THE EFFECT OF THE PHYSICAL FORM OF
CORN ON NET ENERGY VALUE,
FEEDLOT PERFORMANCE AND
CARCASS MERIT OF
BEEF STEERS

By

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CHAPTER I

INTRODUCTION

In the past decade, the cattle feeding industry has gone through an extremely rapid expansion. Conventional farmer-feeder operations have been overshadowed by larger commercial feeding organizations. With increasingly smaller profit margins, the economics of such large feeding operations have brought about the re-evaluation of grain processing practices.

Recently feeding of whole corn has received much interest in the industry. Many years ago whole corn had been fed by the farmer-feeder. As technology increased, so did the number of methods of grain processing. Methods now available to the cattle feeder are dry-grinding, pelleting, conventional steam rolling, steam-flaking, micronizing, popping, reconstitution, high moisture harvesting and others. Accompanying these techniques for increasing nutrient utilization are increased processing costs.

The question which arises has both nutritional and economic implications; namely, can whole shelled corn compete favorably with more elaborately processed grains?

In an attempt to evaluate some of the nutritional aspects of this question in more depth than is possible with a conventional feeding trial, a series of experiments were conducted. Respiration calorimetry and the comparative slaughter technique were used to determine the net energy value of corn differing only in physical form. Whole corn and ground corn were also evaluated on the basis of feedlot performance and carcass merit. *In vitro* zero time rate volatile fatty acid productions were also investigated.

CHAPTER II

REVIEW OF LITERATURE

The physical form of corn grain has drawn much concern from cattle feeders and animal scientists over the past several years. The literature is replete with reports of processing techniques claiming increased nutrient utilization.

Differing physical forms of corn grain were fed as early as the turn of the century. Lane et al. (1898) conducted an experiment with mature dairy cows fed rations differing only in the physical condition of the corn. Each cow received daily, 6.0 pounds of wheat bran, 9.4 pounds of hay and 10.0 pounds of corn stalks along with either whole corn or ground corn. They reported a 9.3% increase in milk yield and a 4.9% increase in butterfat production from the ground corn ration. It was their assumption that the increase in productivity of the ground corn ration was due to its greater digestibility. In a collateral experiment they showed that 57.3% of the whole corn passed through the alimentary tract undigested. This was ascertained by washing the feces and collecting whole and parts of kernels. They were then weighed and calculated to the same water content as fed. Chemical analysis showed little change by the digestive process.

Fain and Jarnigan (1907) supplemented skim milk for dairy calves with either whole corn or ground corn. They reported a greater feed consumption, rate of gain, and feed efficiency for the whole corn ration. Average daily gains were 1.42, and 1.60 pounds per head per day for the ground corn and whole corn rations respectively.

Shaw et al. (1906) feeding whole corn to mature cows, heifers, and calves at rates of 11.0, 6.0, and 3.0 pounds per head per day with ad libitum clover hay reported unmasticated whole corn in the feces to be 22.75%, 10.77%, and 6.28% respectively.

McCandlish (1922) established that whole grain was preferred over ground grain by calves. His conclusion is in accordance with work done by Otis (1904) at the Kansas station who observed that calves would eat whole corn when they were two to three weeks old and seemed less subject to scours than calves fed cracked corn.

Darnell and Copeland (1936) feeding rations of either whole or ground corn at the rate of 50% and 75% of the total grain, showed more milk was produced per pound of grain when whole corn was fed. Hilton et al. (1933) experimenting with calves raised from birth to six months of age reported no difference in body weight gains or height at the withers on whole and ground corn rations.

In more recent work, Embry et al. (1969) feeding ground or rolled corn with either 20% or 50% alfalfa hay reported no difference in the apparent digestibility of the rations. Perry and Mudd (1968) at the Indiana station reported cattle fed gelatinized corn gained 1.25 pounds less than cattle fed raw (whole) corn. Furthermore, increasing levels of gelatinized corn in the ration significantly depressed the dry matter digestibility. They reported an average dry matter digestibility of 80.8% for the 100% raw (whole) corn versus 73.8% for the gelatinized corn ration.

Beeson et al. (1971) comparing whole dry shelled corn, rolled dry shelled corn, reconstituted high moisture ensiled corn (20% moisture), fed to beef cattle, found the average daily gains similar regardless of the treatments. They reported that reconstituted corn (20% moisture) improved feed efficiency five per cent and high moisture corn (26% moisture) was nine per cent more efficient than dried whole corn. Perry et al. (1970) reported that heifers fed roasted corn gained 12% faster, requiring 10% less feed per pound of gain than those fed ground corn.

Vance et al. (1970) in evaluating the physical form of corn with either artificial or natural roughage supplementation reported steers fed whole shelled corn gained significantly ($P < .01$) more fat than steers fed ground or steam-flaked corn. Vance et al. (1970) reported that the physical form of corn, either dry whole shelled or crimped, fed alone or with 20 pounds of corn silage, had no influence on total starch, dry matter, organic matter, or protein digestion coefficients.

Whole high moisture shelled corn was compared to rolled high moisture shelled corn by Hanke et al. (1968). Both treatments were fed with three pounds of alfalfa-brome hay. There was no difference in average daily gain (2.58 vs. 2.57 pounds per head per day). Efficiency data, however, favored the rolled high noisture grain (8.18 vs. 8.66 pounds of feed per pound of gain).

Burkhardt et al. (1969) concluded that there was no advantage from rolling or flaking corn grain when compared to unprocessed grain, on the basis of weight gain and feed efficiency, when the grain was fed with two pounds of hay. Reconstituted high moisture corn (27.4% moisture) was comparable to dry corn on the basis of weight gains and efficiency values except under extreme cold weather conditions.

Woods, *et al.* (1971) summarizing results of four trials with steers reported average daily gains of 2.71 and 2.69 pounds per head per day on dry rolled versus whole corn rations respectively. There was no difference in intake; however, efficiency data favored the dry rolled (7.41 vs. 7.60). No difference was reported in the incidence of liver abscesses.

Average daily gains and efficiency figures sumarized for whole and ground corn rations are given in Table I taken from Sewell (1970). Whole corn rations gave higher average daily gains and were more efficient in converting pounds of feed to pounds of gain. Average daily gains were 3.09 for whole corn versus 2.90 pounds per head per day for ground corn. Whole corn rations required 7.65 pounds to produce a pound of gain whereas ground corn required 7.93 pounds. This table summarizes work from three different experiment stations over a period of three years. Table II summarized the results of three years of research with high moisture corn.

Volatile Fatty Acid Production

Vance *et al.* (1970) reported no significant differences ($P > .05$) in rumen pH among steers fed whole, ground or steam-flaked corn. Table III reports that the whole shelled corn, no-roughage treatment resulted in a significantly higher ($P < .05$) total VFA level than did either of the other two treatments. The no roughage rations produced no significant effect on the percentage of acetic or propionic acid.

