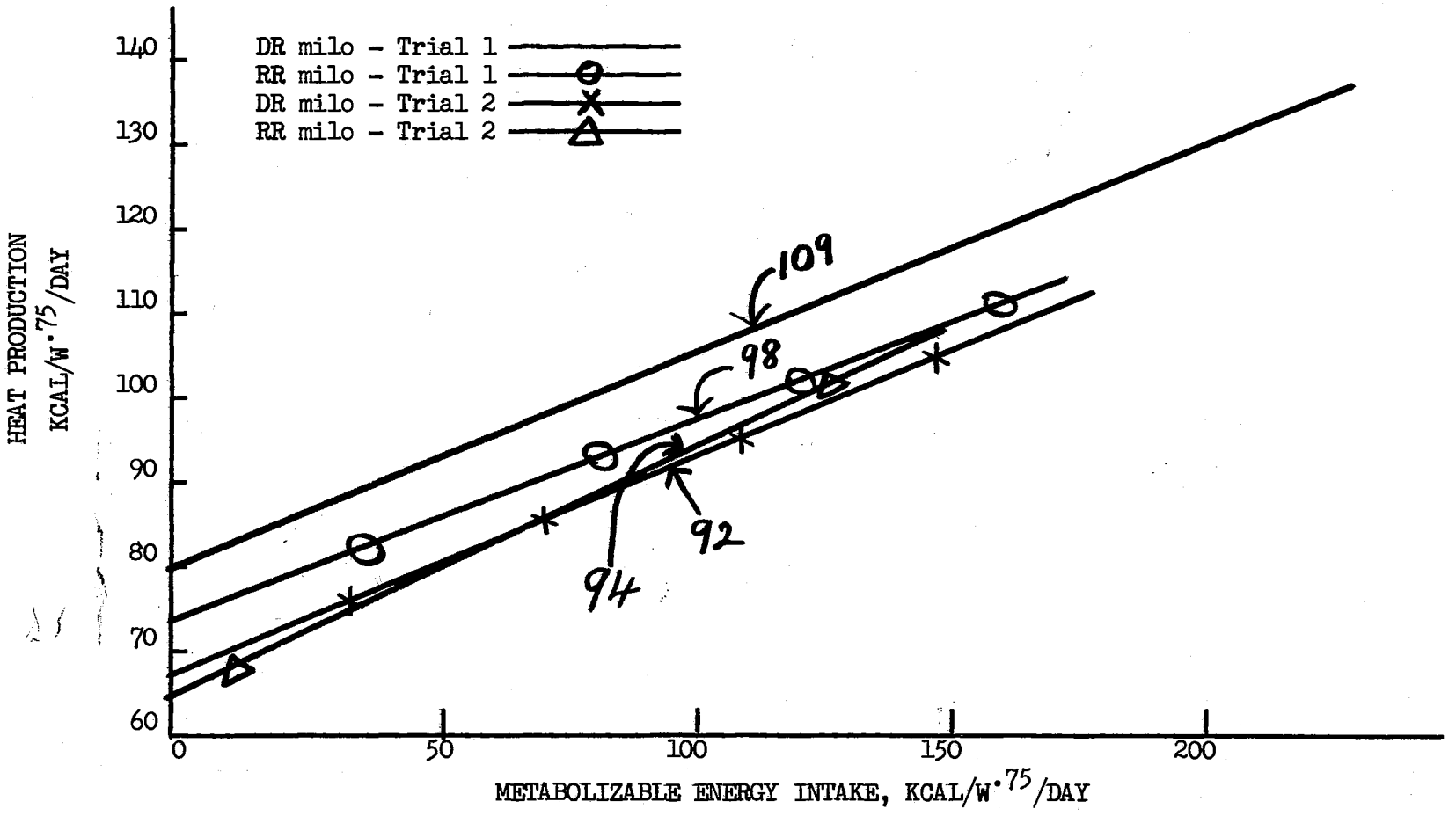

Figure 1. Relationship Between Heat Production and Metabolizable Energy Intake

(NEm). The difference in energy balance between energy equilibrium and ad libitum divided by the difference in dry matter intake between energy equilibrium and ad libitum gives a measure of the net energy value of the feed for production (NEp). In every case energy balance is defined as metabolizable energy minus heat production.

The procedures used for determining NEm and NEp are shown with average values in Appendix Tables XXIII, XXIV, XXV and XXVI for trial 1 and 2, respectively. The results of these calculations along with the NEm+p values are given in Table XII.

All values (NEm, NEp and NEm+p) in every case are almost identical. The values are slightly lower for NEp than for NEm in every case except for the DR milo group during trial 1; however, the magnitude of this difference is not as great as would be expected. Forbes et al. (1930) reported that the net energy of a feed was higher when fed at a maintenance level than above maintenance. Kleiber (1961) stated that net energy for maintenance was higher than for production. The net energy system proposed by Lofgreen and Garrett (1968) shows higher values for NEm than for NEp. The similarity of values for NEm, NEp and NEm+p suggests that under controlled conditions, as maintained in respiration calorimetry, the efficiency of energy utilization for production of a high energy ration might be equal to that for maintenance.

All values were lower at trial 2 than at trial 1. This indicates that the net energy of a feed is not constant but reduces as the animal fattens. Also these values are higher than any that appear in the literature most of which have been determined by the comparative slaughter technique. On similar feed at this station, Schneider (1968)

TABLE XII

NET ENERGY FOR MAINTENANCE, PRODUCTION AND MAINTENANCE PLUS PRODUCTION

Ration and trial	NEm	NEp	NEm+p
		(Mcal/kg DM)	
DR milo			
Trial 1	1.978	1.992	1.986
Trial 2	1.903	1.843	1.897
Average	1.940	1.918	1.942
RR milo			
Trial 1	2.165	2.128	2.140
Trial 2	1.912	1.897	1.920
Average	2.038	2.012	2.030

reported NEm+p values of 1.497 Mcal/kg for dry rolled milo and 1.649 Mcal/kg for comparable reconstituted milo rations. This difference again probably is due to the controlled conditions involved in respiration calorimetry.

Slaughter Technique

Feedlot Performance

Since one steer in the reconstituted milo-fed group died during the feedlot phase all results for that group are based on five steers. Average daily intake during the feedlot period is given in Table XIII. The average number of days in the feedlot was 159 for the dry milo group and 169 for the reconstituted milo group. The basis for removing cattle from the feedlot was weight rather than the number of days on feed. Therefore, the order in which the steers were removed was not consistent with the order in which they were started on feed. Intake of the reconstituted milo was significantly less ($P<.05$) than that of dry milo for both the total ration (1.69 kg) and the milo portion (1.42 kg) only.

Weight gain and feed efficiency results are shown in Table XIV. Average daily weight gain was slightly more for the DR milo group than for the RR milo group but the differences (126 g live shrunk wt or 119 g empty body wt) were not statistically significant. Feed consumed per unit of gain was less for the RR milo group than for the DR milo group but again the differences were not statistically significant. The large difference in feed intake (20.6%) was partially offset by a smaller difference in average daily gain (12.4%). Although there tended to be an advantage (8.4%) in feed efficiency for the RR milo ration, the

TABLE XIII

AVERAGE DAILY INTAKE IN THE FEEDLOT[a]

Feed	DR milo	RR milo	Difference	SE[b]
Total ration (kg)	8.21	6.52	1.69*	0.67
Grain (kg)	6.90	5.48	1.42*	0.56

[a]Expressed on 90% dry matter basis.

[b]Standard error of the difference.

*$P < .05$.

TABLE XIV

WEIGHT GAIN AND FEED EFFICIENCY IN THE FEEDLOT

Item	DR milo	RR milo	Difference	SE[a]
Initial live shrunk wt (kg)	279.3	282.0	2.7	5.38
Final live shrunk wt (kg)	432.6	428.6	4.0	16.27
Avg daily shrunk wt gain (kg)	1.012	0.886	0.126	0.20
Total feed/kg shrunk weight gain (kg)	8.27	7.57	0.70	0.70
Grain/kg shrunk wt gain (kg)	6.95	6.36	0.59	0.59
Initial empty body wt (kg)	272.2	274.6	2.4	5.08
Final empty body wt (kg)	416.5	412.8	3.7	15.33
Avg daily empty body wt gain (kg)	0.953	0.834	0.119	0.13
Total feed/kg empty body wt gain (kg)	8.76	8.03	0.73	0.74
Grain/kg empty body wt gain (kg)	7.37	6.75	0.62	0.62

[a]Standard error of the difference.

differences were not statistically significant. These results support the concept that energy intake is the governing factor that regulates intake on a high energy ration (Newsom et al., 1968; Schneider, 1968).

Average energy gain and efficiency are shown in Table XV. The difference in average daily energy gain was not statistically significant. The daily energy gain per kg of total ration or grain consumed was almost identical for the two groups. The results of this study are in agreement with numerous reports in the literature in that feed consumption is decreased and efficiency increased by reconstituting milo.

Net Energy

The calculated net energy values are given in Table XVI. All net energy expressions were significantly ($P < .01$) higher for the reconstituted milo than for the dry milo. The values for the dry milo are very similar to those reported by Schneider (1968). He obtained values of 1.338, 1.405 and 1.129 Mcal/kg for NEm+p of the total ration, NEm+p of the grain and NEp of the grain, respectively, with group-fed heifers on the same type of ration. The values for reconstituted milo are in close agreement with his 30% moisture milo stored for 20 days and steeped milo. Garrett (1965) reported an average value of 1.315 Mcal/kg for NEp of milo. These results reflect the feedlot performance in that both feed efficiency and net energy values for the reconstituted milo were greater than those for the dry milo.