Oltjen (1970) reported VFA concentrations on all concentrate corn diets, taken four hours post feeding, to be 99 m moles/liter, with a mean pH of 6.0. Oltjen *et al.* (1966) studied rations containing either

TABLE I

WHOLE vs. GROUND DRY SHELLED CORN
TAKEN FROM SEWELL (1970)

Average Daily Gain, Lbs.		Feed/Lb. Gain	
Whole	Ground	Whole	Ground
3.08	2.86	7.37	7.81
2.73	2.76	10.37	10.20
3.99	3.44	4.84	5.29
2.94	2.74	7.35	7.90
3.16	3.07	7.23	7.74
2.66	2.55*	8.74	8.63
Av.			
3.09	2.90	7.65	7.93

*Rolled

TABLE II

WHOLE vs. ROLLED HIGH-MOISTURE CORN
TAKEN FROM SEWELL (1970)

Average Daily Gain, Lbs.		Feed/Lb. Gain	
Whole	Rolled	Whole	Rolled
1.55	1.72	7.37	6.36
1.55	1.58*	7.37	6.18
2.34	2.39	9.32	8.59
2.58	2.57	8.66	8.19
2.44	2.27	8.90	9.29
Av.			
2.09	2.11	8.32	7.72

*Ground

98% cracked corn or cracked wheat. In one trial, they reported the concentration of acetic acid and butyric plus higher acids to be lower on the corn diets than the wheat diets. Propionic acid was higher on the corn diets, and total VFA concentration was lower for the 90% corn diet than the 90% wheat diet.

TABLE III

INTRA-RUMINAL OBSERVATIONS ON CORN RATIONS
TAKEN FROM VANCE ET AL. (1970)

Item	No Roughage		
	Whole	Ground	Steam Flaked
Rumen pH	5.58	5.48	5.67
Total VFA, uM/ml.	155.20	132.10	134.40
Acetic, molar %	39.90	37.00	40.20
Propionic, molar %	45.90	44.10	44.50
Butyric, molar %	7.30	10.70	8.00
Isovaleric, molar %	2.80	2.20	3.00
Valeric, molar %	4.20	5.70	4.00

White et al. (1972) reported results of feeding whole corn and ground corn with either soybean meal or urea as the nitrogen source. Their data indicated that the physical form of the corn or the replacement of soybean protein with urea, did not significantly influence the digestibility of energy, dry matter, nitrogen free extract or crude protein. Nitrogen retention and urinary energy were not significantly different between rations. These workers reported that whole corn rations tended to have a higher pH, increased concentrations of acetate and butyrate, compared to ground corn rations. Total VFA and the concentration of propionate tended to be higher on ground corn rations.

Shaw et al. (1960) in research with dairy steers utilizing 50% concentrate rations of chopped hay and ground corn, reported that grinding and pelleting the hay and flaking the corn produced a marked decrease in the molar percentage of acetate and increased propionate. The processing of the hay and corn resulted in a 12% increase in protein digestibility, 22% increase in weight gain and a 15.3% increase in feed efficiency. Oltjen and Davis (1965) feeding all concentrate rations to steers, reported no significant differences between cracked corn and pelleted corn in any VFA concentrations. Thompson et al. (1965) reported steers fed ground corn produced significantly ($P < .05$) more total VFA's than steers fed flaked corn. They reported no difference in molar percentage of VFA's between treatments.

Woods and Luther (1962) reported results of feeding lambs a 67% concentrate ration based on corn. They found that pelleting the complete ration narrowed the acetic: propionic ratio.

Net Energy (NE)

Morrison (1959) states the NEm+g value of corn is 80.1 Mcal. per 100 pounds. Lofgreen (1970) presented data on 64% and 84% grain rations shown in Table IV. The NEm value for corn was the highest followed by wheat, milo, and barley. NEg values followed the same pattern. Hall et al. (1968) reported (Table V) the net energy values of corn and sorghum grain, at three levels of feeding. They reported differences in the NEm+g values between the grains were not significant ($P > .05$) at any level of intake, although the NE value was significantly higher at maintenance level than the other levels of intake.

TABLE IV

NET ENERGY VALUE OF RATIONS CONTAINING BARLEY, CORN, MILO, OR WHEAT AS THE ONLY GRAIN REPORTED BY LOFGREEN (1970)

Level of Grain	Energy Measure	Grain			
		Barley	Corn	Milo	Wheat
%		(Mcal. per 100 lb. of DM)			
64	NEm	76	84	79	82
	NEg	54	63	57	60
84	NEm	85	92	86	90
	NEg	65	74	65	69
Means	NEm	81	88	83	86
	NEg	60	69	61	65

Garrett _et al._ (1971) working with corn which was rolled after various steaming times and pressures, reported energy utilization as expressed by the level of corn in the diet. As would be expected, and as shown in Table VI the NEm and NEg values expressed in Mcal/kg in crease as the percent corn in the ration increases. Mean values for

TABLE V

NET ENERGY VALUE OF CORN AND SORGHUM GRAIN AT THREE LEVELS OF FEEDING REPORTED BY HALL *ET AL.* (1969)

	Net Energy (m+g)			Net Energy (g)		
Level fed	Maintenance	Intermediate	High	Maintenance to Intermediate	Intermediate to High	Maintenance to High
Trial 1						
Corn	151.8[a] ± 7.8[b]	135.4 ± 5.4	133.1 ± 9.4	11.0 ± 12.9	122.3 ± 25.4	117.0 ± 10.4
Sorgh. Grain	156.0 ± 15.8	138.4 ± 10.0	142.6 ± 10.8	128.8 ± 22.2	153.7 ± 45.3	139.3 ± 20.5
Trial 2						
Corn	167.6 ± 9.2	123.2 ± 6.3	110.4 ± 17.5	86.3 ± 11.6	88.8 ± 54.3	83.5 ± 22.6
Sorgh. Grain	164.4 ± 10.8	114.7 ± 5.7	108.6 ± 5.5	66.7 ± 13.2	91.0 ± 22.4	77.1 ± 8.9
Mean	160.0 ± 9.9	127.9 ± 6.6	123.7 ± 102.0	99.4 ± 15.3	114.0 ± 38.1	104.2 ± 14.9

[a] Mcal per 100 kg

[b] Standard error

NEm and NEg on all corn diets were 1.88 and 1.27 respectively. NEm values for the various processing methods are almost identical; however, NEg values show an increase as the pressure was increased on the rolls, Table VII.

TABLE VI

ENERGY UTILIZATION BY LEVEL OF CORN IN DIET
REPORTED BY GARRETT *ET AL.* (1971)

Item	40%	60%	80%	Mean
Ration NEm*	1.77	1.89	1.98	1.88
Ration NEg	1.11	1.31	1.40	1.27

*Mcal/kg

TABLE VII

ENERGY UTILIZATION BY PROCESSING METHOD
REPORTED BY GARRETT *ET AL.* (1971)

	Dry Rolled	Rolled-8 Min. Steam	Rolled-1.5 Min. Steam	Rolled-3.0 Min. Steam
Item			Atmos. Press. 4.2 kg/cm^2	
Ration NEm*	1.88	1.86	1.88	1.90
Ration NEg	1.20	1.18	1.29	1.41

*Mcal/kg

Absher (1965) used the comparative slaughter technique to determine the NE of milo and corn at three levels of intake. The NEm and NEg of corn were 171 ± 11 and 120 ± 13 kcal/100 kg of air dry grain. Vance *et al*. (1970) used the comparative slaughter technique to determine the NE of dried whole corn, ground corn, and steam-flaked corn. The rations consisted of 87.5% corn fed with either 10% corn cobs or 4% of an artificial roughage. Results are summarized in Table VIII. Reviewing the results of the no roughage rations across all treatments, cattle on the whole corn treatments showed the highest percent increase in fat, highest daily energy gain in Mcal, and the highest daily maintenance requirement. The steam-flaked corn ration had the highest NEm+g value.

TABLE VIII

NET ENERGY VALUES BY COMPARATIVE SLAUGHTER TECHNIQUE REPORTED BY VANCE *ET AL*. (1970)

	No Roughage		
Item	Whole	Ground	Steam Flaked
Gain in fat, %	25.5	20.2	22.3
Gain in Protein, %	18.2	18.7	18.6
Average Daily energy gain, Mcal	4.57	3.91	4.08
Average daily maintenance requirement, Mcal	6.53	6.44	6.49
NEm+g/100 lb. ration, Mcal	54.8	50.4	56.5

Vance *et al.* (1971) used the comparative slaughter technique to determine the net energy of two forms of corn and increasing levels of corn silage. At the zero roughage level, NEm+g, Mcal/100 pounds of ration dry matter, NEm and NEg were higher for the whole corn rations than for crimped corn rations. (See Table IX). These values declined as the percent corn silage in the ration increased. A calculated average NEm value for grain was given as 105.8 Mcal/100 pound ration dry matter.

TABLE IX

NET ENERGY VALUES BY COMPARATIVE SLAUGHTER TECHNIQUE REPORTED BY VANCE *ET AL.* (1971)

Item	Whole Corn	Crimped Corn
	Zero Roughage Level	
NEm+g, Mcal/100 lb. ration DM	82.4	80.8
NEm, Mcal/100 lb. ration DM	97.1	95.5
NEg, Mcal/100 lb. ration DM	75.5	69.3

CHAPTER III

MATERIALS AND METHODS

Feedlot Trial

Introduction

Twelve choice yearling steers, six Hereford and six Angus, were utilized in an equalized paired feeding study to evaluate whole corn and ground corn for net energy value, carcass merit and feedlot performance. Initial weights are given in Table X.

Animals

The animals were wintered on a dry bermudagrass pasture until April at which time they were moved to a drylot. They were maintained on a very low quality alfalfa hay for a two week period at the end of which they were moved to the feedlot. For a twenty-one day period the animals were fed alfalfa hay and a grain mixture consisting of 50% whole corn and 50% ground corn. The alfalfa was gradually removed from the ration. Twelve yearling steers with an average initial weight of 283 kg were selected on the basis of uniformity, body conformation, and weight. Weights were determined by weighing the animals when full and calculating a four percent shrink. The animals were paired on the basis of weight and breed.

TABLE X

ANIMAL ALLOTMENT BY WEIGHT AND BREED

Breed	Initial Weight, kg Whole Corn	Ground Corn
Hereford	295.45	295.45
Hereford	281.82	284.09
Hereford	277.27	272.73
Angus	311.36	295.45
Angus	281.82	279.54
Angus	254.54	265.90
Mean	283.64	282.27

$^{*}\bar{d} = 1.51$

$^{**}S_{\bar{d}} = 3.65$

* $\bar{d}$ = Mean difference between pairs.

** $S_{\bar{d}}$ = Standard error of the mean difference.

Rations and Feeding

The rations involved in both trials were idential in composition differing only in method of corn processing. Corn was ground through a six sixty-fourths square inch screen. Ration composition is presented in Table XI. The composition of the supplement is shown in Table XII. The supplement and the alfalfa were pelleted through a three-eighths inch die. Cottonseed hulls, alfalfa pellets and the supplement pellets were mixed daily with the appropriate form of corn.

TABLE XI

RATION COMPOSITION

Item	Percent
Corn Grain	84.0
Cottonseed Hulls	7.0
Alfalfa	3.0
Supplement	6.0
	100.0

TABLE XII

CORN SUPPLEMENT

Item	Percent
Soybean Oil Mean 44% (41)	54.68
Urea 45% N	11.50
Potassium Chloride 57% K	5.50
Calcium Carbonate 38% Ca	9.00
Dicalcium Phosphate 26% Ca	9.00
Salt	5.50
Stillwater Mill Trace Mineral Mix	0.25
Stilbestrol (Elanco 2 grams/lb.)	0.42
Aurofac (10 grams/lb.)	1.00
Vitamin A - (30,000 I.U./gram)	0.15
Wheat Midds. 14%	3.00
	100.00

One member of each pair of animals was alloted at random to one of two rations reported previously. Animals were paired to increase the precision of the comparison of whole corn and ground corn. The animals were fed twice daily. Equalized feed consumption was maintained for each pair by adjusting intake to that member which sonsumed the least amount of feed the previous feeding. Intake was equalized to reduce the confounding of level of intake with form of corn. The animals were weighed every 28 days before the morning feeding.

Energy Balance Trial

An energy balance trial using respiration calorimetry was conducted to determine the net energy value of corn grain.

Animals

The energy balance trial was conducted on the six pairs of animals being used in the feedlot trial. As each pair approached 364 kg, they were moved to the metabolism unit for a 14 day adjustment period.

Digestion and Balance Trial

The steers were placed in the metabolism stalls by pairs. Following the 14 day adjustment period, feces and urine were collected for seven days. Daily feed consumption was held constant during the digestion trial and energy balance trial.

The animals experienced some difficulty in adjusting to the metabolism stalls. Feed consumption dropped but in most cases returned to 85% of feedlot consumption by the collection period. Water was available at all times.

Following the fecal and urine collection period, the steers were placed in open circuit respiration chambers for a three day period, the last two of which included two consecutive 24-hour gas collection periods. Operating procedures were as follows: the chambers were sealed for at least 12 hours before the initial gas collection. Outdoor air was pulled into the chamber, cooled and circulated. Exhaust gas was drawn from the chamber so that the rate of air passage through the chamber approximated 350 liters per minute. Dry gas meters measured the volume of air passing through the chambers. The exhaust gases from the chamber were sampled by spirometers.

At the start of the first collection period, the gas meters were read, spirometers turned on and chamber air analyzed for oxygen, carbon dioxide and methane. The end of the first collection period was also the beginning of the second collection. At this time the meters were read, chamber air analyzed and spirometer air analyzed. This analysis was repeated at the end of the second collection period. Barometric pressure, room temperature, and exhaust gas wet bulb and dry bulb temperatures were recorded. At the end of the two day gas collection period, the animals were returned to the feedlot.