Comparison of Techniques

Determining NEm+p of the Ration

A comparison of techniques for estimating NEm+p of the total

TABLE XV

ENERGY GAIN AND EFFICIENCY

Item	DR milo	RR milo	Difference	SE[a]
Avg initial body energy (Mcal/hd)	429.97	433.82	3.85	8.03
Avg final body energy (Mcal/hd)	1132.59	1129.78	2.81	109.58
Avg daily energy intake (Mcal/hd)	33.02	26.41	6.61*	2.45
Avg daily energy gain (Mcal/hd)	4.64	4.15	0.49	0.74
Avg daily energy gain per kg feed (kcal)	3.89	3.83	0.06	0.83
Avg daily energy gain per kg grain (kcal)	4.63	4.55	0.08	0.99

[a]Standard error of the difference.

*$P < .05$.

TABLE XVI

NET ENERGY VALUES

Item	DR milo	RR milo	Difference	SE[a]
		(Mcal/kg, 90% DM)		
NEm+p of total ration	1.311	1.524	0.213**	0.054
NEm+p of grain	1.375	1.628	0.253**	0.065
NEp of grain	1.003	1.310	0.307**	0.086

[a]Standard error of the difference.

**P< .01.

ration is summarized in Table XVII. The values for the DR milo and RR milo rations as measured by respiration calorimetry were obtained by averaging the results of the two balance trials. Net energy determined by respiration calorimetry was significantly ($P<.001$) higher than that determined by comparative slaughter technique. The values were 33.6% higher for the DR milo ration and 22.6% higher for the RR milo ration when determined by respiration calorimetry than those determined by the slaughter technique.

As previously stated, the values determined by the slaughter technique are in agreement with other reports in the literature. It appears logical that somewhat higher values should be obtained with respiration calorimetry since the maintenance requirement of an animal would be less while confined to a respiration chamber than in the feedlot due to less activity and environmental stress. Also, the values determined by the slaughter technique are based on the entire feeding period while those determined by respiration calorimetry are based on the average of two short periods; one at the beginning and one at the end of the feeding period.

The values were significantly ($P<.001$) higher when determined by respiration calorimetry than by slaughter technique, even when averaged across treatment. The RR milo ration was significantly higher ($P<.01$) in NEm+p than the DR milo ration when measured by the slaughter technique but not significantly higher when measured by respiration calorimetry. These results have been emphasized in earlier sections of this report.

TABLE XVII

COMPARISON OF TECHNIQUES FOR MEASURING NEm+p

Item	Respiration Calorimetry	Slaughter Technique	Difference	SE[a]
		(Mcal/kg feed, 90% DM)		
DR milo ration	1.752	1.311	0.441***	0.069
RR milo ration	1.868	1.524	0.344***	0.023
Average	1.805	1.408	0.397***	0.054
Difference	0.116	0.213**		
SE[a]	0.061	0.055		

[a]Standard error of the difference.

**P< .01.

***P< .001.

Determining Energy Gain - NEp

The values for NEp as determined by respiration calorimetry and slaughter technique are shown in Table XVIII. These values represent the average amount of energy that was available to the animal for production based on the amount of dry matter consumed daily. All NEp values were greater when determined by respiration calorimetry than by the slaughter technique. There was a significant ($P<.001$) difference between the methods for the DR milo ration and the average of the two rations but not for the RR milo ration.

Difference between rations were not statistically significant when determined by either technique. Respiration calorimetry showed a slight advantage (1.298 kcal/$W^{.75}$/kg DM daily) for the DR milo ration. The slaughter technique showed a slight advantage (0.777 kcal/$W^{.75}$/kg DM daily) for the RR milo ration. These results would be expected based on results discussed in earlier sections of this report.

Volatile Fatty Acid Analysis

The mean concentration (micromoles/ml of rumen fluid) of rumen total volatile fatty acids (TVFA) taken at 0, 1, 2 and 4 hr after feeding of steers fed the two rations are shown in Figure 2 for the initial balance trial. Total volatile fatty acid concentration increased rapidly during the first hour for both rations. There was a rapid decline at 2 hr and a gradual decline at 4 hr postfeeding for the DR milo ration. The decline was rather constant and rapid from 1 to 4 hr postfeeding for the RR milo ration. Although the differences were not statistically significant the TVFA concentration tended to be higher in the rumen fluid of animals fed the RR milo ration.

TABLE XVIII

COMPARISON OF TECHNIQUES FOR MEASURING NEp

Item	Respiration Calorimetry	Slaughter Technique	Difference	SE[a]
		(kcal/$W^{.75}$/kg DM daily)		
DR milo ration	11.196	7.654	3.542***	0.769
RR milo ration	9.898	8.431	1.467	0.772
Average	10.606	8.007	2.599***	0.571
Difference	1.298	0.777		
SE[a]	0.771	0.783		

[a]Standard error of the difference.

***$P < .001$.

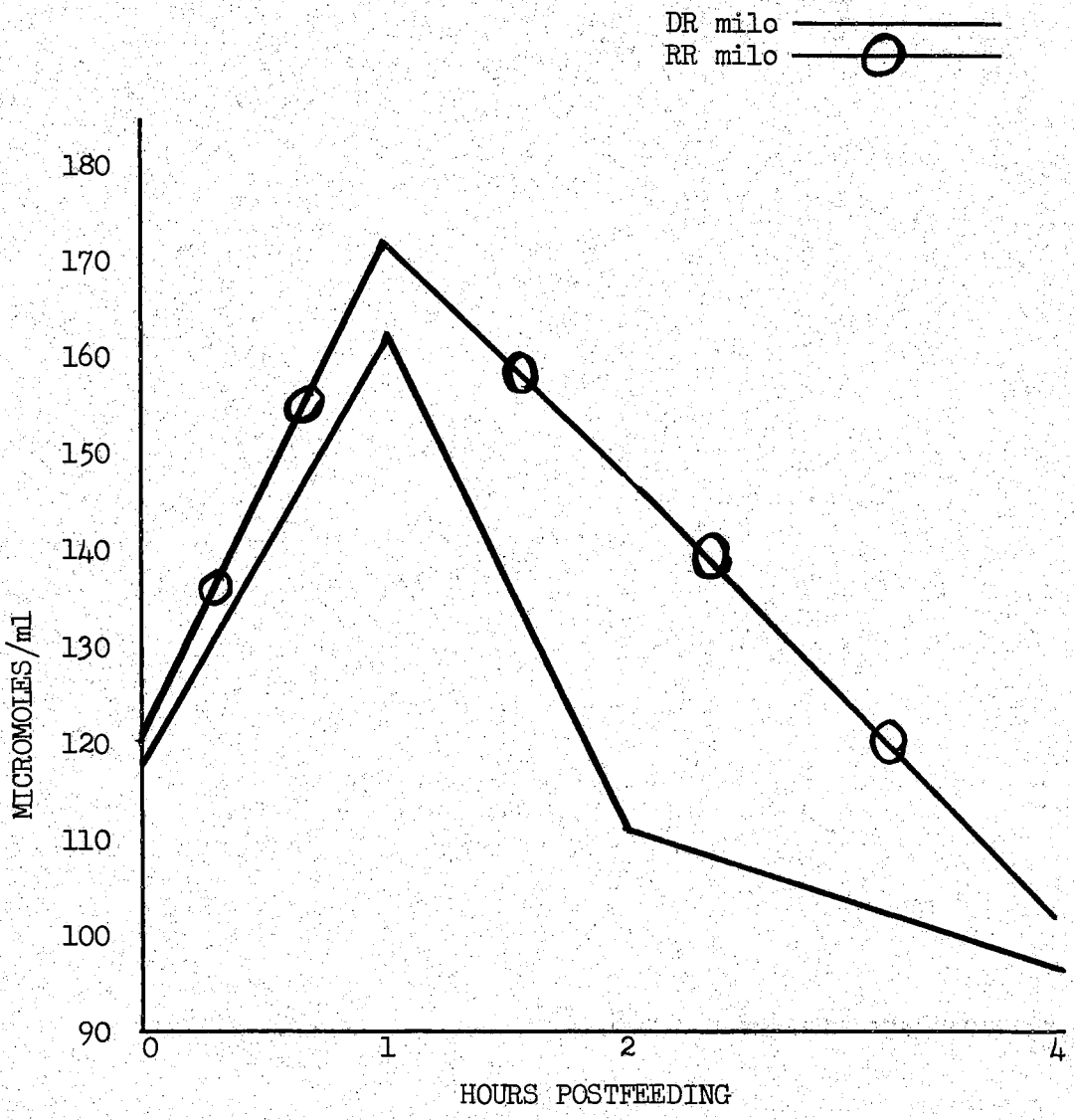

Figure 2. Total Rumen Volatile Fatty Acids - Trial 1

The average molar percent of each acid for the four sampling times is given in Appendix Table XXVII for the two rations in both balance trials. Figures 3 and 4 present the proportion (moles/100 moles TVFA) of acetic and propionic acids, respectively, in the rumen fluid of the steers in the initial balance trial. The percent of acetic acid increased gradually to 2 hr postfeeding then decreased at 4 hr postfeeding for the DR milo ration. For the RR milo ration the percent of acetic acid (Figure 3) increased rapidly for 2 hr then decreased at 4 hr postfeeding. The propionic acid concentration remained almost constant to 1 hr, increased to 2 hr and remained fairly constant at 4 hr postfeeding for the DR milo ration. For the RR milo ration, the molar percent of propionic acid (Figure 4) decreased to 2 hr postfeeding but increased at 4 hr. In trial 1 the molar percent of both acids was higher in the rumen fluid of steers fed the DR milo ration than those fed the RR milo ration. Animal to animal variation was large and statistically significant ($P<.01$) as shown by the large standard errors given in Appendix Table XXVII. Significant differences between rations were not detectable, probably because of insufficient numbers and the large variation between animals.