Specific Gravity Determination

As the animals approached a mean market weight of 461 kg they were slaughtered. Specific gravity of the left fore and hind quarters was determined by a procedure identical to that reported by Schneider (1971). Specific gravity was determined in order to calculate energy gain. The equation used to predict empty body weight (EBW) is given in Table XIII.

Sample Preparation

During the digestion trial, samples of feed, feces, and urine were collected every 24 hours. A week's collection was composited and a representative aliquot was frozen for future analysis. Urine was acidified with 1:3 HCl during collection and storage prior to analysis.

Feces samples were dried at 60 degrees centigrade in a forced air oven and ground through a one mm. screen in a Wiley Mill.

TABLE XIII

PREDICTION OF EMPTY BODY WEIGHT FROM LIVE SHRUNK WEIGHT AND HOT CARCASS WEIGHT

$$Y = 9.03 + 0.942X \pm 3.630$$

Y = Empty body wt., kg

X = Live shrunk wt., kg

$$Y = 19.25 + 1.458X \pm 7.319$$

Y = Empty body wt., kg

X = Hot carcass wt., kg

Analysis of Feed, Feces, Urine

Proximate analysis was determined on all samples of feed and feces, (A.O.A.C., 1960). Gross energy was determined on dried feed and feces samples by combustion in a Parr oxygen bomb adiabatic calorimeter.

Filtered urine samples were dried on powdered cellulose at 60 degrees centigrade in a vacuum oven before being analyzed for gross energy. Nitrogen determinations were made on wet fecal samples and urine samples by the Kjeldahl procedure.

Statistical Analysis

A paired feeding trial was used in this study to eliminate a source of variance that exists from pair to pair. The test criterion was t as expressed in the following equation:

$$t = \frac{\bar{d}}{S_{\bar{d}}}$$

with $$S_{\bar{d}} = \sqrt{\frac{D_j^2 - \frac{(D_j)^2}{n}}{n\,(n-1)}}$$

where $\bar{d}$ is the mean difference between pairs; D_j is the difference between the pairs; and n is the number of pairs of animals. The null hypothesis tested was that the mean of the population of differences was zero, Steel and Torrie (1960). The t-test was used to test for significance in both trials.

In Vitro Study

An *in vitro* zero time rate volatile fatty acid study was conducted to determine the rate of production of VFA in the rumen. This study is reported in Appendix A.

CHAPTER IV

RESULTS AND DISCUSSION

Feedlot Trial

Feedlot Performance

The results of the feedlot trial are given in Table XIV. There were no significant differences ($P > .05$) in average daily gain, average daily feed intake, or the amount of feed required per pound of gain, between whole corn or ground corn rations. There was a tendency for ground corn rations to give slightly higher average daily gains and slightly lower feed efficiencies when the time spent in the digestion and metabolism trials was not subtracted from the total feeding period. Average daily empty body weight (EBW) gain, total feed per kg of EBW gain, and grain per kg of EBW gain, were not significantly different between rations. By subtracting from the total feeding period, the time spent in the digestion and metabolism trials, a more accurate estimate of feedlot performance can be obtained. The results of this are given in Table XV. Average daily gains were slightly but not significantly higher for cattle fed whole corn; however, the amount of feed required per pound of gain was smaller for cattle fed ground corn ($P > .05$). These results are more consistent with work by other researchers feeding rations under feedlot conditions.

TABLE XIV

RESULTS OF FEEDLOT PERFORMANCE (234 Days)

	Whole Corn	Ground Corn	$\bar{d}$[1]	$S_{\bar{d}}$[2]
Number of Steers	6	6		
Initial live shrunk wt., kg	284.49	281.95	2.54	3.20
Final live shrunk wt., kg	453.60	466.66	-13.06	14.93
Average daily gain, kg	0.71	0.77	- 0.06	0.053
Average daily intake, kg (total)	6.01	6.03	- 0.02	0.0013
Average daily intake, kg (grain)	5.04	5.07	- 0.03	0.0250
Total feed/kg gain, kg	16.24	14.54	1.70	1.8178
Grain/kg gain, kg	7.41	6.64	0.77	0.8289
Initial empty body wt., kg	254.04	252.02	2.02	
Final empty body wt., kg	449.12	462.49	-13.37	
Average daily EBW[3] gain, kg	0.82	0.88	- 0.06	0.0754
Total feed/kg EBW gain, kg	13.99	12.69	1.30	1.2581
Grain/kg EBW gain, kg	6.38	5.79	0.59	0.5867

[1] $\bar{d}$ = Mean difference between pairs

[2] $S_{\bar{d}}$ = Standard error of the mean difference

[3] EBW = Empty Body Weight

TABLE XV

AVERAGE DAILY GAIN AND FEED EFFICIENCY FOR THE CORRECTED FEEDING PERIOD

Item	Whole	Ground	$\bar{d}$[1]	$S_{\bar{d}}$[2]
Average Daily Gain, kg	1.09	1.07	.02	.03
Feed/lb. gain, kg	3.16	3.10	.06	.08

[1] $\bar{d}$ = Mean difference between pairs

[2] $S_{\bar{d}}$ = Standard error of the mean difference

A peculiarity noted during the trial was the rapidity with which cattle on whole corn would consume their daily feed. These cattle would consistently consume their ration in one-half the time of the cattle on ground corn. Apparently ground corn had a less desirable physical form and was therefore less palatable. This feeding period was considerably longer than what is generally considered to be a typical feeding trial for cattle of this weight because of the lower average intakes and gains compared to those usually obtained under group fed, ad libitum conditions. In general, it took the animals 30 to 45 days to recover their pre-digestion trial weights upon completion of their digestion and metabolism trials. Moreover, since the cattle were pair fed, feed intake and rate of gain performance of the cattle on the whole corn treatment was limited by the cattle on the ground corn ration. It was most apparent throughout the trial that the ground corn treatment was the intake limiter. Had the cattle not been pair fed, it is possible that the cattle on whole corn would have consumed significantly more feed and gained more rapidly than those on ground corn. Although there were minor bloat problems with both rations, cattle being fed whole corn seemed less subject to digestive disturbances and seldom went off feed.

Carcass Merit

Results are presented in Table XVI. Carcass characteristics and dressing percentages were not significantly different between cattle on whole corn or ground corn rations. Cattle fed ground corn rations tended to have slightly higher carcass merit and dressing percents. These results are in general agreement with Martin *et al.* (1971) and Lofgreen (1971). Woods *et al.* (1971) reported carcass grade and yield values to be similar for cattle fed whole corn and rolled corn.

Energy Balance Trial

Net Energy - Comparative Slaughter Technique

Average body compositions at the beginning and end of the trial are presented in Tables XVII and XVIII. Cattle fed ground corn appeared to gain more fat, 39.55% versus 36.70%, while whole corn appeared to produce slightly more gain in protein, 16.83% versus 16.07%. However, these differences were not significant ($P > .05$).