Ruminal concentrations of butyric, isovaleric and valeric acids are shown in Figures 5, 6 and 7, respectively, for steers fed the DR and RR rations. The rumen fluid of steers fed RR milo contained higher percentages of butyric and valeric acids but a lower percentage of isovaleric than those fed DR milo. Differences between the two treatment groups were significant ($P<.10$) for butyric and valeric acid. There was not conclusive evidence ($F\approx1$) that the concentration of these three acids varied with respect to time of sampling. Again, the

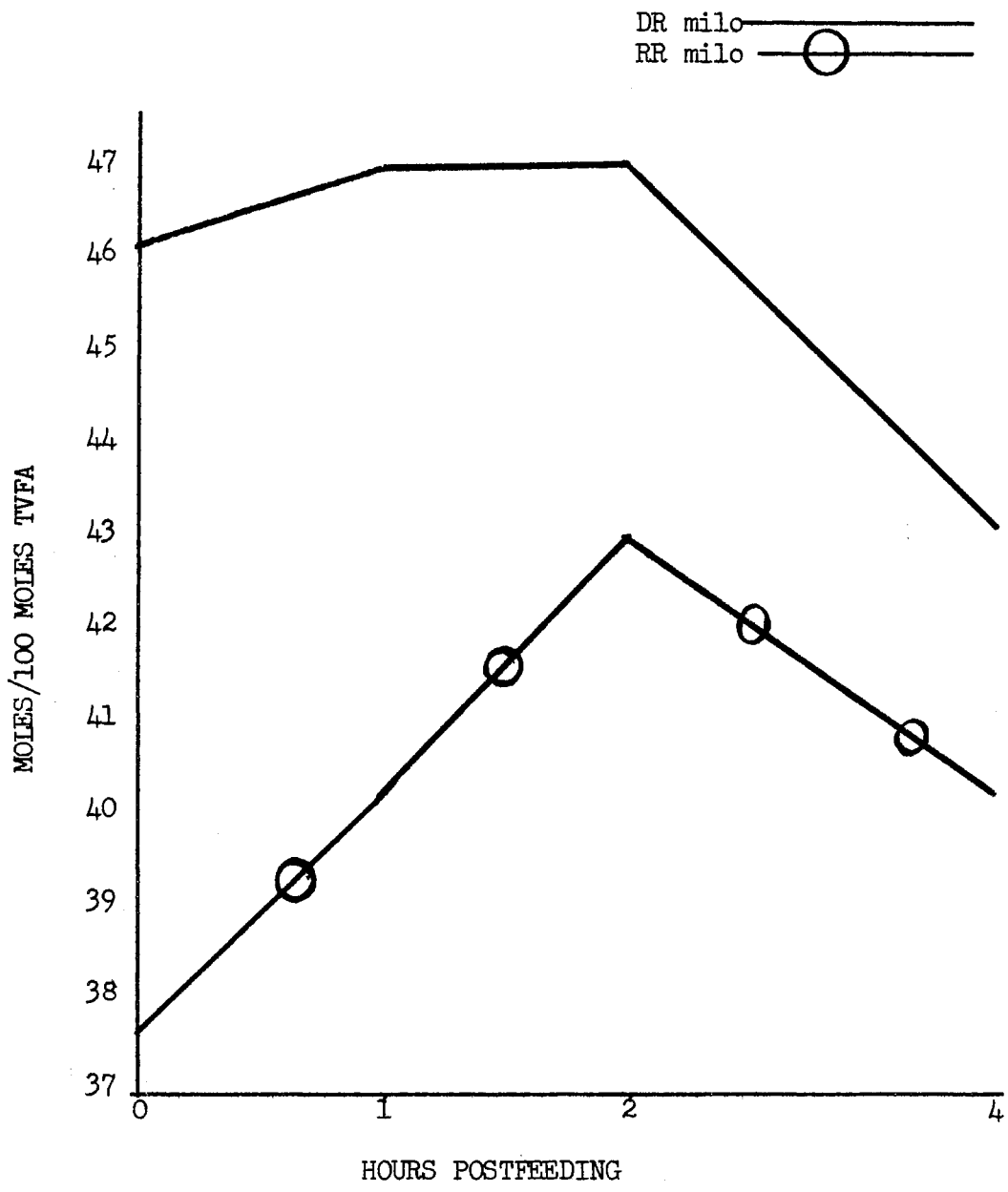

Figure 3. Acetic Acid Concentration in Rumen Fluid - Trial 1

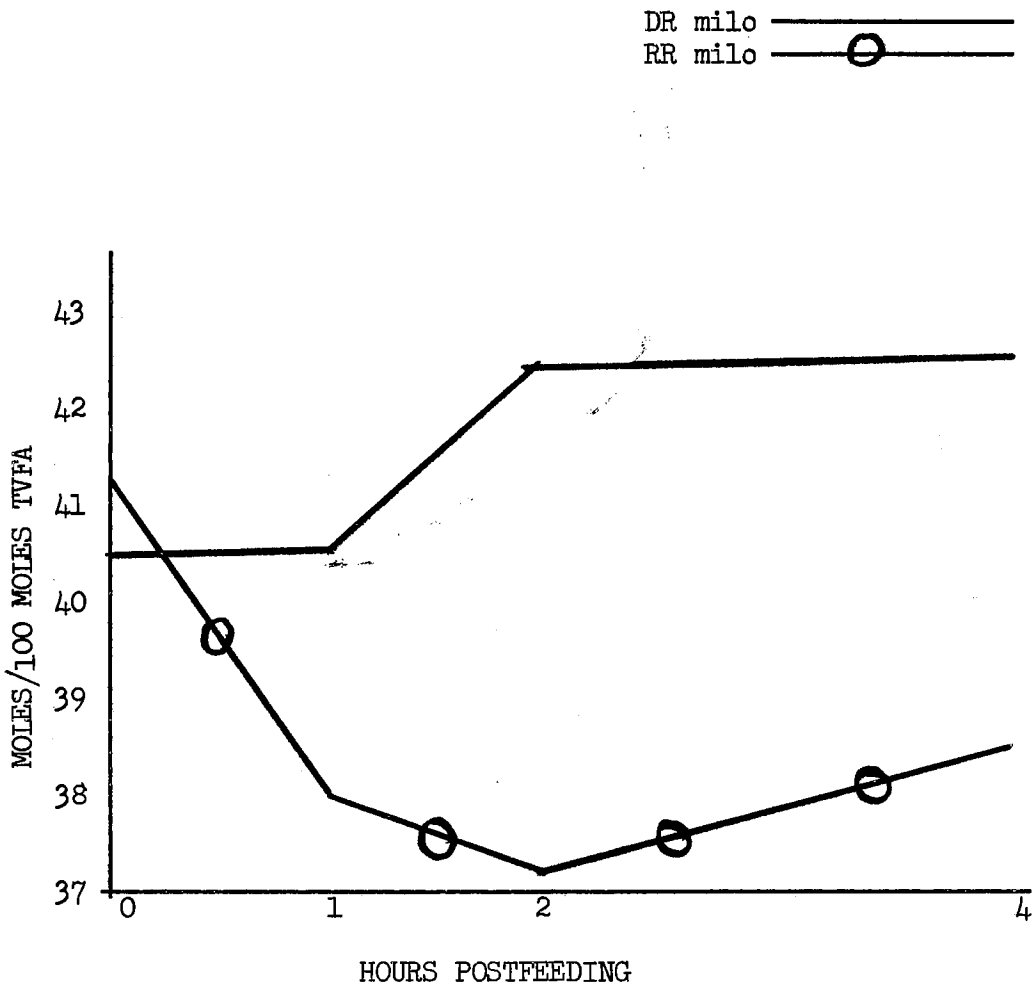

Figure 4. Propionic Acid Concentration in Rumen Fluid - Trial 1

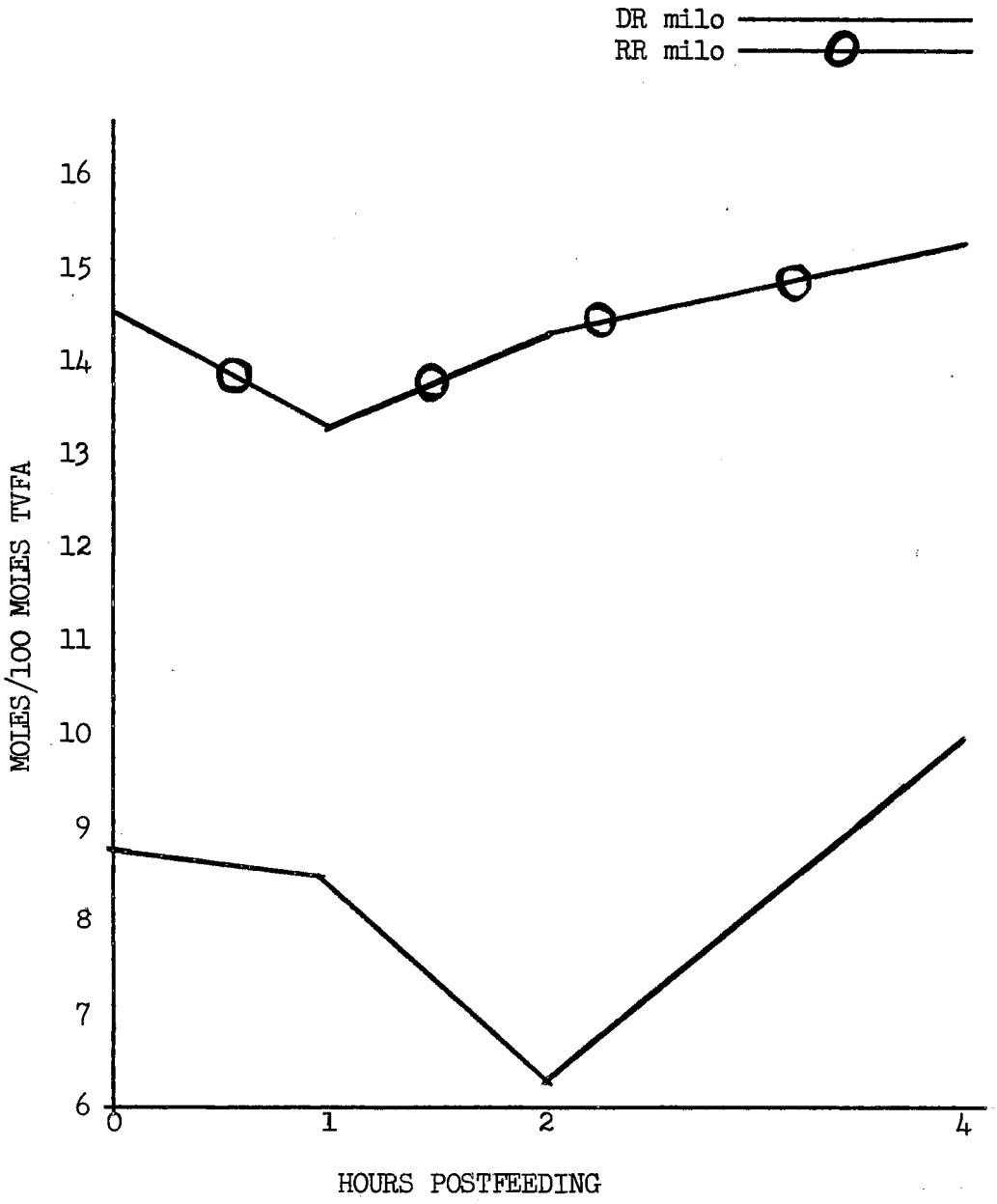

Figure 5. Butyric Acid Concentration in Rumen Fluid - Trial 1

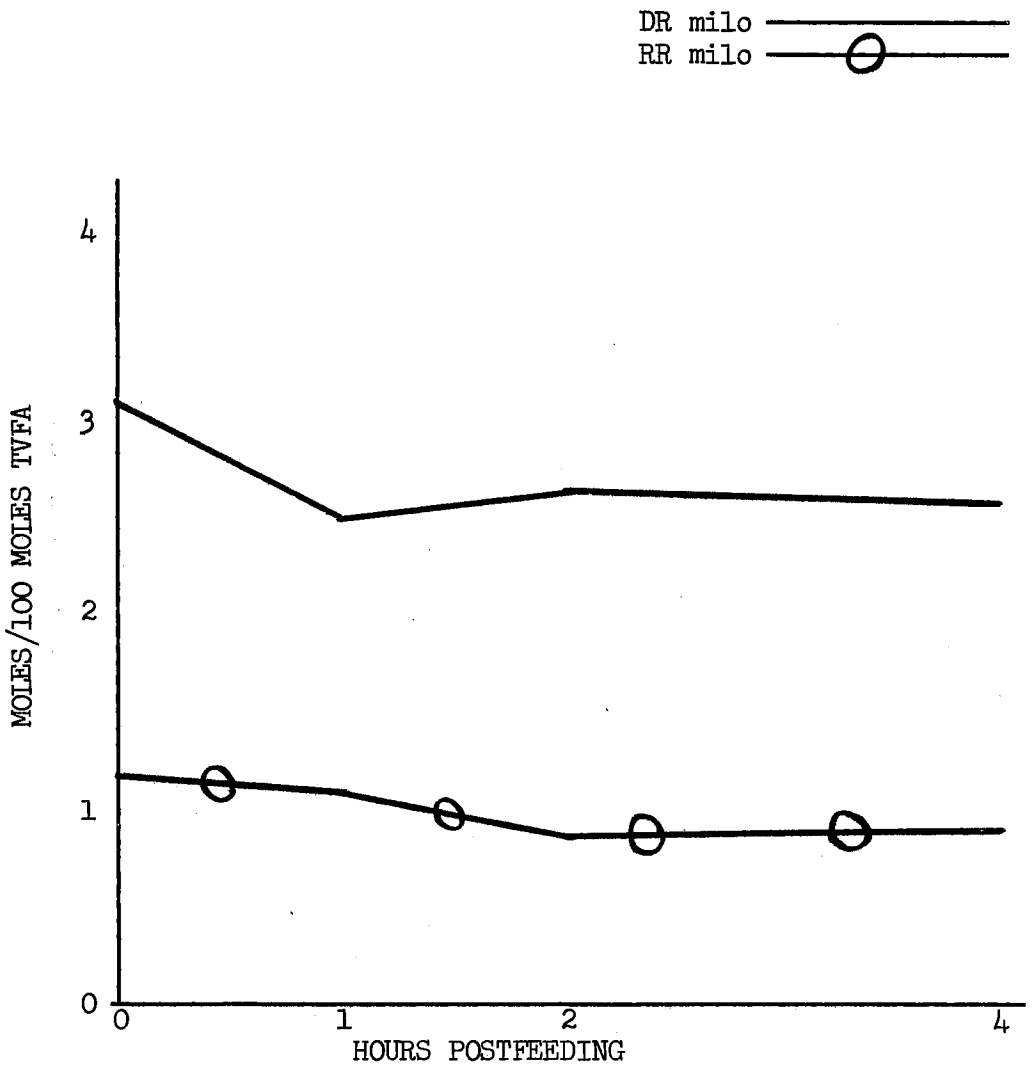

Figure 6. Isovaleric Acid Concentration in Rumen Fluid - Trial 1