TABLE XVI

RESULTS OF CARCASS MERIT

Item	Whole Corn	Ground Corn	$\bar{d}$	$S_{\bar{d}}$
Number of Steers	6	6		
Dressing Percentage[1]	62.11	62.39	- .28	.1574
Carcass Grade[2]	8.83	9.00	- .17	.4014
Ribeye area, sq. in.	14.78	16.44	-1.66	.9414
Fat thickness, in.[3]	.61	.48	.13	.1258
Marbling[4]	12.33	12.66	- .33	.8432
Cutability, percent	50.66	51.43	- .77	.7088

[1]Calculated on basis of live shrunk weight and chilled carcass weight.

[2]U.S.D.A. carcass grade converted to following numerical designations:
- High prime - 15
- Average prime - 14
- Low prime - 13
- High choice - 12
- Average choice - 11
- Low choice - 10
- Good - 9
- Average good - 8
- Low good - 7

[3]Average of three measurements determined on tracing at the 12th rib.

Marbling scores: 1 to 30, 11 - slight

14 - small

17 - modest

TABLE XVII

BODY COMPOSITION DATA

Item	Whole Corn	Ground Corn
Initial Empty Body		
Weight, kg	254.04	252.02
Fat %	11.10	11.18
Protein %	19.28	19.27
Water %	65.40	65.32
Final Empty Body		
Weight,kg	449.12	462.49
Fat %	22.03	24.06
Protein %	18.24	17.81
Water %	55.25	53.76

TABLE XVIII

BODY GAIN DATA

Item	Whole	Ground	$\bar{d}$	$S_{\bar{d}}$
Empty Body Gain				
Weight, kg	195.08	210.47	15.39	17.92
Fat, kg	71.60	83.24	11.64	5.16
Fat %	36.70	39.55		
Protein, kg	32.83	33.88	1.00	3.78
Protein %	16.83	16.07		
Water, kg	81.32	83.85	2.53	10.89
Water, %	41.69	39.84		

Net energy values determined by the comparative slaughter method for whole and ground corn rations are summarized in Table XIX. All net energy values tended to be slightly higher for ground corn although none of the differences were significant ($P > .05$). Steers fed ground corn tended to store more fat as indicated by a greater energy retention: 3.64 versus 4.13 Mcal per day on whole versus ground corn. Vance _et al_. (1972) reported NEm and NEg values for whole corn and crimped corn rations fed with increasing levels of corn silage. With no corn silage in the ration, these workers reported NEm values of 2.14 and 2.11 Mcal/kg of ration DM for whole and crimped corn respectively. Values for NEg were 1.58 and 1.53 Mcal/kg of ration DM for whole and crimped corn respectively. At 2.3 kg of corn silage/head/day NEm values of 2.07 and 2.03 and NEg values of 1.43 and 1.33 Mcal/kg/ration DM were reported for whole versus crimped corn, respectively. This level of roughage is similar to that used in this study. Their values are in agreement with those in this study.

TABLE XIX

NET ENERGY CONTENT OF THE RATIONS

Item	Whole Corn	Ground Corn	$\bar{d}$	$S_{\bar{d}}$
Energy retained, Mcal/day	3.64	4.13	-.49	.54
Ration DM Intake, kg/day	6.01	6.03	.02	.03
NEm Mcal/kg Corn DM	1.90	2.19	-.26	.18
NEg Mcal/kg Corn DM	1.27	1.46	-.17	.12

Digestion and Energy Balance Trial

Proximate analysis of the complete rations and digestion coefficients are given in Tables XX and XXI, respectively. Although not statistically significant, ground corn tended to have a higher digestibility of dry matter, organic matter, ether extract and crude fiber. There were no significant differences in the digestibility of nitrogen or nitrogen balance on either ration.

Brown (1966) reported digestion coefficients for dry matter, organic matter and crude protein on corn rations at high levels of intake of 69.26, 70.49 and 68.59%, respectively. In comparing whole and crimped corn rations, containing zero roughage, Vance et al. (1971) reported apparent digestibilities for dry matter, organic matter and protein to be higher for crimped corn: dry matter, 84.2 versus 86.4%, organic matter 85.0 versus 87.1%; and protein 79.1 versus 81.3% for whole and crimped corn, respectively. White et al. (1972) using 96% corn-urea rations , reported digestion coefficients of dry matter-86.6%, NFE-91.4%, crude protein-76.2%, cellulose-35.8% and ether extract-70.4%.

Dry matter intake for animals during digestion trials and gas collections are presented in Table XXII. The results of calorimetric studies on whole corn and ground corn rations are presented in Tables XXIII and XXIV. There was no significant difference between rations for dry matter intake, although steers fed ground corn appeared to consume slightly more feed: 5.44 versus 4.74 kg/day. This increase in intake may account for the slight but nonsignificant increase ($P > .05$) in gross energy and heat production on ground corn. Although not statistically significant, digestion coefficients for dry matter

TABLE XX

PROXIMATE ANALYSIS OF RATIONS*

Item	Whole Corn %	Ground Corn %
Dry Matter	88.37	85.63
Ash	2.76	2.94
Crude Protein	13.00	12.64
Fat	4.69	4.77

*Values are on a DM basis

TABLE XXI

DIGESTION COEFFICIENTS ON COMPONENTS OF CORN RATIONS

Item	Whole Corn	Ground Corn	$\bar{d}$*	$S_{\bar{d}}$**
Number of Steers	6	6		
Dry Matter	80.93	81.97	-1.04	2.27
Organic Matter	81.74	82.68	- .94	2.18
Ether Extract	76.17	77.03		
Crude Fiber	33.14	33.81		
N-free Extract	81.31	80.97		
Nitrogen	78.99	78.37	.63	1.50
N-balance, gm/day	31.49	26.68	-4.82	7.81

*$\bar{d}$ = Mean difference between pairs

**$S_{\bar{d}}$ = Standard error of the mean difference and organic matter were higher for ground corn treatments coinciding with higher digestible and metabolizable energy values per kg of ground corn. There was essentially no difference between rations for the grams of protein or fat gained.

TABLE XXII

AVERAGE DAILY DRY MATTER FEED CONSUMPTION DURING THE DIGESTION TRIAL AND GAS COLLECTION, IN kg

Pairs	Digestion Trial	Gas Collection
W015	9.04	4.48
G032	7.36	7.39
W024	6.53	6.15
G413	6.42	5.07
W023	4.70	5.70
G007	5.55	4.40
W624	6.17	5.19
G411	7.19	5.19
W099	6.46	4.13
G428	5.19	4.89
W1000	6.99	5.67
G092	6.69	5.66

Means	Whole	Ground	$\bar{d}$	$S_{\bar{d}}$
Digestion Trial	6.65	6.40	.25	.44
Gas Collection	4.74	5.43	.69	.84

TABLE XXIII

EFFECTS OF PHYSICAL FORM OF CORN ON ENERGY UTILIZATION IN STEERS

Item	Whole Corn	Ground Corn	$\bar{d}$	$S_{\bar{d}}$
Number of Steers	6	6		
Average Weight, kg	396.0	388.0	8.0	
Metabolic Weight, $W^{.75}$	88.7	87.4	1.3	
Dry Matter Intake, kg/day	4.7	5.4	.3	.7
Energy Intake GE kcal./day	24445.8	24667.2	-221.4	3205.6
Heat Production/$W^{.75}$	91.1	104.5	- 13.3	3.4
Heat Production/kg Feed	1471.0	1670.0	-199.0	128.1
CH_4 As % of GE	2.3	1.8	.4	.5
DE/kg of Ration	2891.1	3068.1	-176.9	175.9
ME/kg of Ration	2710.5	2923.3	- 32.1	205.6
Energy Gain/kg of Ration	1239.9	1253.3	- 13.3	298.7
Grams Protein Gained	123.5	116.5	6.9	63.1
Grams Fat Gained	807.1	837.0	- 29.8	214.0

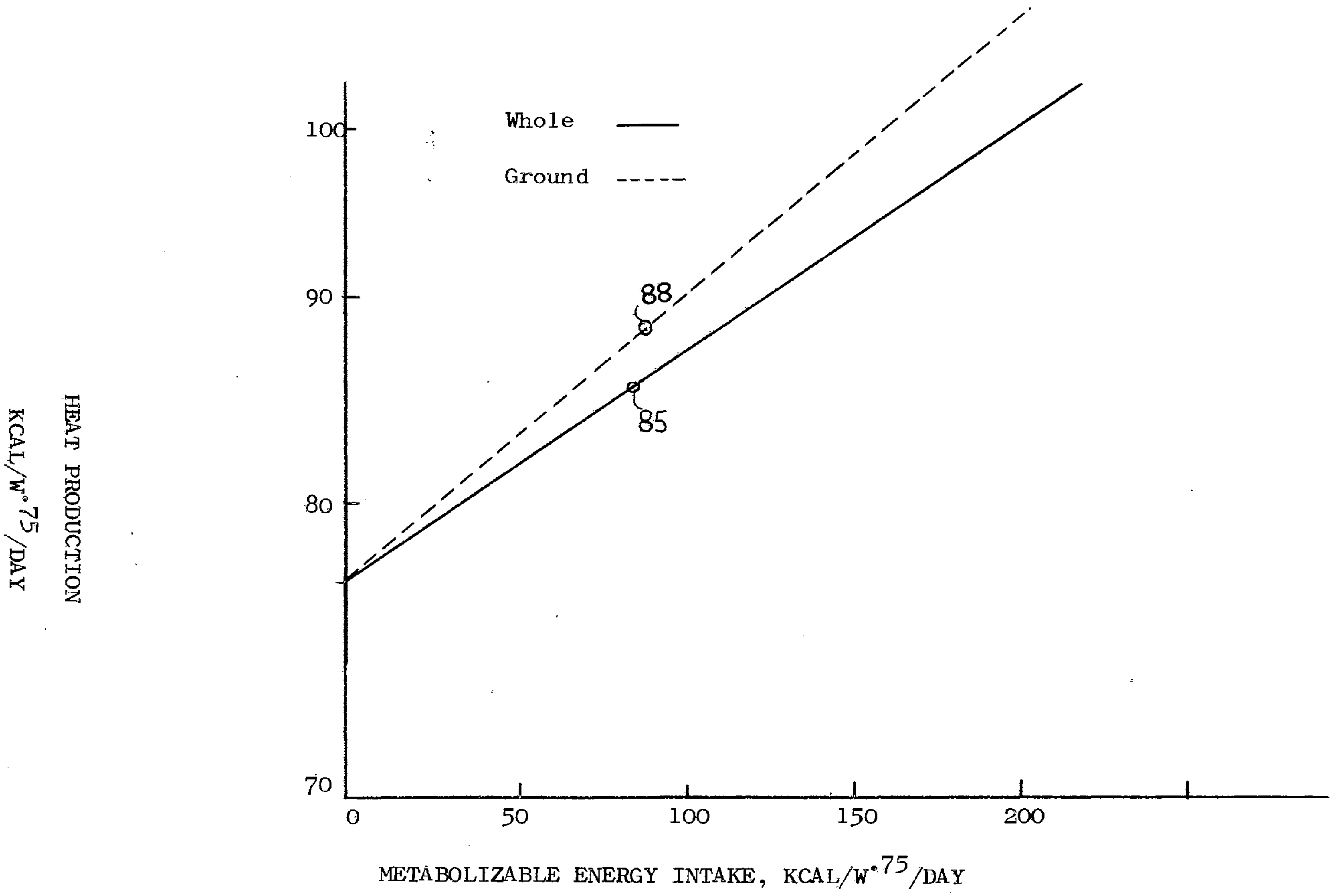

Figure 1. Relationship Between Heat Production and Metabolizable Energy Intake

TABLE XXIV

ENERGY UTILIZATION ON CORN RATIONS

Item	Whole Corn	Ground Corn
Gross Energy kcal/kg	4445.26	4496.40
DE as % of GE	65.04	68.24
ME as % of GE	60.98	65.02
Heat Production as % of GE	23.47	26.34
Energy Retained/kg Feed	1977.33	2056.35
Energy Gain	1667.25	1738.73
ME as % of DE	93.75	95.28
Energy Gain as % of ME	59.36	59.43

Digestible and metabolizable energy values as a percent of gross energy for both treatments appear realistic considering the slight increase in the digestibility of ground corn over whole corn. The National Research Council reports metabolizable energy as a percent of digestible energy value for corn as 85.5%.

As shown in Table XXIV values determined for ME as a percent of DE were 93.75 and 95.28% for whole and ground corn, respectively. These values are somewhat higher than those reported by other workers and NRC. Moe et al. (1966) reported values for ME as a percent of DE for rations of 40, 60, and 80 percent corn-soybean meal mixtures, at intakes of 2.04, 2.18, and 2.01 times maintenance of 85.2, 87.4, and 88.14%, respectively.

Metabolizable energy is plotted against heat production in Figure 1. There are two important portions to the plot: (1) heat production associated with the level of ME intake from zero to energy equilibrium and (2) heat production associated with the 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 (NEm). The difference in energy balance between energy equilibrium and ad libitum gives a measure of net energy value of the feed for production (NEg). In every case energy balance is defined as ME minus heat production.

The procedures used for determining NEm and NEg are shown with average values in Tables XXV, XXVI, XXVII, and XXVIII. The results of these calculations are shown in Table XXIX.

NEm and NEg values are very similar for both treatments. The values in both cases are slightly lower for NEg; however, the magnitude of the difference is not as large as would be expected. Forbes et al. (1930), Kleiber (1961) and Lofgreen and Garrett (1968) proposed that NEm should be higher than NEg. The similarity in NEm and NEg that exists in this study indicates that under controlled conditions such as exists in respiration calorimetry, the efficiency of energy utilization for production on high grain rations may be equal to that for maintenance.