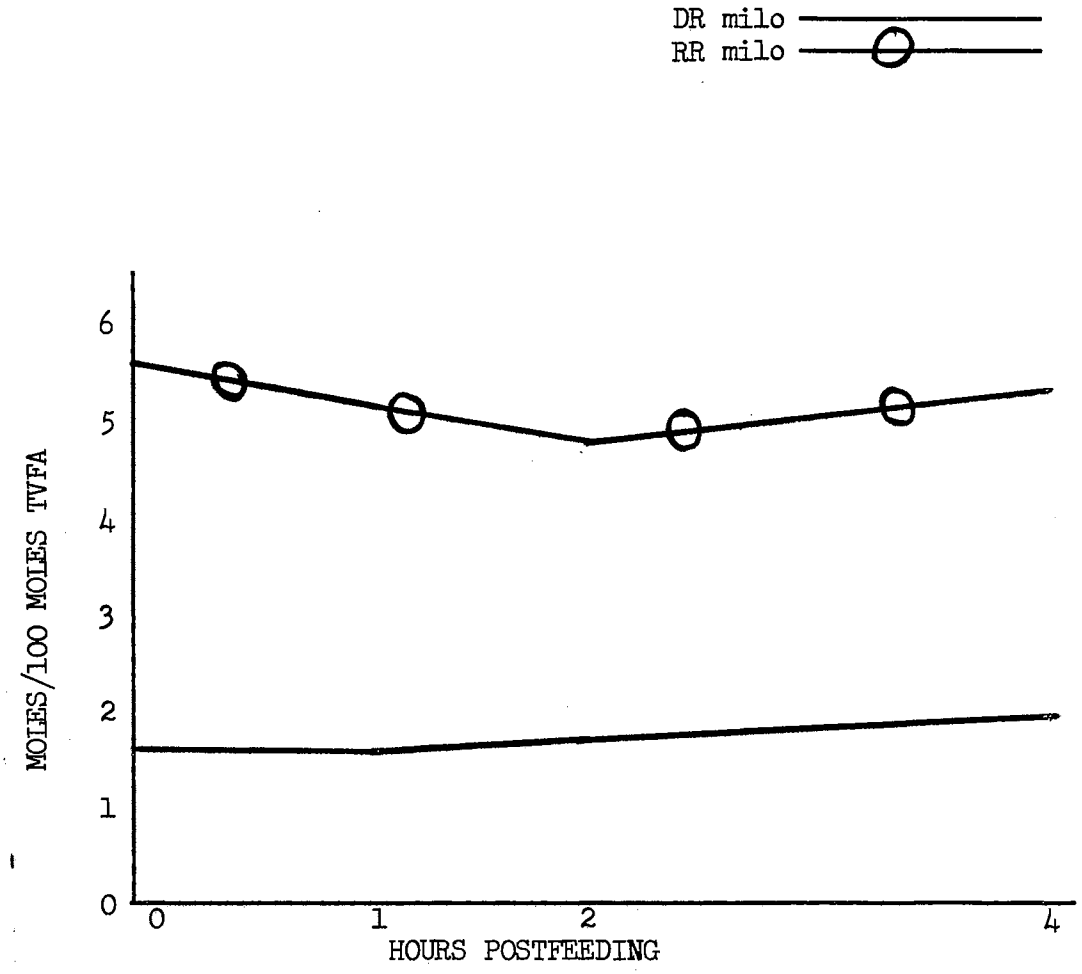

Figure 7. Valeric Acid Concentration in Rumen Fluid - Trial 1

variation due to animals was significant ($P<.01$) for all three acids and was probably an important factor contributing to the low level of significant differences between rations for butyric and valeric acids. Part of the animal variation was probably due to the difference in the length of time required for the animals to consume the feed offered on the morning the samples were taken.

Total volatile fatty acid concentration (micromoles/ml) in the rumen fluid of the steers in the final balance trial (trial 2) are shown in Figure 8. The concentration was slightly lower for the RR milo ration prior to feeding but slightly higher than that for the DR milo ration by 1 hr postfeeding. There was a rapid increase in TVFA to 4 hr postfeeding for the RR milo ration. The TVFA increased constantly but more gradually to 2 hr but decreased at 4 hr postfeeding for the DR milo ration.