TABLE XXV

CALCULATION OF NET ENERGY FOR MAINTENCE WHOLE CORN RATION

Item	Fasting	Energy Equilibrium
ME Intake (Mcal/$W_{kg}^{.75}$/day)	0	.0850
DM Required (kg/$W_{kg}^{.75}$/day)	0	.0314
Heat Produced (Mcal/$W_{kg}^{.75}$/day)	.077	.0850
Energy Gain (Mcal/$W_{kg}^{.75}$/day)	-.077	.0
Difference (Equilibrium-Fast)		
DM Intake (kg)	.0314	
Energy Gain (Mcal/kg DM)	- .077	
NEm of Ration (Mcal/kg DM)*	2.4522	

*NEm = $\frac{\text{Energy Gain}}{\text{DM Intake}}$

TABLE XXVI

CALCULATION OF NET ENERGY FOR MAINTENANCE GROUND CORN RATION

Item	Fasting	Energy Equilibrium
ME Intake (Mcal/$W_{kg}^{.75}$/day)	0	.0880
DM Required (kg/$W_{kg}^{.75}$/day)	0	.0318
Heat Produced (Mcal/$W_{kg}^{.75}$/day)	.077	.0880
Energy Gain (Mcal/$W_{kg}^{.75}$/day)	-.077	.0
Difference (Equilibrium-Fast)		
DM Intake (kg)	.0301	
Energy Gain (Mcal)	.077	
NEm of Ration (Mcal/kg DM)*	2.5581	

*NEm = $\frac{\text{Energy Gain}}{\text{DM Intake}}$

TABLE XXVII

CALCULATION OF NET ENERGY FOR PRODUCTION WHOLE CORN RATION

Item	Energy Equilibrium	Ad Libitum
DM Intake (kg/$W_{kg}^{.75}$/day)	.0314	.0531
Energy Gain (Mcal/$W_{kg}^{.75}$/day)	.0	.0536
Difference (ad libitum-equilibrium)		
DM Intake (kg)	.0217	
Energy Gain (Mcal)	.0536	
NEp of Ration (Mcal/kg DM)*	2.4200	

$*NEp = \frac{\text{Energy Gain}}{\text{DM Intake}}$

TABLE XXVIII

CALCULATION OF NET ENERGY FOR PRODUCTION GROUND CORN RATION

Item	Energy Equilibrium	Ad Libitum
DM Intake (kg/$W_{kg}^{.75}$/day)	.0308	.0626
Energy Gain (Mcal/$W_{kg}^{.75}$/day)	.0	.0774
Difference (ad libitum - equilibrium)		
DM Intake (kg)	.0318	
Energy Gain (Mcal)	.0774	
NEp of Ration (Mcal/kg DM)*	2.4336	

$*NEp = \frac{\text{Energy Gain}}{\text{DM Intake}}$

TABLE XXIX

SUMMARY OF NET ENERGY VALUES DETERMINED BY RESPIRATION CALORIMETRY

Item	Whole Corn	Ground Corn
	Mcal/kg	
NEm	2.45	2.56
NEp	2.42	2.43

CHAPTER V

SUMMARY AND CONCLUSIONS

Beef cattle feedlot rations containing whole corn or ground corn were compared on the basis of feedlot performance, net energy value using the comparative slaughter technique, respiration calorimetry and volatile fatty acid productions.

There were no significant differences between breeds. The feedlot performance trial showed no significant differences between rations; however, ground corn rations gave a very slight increase in average daily gain, intake, and feed efficiency. There were no significant differences between rations in carcass merit.

The net energy values of corn for maintenance and gain determined by the comparative slaughter technique were as follows: NEm 1.90 and 2.19, NEg 1.29 and 1.46 Mcal/kg DM for whole and ground corn, respectively. Net energy values determined by respiration calorimetry were: NEm 2.45 and 2.50, NEg 2.42 and 2.43 Mcal/kg DM for whole and ground corn, respectively. No significant differences were found in the net energy values between treatments. The comparative slaughter technique appeared to give a more accurate estimate of net energy value. For respiration calorimetry net energy values to be accurate, feed intakes should be equivalent to those obtained under feedlot conditions.

The results of an *in vitro* zero time rate study are presented in Appendix A. There was essentially no difference in the rate of production of volatile fatty acids in steers fed whole corn rations or ground corn rations. There was no significant difference in molar percent or sample composition in ug/ul for acetic, propionic, butyric, isovaleric and valeric acids on whole corn or ground corn rations.

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APPENDIX

IN VITRO, ZERO TIME RATE, VOLATILE FATTY ACID STUDY

In Vitro Technique

Volatile fatty acids produced from microbial fermentation in the rumen represent an important energy source to the animal. Researchers have spent many years trying to quantitate volatile fatty acids in the ruminant. The number of methods available to do this indicate the magnitude of the problem involved. Complicating the situation in the ruminant are factors such as fluctuatious in pH, entry rate of saliva, amount of substrate, removal of substrate, and interconversion of substrate. Absorption of volatile fatty acids depends on their concentration and the pH. Any accurate estimate of the production of VFA's requires that measurements be taken at frequent intervals.

By utilizing an *in vitro* technique, several workers (Stewart, Stewart, and Schultz, 1958; Hungate, Mah and Simeson, 1961), have been able to reduce the amount of variation involved in *in vivo* techniques. The procedure utilized by these workers involves removing a sample of rumen ingesta from the animal and incubating it anaerobically for short periods of time. The rate of production of volatile fatty acids is then estimated by the increase in VFA levels in the sample during the incubation periods. The slope of this curve at zero time is assumed to be the rate of production *in vivo* at the time of removal from the animal. It has been suggested (Carrol and Hungate, 1954), that if anaerobiasis, proper temperature, pH and buffering capacity are properly regulated, short term incubation of rumen contents will simulate normal microbial activities.

el-Shazly *et al.* (1961) demonstrated a parallel response between *in vivo* and *in vitro* VFA production rates up to twelve hours incubation time. Hungate *et al.* (1961) reported manometric estimations of rate of VFA production gave lower results than those obtained by using the zero time rate method.

Other short term *in vitro* methods for measuring rate of fermentation, have been reviewed by Hungate, and include methods utilizing washed cell suspension of bacteria and protozoa and use of whole rumen contents. Manometry, a technique employed with whole rumen contents, serves as a good indication of complete rumen activity. Calorimetry can also be used to estimate rumen activity. The theory involved being that the amount of heat evolved from a sample of whole rumen contents, is directly related to the amount of substrate present, and the quantity of end products formed.

In Vitro Trial

The rate of production of volatile fatty acids was determined by a procedure similar to that of Carroll and Hungate (1954).

Animals

Four very uniform Hereford steer calves weighing approximately 250 kg were fitted with permanent rumen cannulae and placed in metabolism stalls. They were allotted at random to one of two treatments, either a whole corn or ground corn ration. The animals were adapted to the metabolism stalls and their rations over a period of eight weeks. These four steers had been wintered on a dried bermuda grass pasture before being placed on test.