The proportions of acetic and propionic acids (molar percent) in the rumen fluid are shown in Figures 9 and 10, respectively. Rumen fluid of steers fed the DR milo ration was higher in proportion of acetic acid while that from the steers fed the RR milo ration was higher in proportion of propionic acid. The molar percent of acetic decreased for 2 hr then increased to 4 hr postfeeding for the DR milo ration. For the RR milo ration, the molar percent of acetic increased rapidly for 1 hr then decreased rapidly to 2 hr and remained almost constant to 4 hr postfeeding. The concentration of acetic acid was lower at 2 and 4 hr postfeeding than before feeding and at 1 hr postfeeding for both rations with the variation due to time of sampling being significant ($P<.05$). Inverse proportions of propionic acid accompanied the changes of acetic for both rations. Differences between

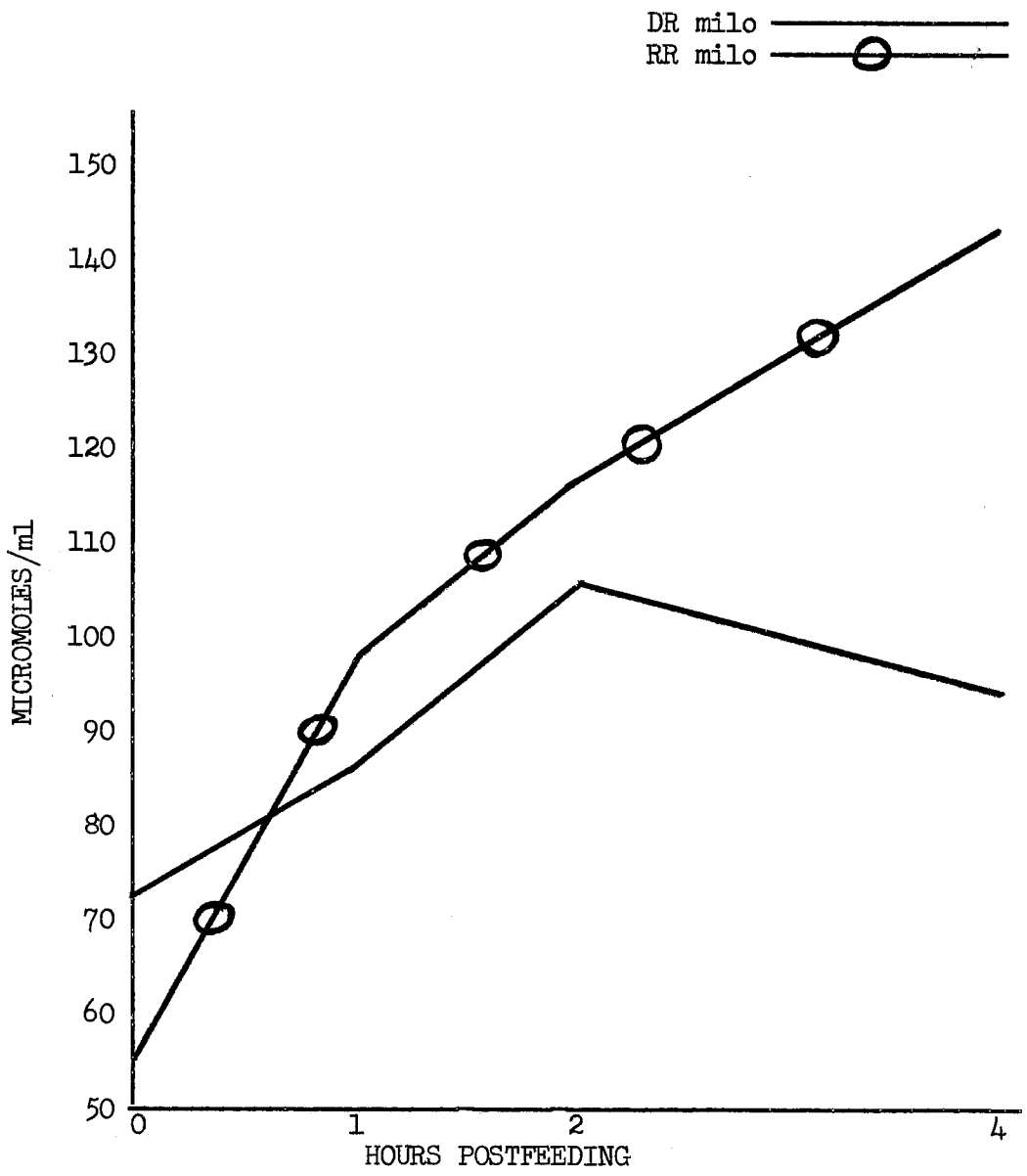

Figure 8. Total Rumen Volatile Fatty Acids - Trial 2

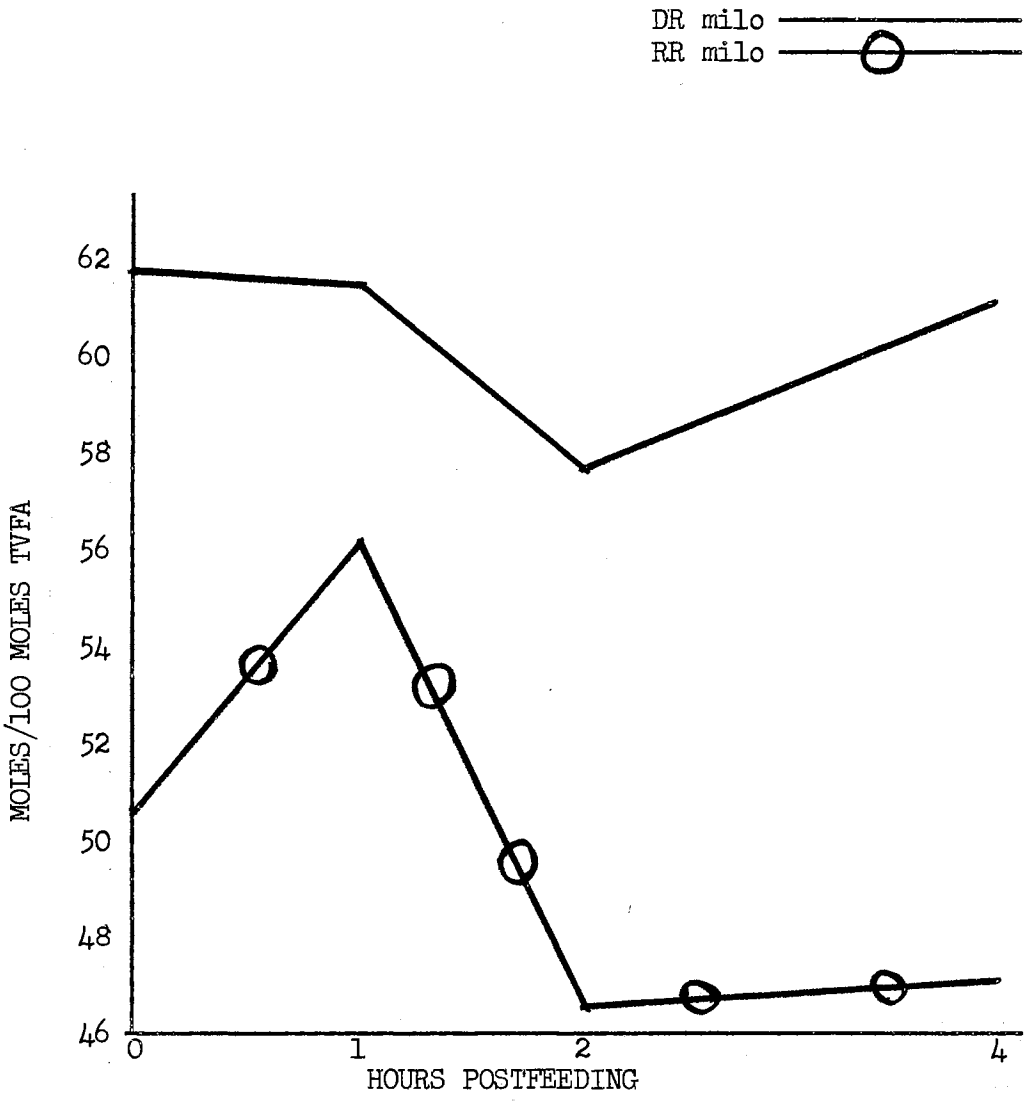

Figure 9. Acetic Acid Concentration in Rumen Fluid - Trial 2

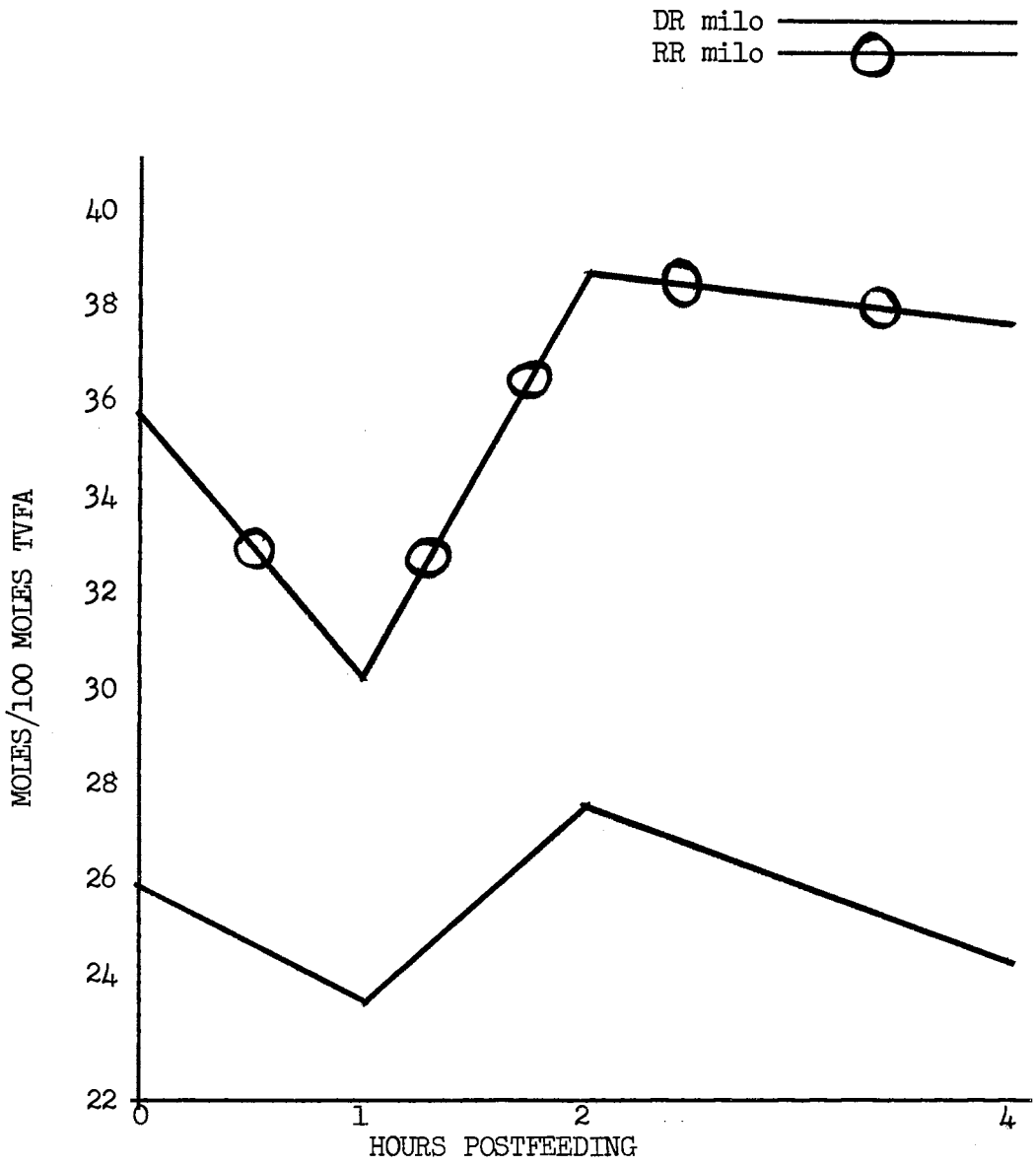

Figure 10. Propionic Acid Concentration in Rumen Fluid - Trial 2

rations were statistically significant ($P<.10$) for acetic but not for propionic acid and animal variation was significant ($P<.01$) for both acids.

Ruminal concentrations of butyric, isovaleric and valeric acids for cattle in trial 2 are presented in Figures 11, 12 and 13, respectively. The proportion of butyric acid increased to 2 hr postfeeding then remained almost constant to 4 hr for both rations. The effect due to time of sampling was significant ($P<.01$). Isovaleric acid decreased to 2 hr postfeeding for the RR milo ration but remained fairly constant with time for the DR milo ration. Valeric acid showed little change with time and, as in trial 1, was higher for the RR milo ration than for the DR milo ration. Differences between the two rations were not statistically significant for either acid. Again, animal to animal variation was significant ($P<.01$). As in trial 1, the length of time required by the animals to consume the feed was probably responsible for part of the animal to animal variation.

The relationship of acetic and propionic acids in the two trials is of special interest. It has been pointed out earlier than digestible and metabolizable energy were significantly greater for the RR milo ration than for the DR milo ration during the final balance trial while only digestible energy was greater for the RR milo ration during the initial balance trial. As discussed previously, the 10-day adjustment period was possibly not long enough to permit complete adaptation and maximum utilization of the reconstituted milo by the rumen microorganisms. The proportions of acetic and propionic acids support this idea. The molar percentage of propionic acid was greater than that of acetic for the RR milo ration at the final balance trial;

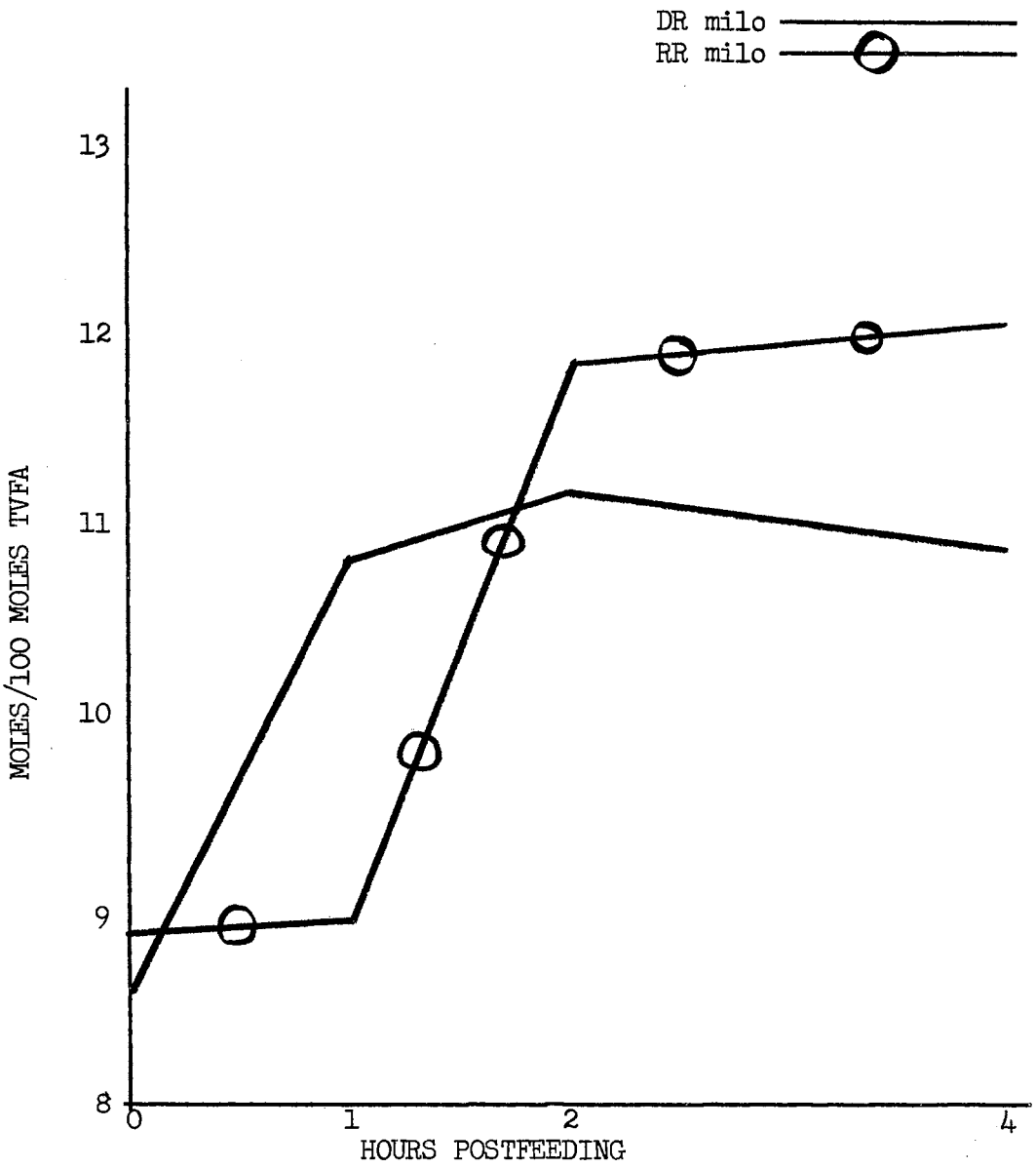

Figure 11. Butyric Acid Concentration in Rumen Fluid - Trial 2

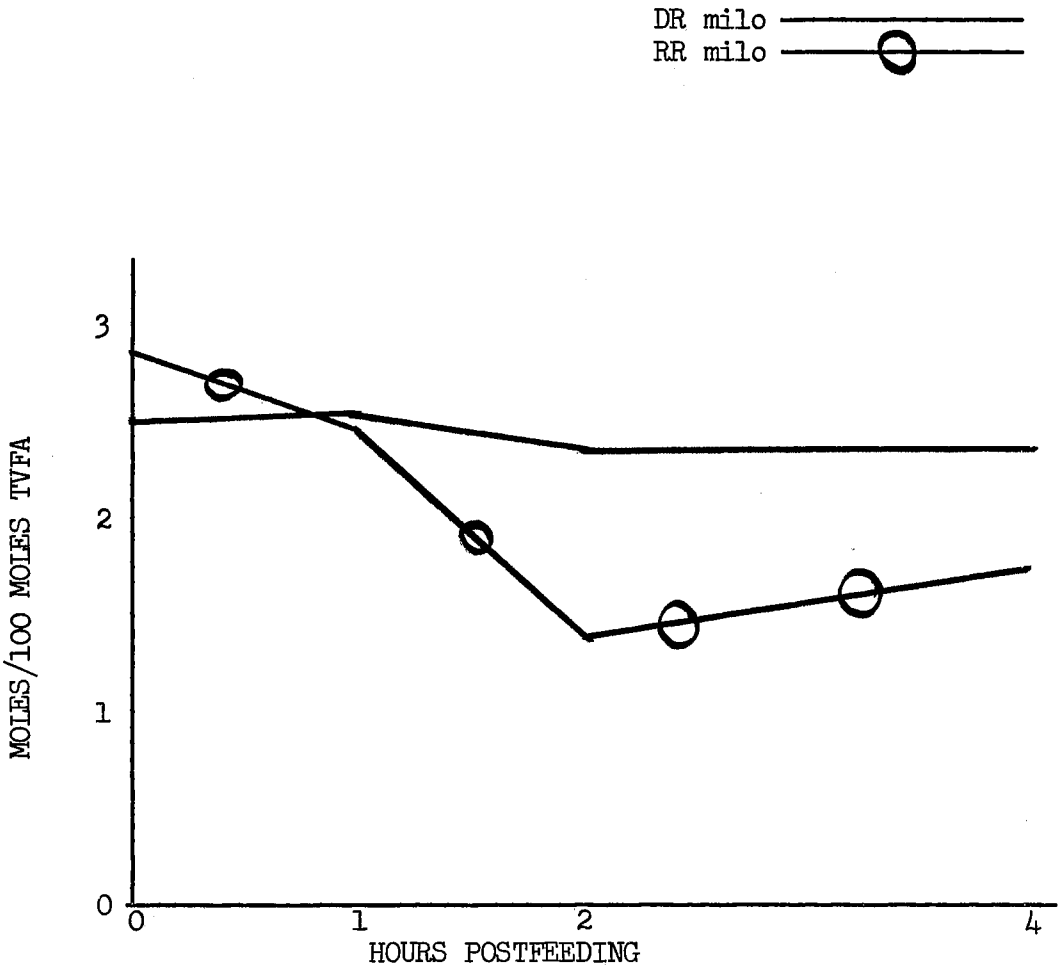

Figure 12. Isovaleric Acid Concentration in Rumen Fluid - Trial 2

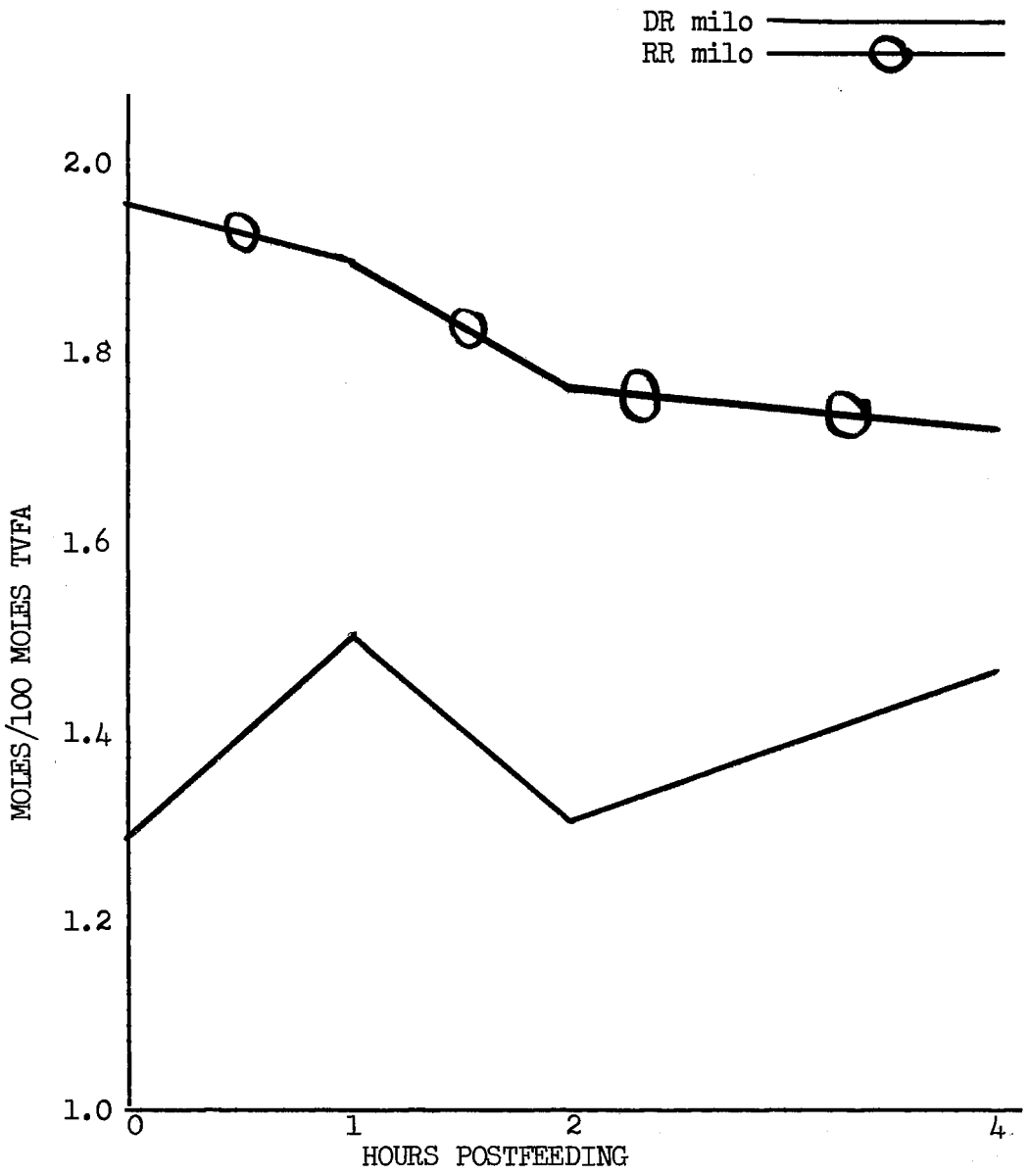

Figure 13. Valeric Acid Concentration in Rumen Fluid - Trial 2

however, the reverse occurred at the initial balance trial. This increased proportion of propionic acid accompanied the increased utilization of energy during trial 2. The average acetic:propionic acid ratio was 1.11:1 for the DR milo ration and 1.04:1 for the RR milo ration at the initial balance trial. At the final balance trial the ratios were 2.41:1 and 1.43:1; respectively, for the two groups. A low acetic:propionic acid ratio is generally accepted as desirable for finishing rations. Blaxter (1962) reported that a lower proportion of propionic to acetic acid in the digestion products was accompanied by a lower efficiency of body fat synthesis. Bull, Johnson and Reid (1967) questioned the theory and reported that acetic acid was used for fattening with an efficiency resembling that of other acids. However, Orskov et al. (1969) infused acetic and propionic acids into the rumen of lactating cows and found that with acetic acid more energy was secreted as milk while with propionic acid more energy was deposited as body tissue. They stated that they had obtained similar results in other studies which showed that diets giving rise to a high proportion of propionic acid in the rumen fluid resulted in a greater deposition of tissue energy than those giving rise to a high proportion of acetic acid.

CHAPTER V

SUMMARY AND CONCLUSIONS

Eighteen yearling Hereford steers were used to investigate the effect of reconstituting milo on its net energy value for feedlot cattle and to compare respiration calorimetry and the comparative slaughter technique as methods of determining the net energy value of high energy rations. One group of six steers was fed a dry rolled (DR) milo ration, another group of six steers was fed a reconstituted rolled (RR) milo ration (38% moisture) and a third group of six steers constituted the initial slaughter group. Initial body composition of the 12 experimental animals was estimated from that of the slaughter group which was determined by carcass specific gravity. The animals were individually fed twice daily for about 40 days after which they were fed three times daily so as to obtain daily intakes comparable to ad libitum group-fed cattle.

Total energy balance and fasting trials were conducted with all animals at the beginning and at the end of the experiment. Feces and urine were collected over a 7-day period and gaseous exchange was measured for two consecutive 24-hr periods in each trial. Rumen fluid samples were taken in each trial for volatile fatty acid analysis. All animals were slaughtered immediately after the second energy balance trial and final body composition was estimated from carcass specific gravity measurements.

Energy gained by the body during the feedlot period was determined by subtracting initial energy content of the empty body from the amount present at the end of the experiment. Energy gain was also measured during each balance trial by subtracting heat production from metabolizable energy. Fasting heat production was considered to be equal to the energy required by the animal for maintenance. Net energy (NEm+p) of the rations was then determined by both the respiration calorimetry and slaughter technique methods.

One steer in the RR milo fed group died during the feedlot period. Death was due to bloat and was not attributed to the milo processing treatment. During the feedlot period average daily dry matter intake was significantly ($P < .05$) less for the cattle on the RR milo ration however, average daily weight gain and feed efficiency were not significantly different between the two treatments. The NEm+p (Mcal/kg 90% DM intake) of the RR milo ration was significantly ($P < .01$) greater than the NEm+p of the DR milo ration.

Average daily dry matter intake was significantly ($P < .001$ for trial 1 and $P < .01$ for trial 2) less for the cattle on the RR milo ration during the two energy balance trials therefore all comparisons were made on the basis of dry matter consumption. In trial 1 the DE content (Mcal/kg DM intake) of the RR milo ration was significantly ($P < .01$) higher than that of the DR milo ration and although ME and NEm+p tended to be higher for the RR milo ration the differences were not statistically significant. In trial 2, DE and ME were significantly ($P < .05$ and $P < .01$, respectively) greater for the RR milo ration. However, HI was also significantly ($P < .01$) greater for the RR milo ration, consequently NEm+p was not significantly different for the two

rations. Rumen VFA analysis indicated a greater proportion of acetic acid than propionic in trial 1 with the reverse occurring in trial 2 for the RR milo ration. The increased proportion of propionic acid accompanied an increased efficiency of energy utilization in trial 2.

The NEm+p (Mcal/kg 90% DM intake) of the two rations was significantly ($P < .001$) greater when determined by respiration calorimetry than when determined by the slaughter technique. The average difference was 28.2%. Net energy for production (kcal/$W^{.75}$/kg DM daily) was significantly ($P < .001$) greater when determined by respiration calorimetry than by the slaughter technique for the DR milo ration and the average of the two rations but not for the RR milo ration.

The higher values obtained by respiration calorimetry are logical since the maintenance requirement of an animal would be considerably less while confined to a respiration chamber than in the feedlot due to less activity and environmental stress. Average daily gain and feed efficiency (kg feed/kg gain) are not significantly changed by reconstituting milo, however dry matter intake is significantly reduced compared to dry rolled milo.

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APPENDIX

TABLE XIX

DETERMINATION OF SOLUBLE CARBOHYDRATES

1. Transfer a sample containing not more than 800 mg soluble sugars (500-5000 mg sple) to a dry 100 ml volumetric flask. Add 1 g NaCl and 40 ml isopropionol. Let stand for 10 minutes mixing frequently.

2. Add sufficient water to bring the volume to about 90 ml. Keep at 20° for 60 minutes, mixing frequently by rotation. Add water to the mark, mix, adjust to the mark again and mix.

3. Add 200 mg Celite; continue to extract for 30 min. with frequent mixing at 20°C.

4. Filter through Whatman No. 54 filter paper. Cover the funnel to prevent evaporation of alcohol.

5. Prepare several reagent blanks by same procedure.

6. Transfer 50 ml of filtrate (at 20°) to a 250 ml volumetric flask. Make a mark with a grease pencil at 50 ml line.

7. Add small amount of talcum, 1-2 drops Octanol and 50-60 ml water. Remove ethanol by boiling on a hot plate until volume is 40-45 ml. Cool. Watch flask during boiling, adding 1-2 drops octanol when foaming is noted.

8. Add 5 ml 0.4M acetate buffer and 5 ml enzyme preparation. Incubate 6 hours in a 50°C water bath.

9. Add 10 ml $ZnSO_4$ solution and 2-3 drops phenophthalein indicator. While rotating the flask, rapidly add 0.5 N NaOH until precipitation of $Zn(OH)_2$ begins. Thereafter carefully add the alkali until the contents are fairly pink.

10. Wash down the sides of the flask and add 0.5 N H_2SO_4 drop-by-drop until the solution is colorless. Dilute to the mark, let stand 10 minutes, mixing frequently, and filter through Whatman No. 54. Filtrates may be stored in the refrigerator at this stage but preferably no more than 24 hours.

11. Transfer exactly 2, 3, 4 and 5 ml of the samples and blanks to the bottom of 29 x 200 mm test tubes. Best results are obtained when the tube contains 3-3.5 mg glucose. Cover the beakers with glass marbles or small beakers. Add water to bring volume to 5 ml.

12. Add exactly 5 ml 0.04M FeCy reagent, mix immediately by rotation and incubate exactly 30 min. at 80°C.

13. Cool rapidly in running water to 20-25°.

14. Prepare 5 ml water blanks with each run.

TABLE XIX (continued)

15. Remove the cover. Add 1 ml KI solution and 5 ml $ZnSO_4$-acetic acid reagent, mixing gently after each addition. Cover the tubes immediately after last addition to prevent loss of I_2. Let stand at least 20 minutes with occasional mixing.

16. Titrate with 0.01N thiosulfate until almost colorless. Add first few ml around sides of tube to prevent loss of I_2. Add 0.5 ml starch indicator, wash down walls with stream of water and titrate drop-by-drop until the color is pure white.

17. The reducing sugar titration procedure can be standardized using 2 to 4 mg glucose in the 5 ml volume.

Calculation: Percent reducing sugar expressed as glucose can be calculated by:

$$\% R_s = aT \left[\frac{200\ V}{v\ W} \right]$$

Where

T = ml difference between thiosulfate titration of blank and sample solution.

a = mg glucose equivalent per ml thiosulfate.

i.e., $\left(\frac{\text{mg standard glucose}}{\text{T (standard)}} \right)$

V = ml final volume of digest clarified with $Zn(OH)_2$ (250 ml in this case).

v = ml aliquot of filtrate taken for analysis.

W = mg weight of sample.

The factor 200 comes from 2 (only 50 ml first filtrate used) and 100 to convert to percent.

TABLE XX

ENERGY BALANCE - TRIAL 1

Energy fraction	DR milo	RR milo
	(Mcal/day)	
Energy losses		
Fecal	7.250	3.769
Urine	2.978	2.633
Methane	0.861	0.681
Heat increment	4.214	2.909
Heat production	10.167	8.178
Energy utilization		
GE	27.359	18.861
DE	20.109	15.092
ME	16.270	11.790
NEm	5.955	5.282
NEp	6.103	3.600

TABLE XXI

ENERGY BALANCE - TRIAL 2

Energy fraction	DR milo	RR milo
	(Mcal/day)	
Energy losses		
Fecal	7.378	5.017
Urine	2.716	1.889
Methane	1.548	1.048
Heat increment	4.240	4.177
Heat production	10.644	10.289
Energy utilization		
GE	27.740	21.356
DE	20.362	16.339
ME	16.098	13.402
NEm	6.403	6.110
NEp	5.455	3.113

TABLE XXII

ENERGY UTILIZATION

Energy fraction	Trial 1 DR milo	Trial 1 RR milo	Trial 2 DR milo	Trial 2 RR milo
		(% of GE)		
DE	73.50	80.02	73.40	76.51
ME	59.47	62.51	58.03	62.76
NEm+p	44.08	47.09	42.75	43.19
		(% of ME)		
NEm+p	74.11	75.34	73.66	68.82

TABLE XXIII

CALCULATION OF NET ENERGY FOR MAINTENANCE - TRIAL 1

Item	DR milo		RR milo	
Level of feeding	Fasting	Equilibrium	Fasting	Equilibrium
ME intake (Mcal/$W^{.75}$/day)	0	.109	0	.098
DM required (kg/$W^{.75}$/day)	0	.0405	0	.0345
Heat produced (Mcal/$W^{.75}$/day)	.080	.109	.074	.098
Energy gain (Mcal/$W^{.75}$/day)	-.080	0	-.074	0
Difference (equilibrium - fast)				
DM intake (kg)		.0405		.0345
Energy gain (Mcal)		.080		.074
NEm of ration (Mcal/kg DM)[a]		1.978		2.165

[a] $NEm = \frac{\text{Energy gain}}{\text{DM intake}}$.

TABLE XXIV

CALCULATION OF NET ENERGY FOR PRODUCTION - TRIAL 1

Item	DR milo		RR milo	
Level of feeding	Equilibrium	Ad libitum	Equilibrium	Ad libitum
DM intake (kg/$W^{.75}$/day)	.0405	.0815	.0345	.0578
Energy gain (Mcal/$W^{.75}$/day)	0	.0822	0	.0503
Difference (ad libitum - equilibrium)				
DM intake (kg)		.041		.0233
Energy gain (Mcal)		.0822		.0503
NEp of ration (Mcal/kg DM)[a]		1.992		2.128

[a] $NEp = \frac{\text{Energy gain}}{\text{DM intake}}$.

TABLE XXV

CALCULATION OF NET ENERGY FOR MAINTENANCE - TRIAL 2

Item	DR milo		RR milo	
Level of feeding	Fasting	Equilibrium	Fasting	Equilibrium
ME intake (Mcal/$W^{.75}$/day)	0	.092	0	.094
DM required (kg/$W^{.75}$/day)	0	.035	0	.034
Heat produced (Mcal/$W^{.75}$/day)	.067	.092	.065	.094
Energy gain (Mcal/$W^{.75}$/day)	-.067	0	-.065	0
Difference (equilibrium - fast)				
DM intake (kg)		.035		.034
Energy gain (Mcal)		.067		.065
NEm of ration (Mcal/kg DM)[a]		1.909		1.912

[a] $NEm = \frac{\text{Energy gain}}{\text{DM intake}}$.

TABLE XXVI

CALCULATION OF NET ENERGY FOR PRODUCTION - TRIAL 2

Item	DR milo		RR milo	
Level of feeding	Equilibrium	Ad libitum	Equilibrium	Ad libitum
DM intake (kg/$W^{.75}$/day)	.035	.066	.034	.051
Energy gain (Mcal/$W^{.75}$/day)	0	.057	0	.033
Difference (ad libitum - equilibrium)				
DM intake (kg)		.031		.017
Energy gain (Mcal)		.057		.033
NEp of ration (Mcal/kg DM)[a]		1.843		1.897

[a] $NEp = \frac{\text{Energy gain}}{\text{DM intake}}$.

TABLE XXVII

MEAN CONCENTRATION OF VOLATILE FATTY ACIDS IN THE RUMEN FLUID OF STEERS

Trial, acid and ration	Hours Postfeeding 0	1	2	4	SE[a]
	(moles/100 moles TVFA)				
Initial balance trial					
Acetic acid					
DR milo	46.05	46.88	46.97	43.03	7.39
RR milo	37.52	40.11	42.89	40.17	7.39
Propionic acid					
DR milo	40.49	40.53	42.42	42.52	10.86
RR milo	41.24	38.02	37.18	38.48	10.86
Butyric acid					
DR milo	8.76	8.50	6.27	9.92	4.56
RR milo	14.65	13.33	14.27	15.19	4.56
Isovaleric acid					
DR milo	3.06	2.47	2.61	2.57	1.90
RR milo	1.17	1.09	0.83	0.87	1.90
Valeric acid					
DR milo	1.66	1.64	1.72	1.97	2.30
RR milo	5.58	5.10	4.83	5.29	2.30
Final balance trial					
Acetic acid					
DR milo	61.81	61.45	57.78	61.15	7.67
RR milo	50.61	56.09	46.43	46.90	8.40
Propionic acid					
DR milo	25.73	23.76	27.38	24.24	9.14
RR milo	35.73	30.18	38.16	37.62	10.01
Butyric acid					
DR milo	8.69	10.81	11.19	10.80	2.19
RR milo	8.89	8.98	11.84	12.08	2.41
Isovaleric acid					
DR milo	2.49	2.51	2.35	2.37	0.99
RR milo	2.84	2.46	1.36	1.71	1.09
Valeric acid					
DR milo	1.28	1.49	1.30	1.45	0.48
RR milo	1.94	1.89	1.77	1.72	0.52

[a]Standard error of the mean (see Appendix Table XXVIII for an example of the analysis of variance used).

TABLE XXVIII

EXAMPLE OF ANALYSIS OF VARIANCE USED TO ANALYZE THE VOLATILE FATTY ACID DATA[a]

Source of variation	Degrees of freedom	Sum of squares	Mean squares	F
Total	47	4188.9579		
Between rations	1	376.8802	376.8802	1.15
Between times	3	91.1763	30.3921	2.82
Ration X time	3	122.9922	40.9974	3.80
Between animals within rations	10	3274.4567	327.4457[b]	30.37
Time X animals per ration	30	323.4525	10.7818	

[a]Results given are for acetic acid concentration, trial 1.

[b]Variance used to estimate the standard error of the treatment mean.

VITA

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Doctor of Philosophy

Thesis: EFFECT OF METHOD OF PROCESSING MILO UPON THE EFFICIENCY OF ENERGY UTILIZATION BY BEEF STEERS AS MEASURED BY RESPIRATION CALORIMETRY AND SLAUGHTER TECHNIQUE

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