Feeding Regime

Four timed automatic feeders were used to feed the animals. These feeders were designed to dispense a given amount of feed hourly over a twenty-four hour period. The animals adapted to this feeding schedule quickly; however, one animal would occasionally let several feedings accumulate before eating. This only occurred late at night. The animals were fed ad libitum. The mean consumption values for the days on which samples were taken is shown in Table XXX. The mean values for the animals fed whole corn versus animals fed ground corn indicate the animals on the whole corn ration consumed slightly more feed (7.22 kg vs. 6.39 kg).

Rumen Sampling

When the average daily ration consumption was considered maximal, rumen samples were obtained. Two samples were taken daily, one in the morning at approximately 8:00 a.m. and the other at approximately 1:00 p.m. Sampling was accomplished by applying suction from a mechanical suction pump to a polyethylene hose inserted through the fistula. The polyethylene hose was attached to a warmed and CO_2 gased collection flask. Approximately 2000 ml. of ingesta were removed from the animal. The ingesta was thoroughly mixed and transferred to four identical fermentation flasks which had been gased with CO_2 and pre-warmed.

TABLE XXX

FEED CONSUMPTION* ON SAMPLING DAYS

Date	Animal	Consumption kg
6-18-71	A	6.25
7-03-71	A	8.03
6-26-71	D	7.15
7-09-71	D	4.58
8-20-71	B	6.26
8-24-71	B	6.45
8-21-71	C	5.82
8-25-71	C	6.45
	$\overline{x}$	6.37 -whole corn
	$S\overline{x}$	.9279
6-18-71	B	7.78
7-03-71	B	3.33
6-26-71	C	4.36
7-09-71	C	3.08
8-20-71	D	6.41
8-24-71	D	6.57
8-21-71	A	6.03
8-25-71	A	6.22
	$\overline{x}$	5.47 -ground corn
	$S\overline{x}$	.9279

* Dry Matter Basis

In Vitro Procedure

Zero time samples were taken before the four fermentation flasks were incubated. Incubation of the flasks was accomplished by emersion in a water bath maintained at 39°C.

The subsample microbial activity was terminated by the addition of five drops of a saturated solution of mercuric chloride. The subsamples were centrifuged for ten minutes at 10,000 revolutions per minute. The supernate was removed and frozen for future gas-liquid chromatographic analysis.

Chromatographic Analysis

Two milliliters of rumen fluid supernate were mixed with 0.4 ml. of a solution of 25 percent metaphosphoric acid with 2.0772 mg/ml of 2-ethyl-butyric acid, and retained in an ice bath for 30 minutes. The samples were then centrifuged at 10,000 revolutions per minute for 10 minutes. Samples of one-half ul were injected directly into a six-foot u-shaped column of SP-1200. The chromatograph, detector, and operating procedure was previously reported by Hinman (1971).

In Vitro Zero Time Rate VFA Study

Results of the zero time rate *in vitro* volatile fatty acid study are given in Figures 2 and 3. Total volatile fatty acids expressed in uM/ML are plotted against time for each ration. Samples taken in the morning are compared to samples taken in the afternoon. On both rations, concentrations for the morning samples are lower than the afternoon samples. The only explanation offered for this is that water was unavailable to the animal after the morning sample was taken.

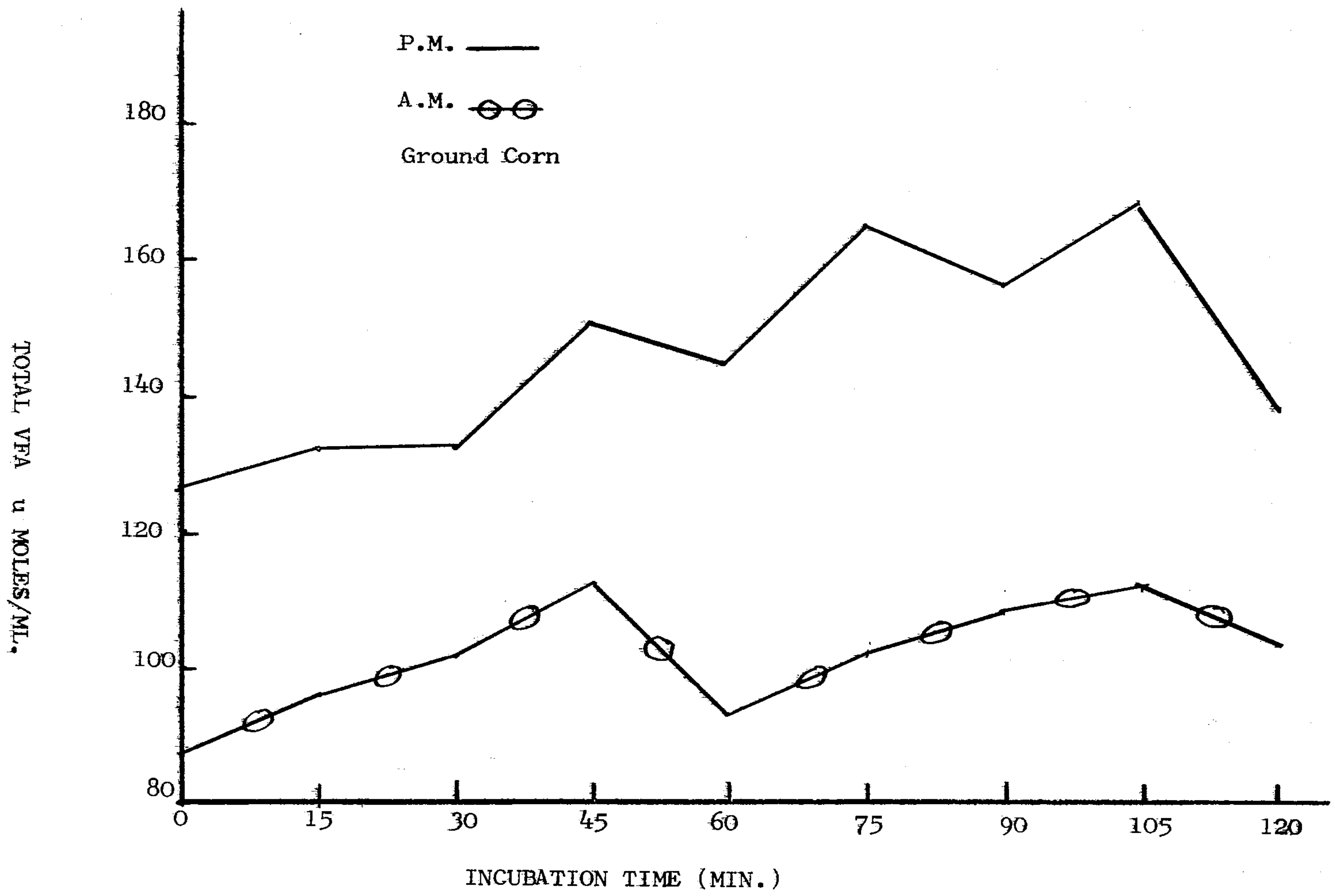

Figure 2. Concentration of Total VFA Over Incubation Period for Ground Corn Ration

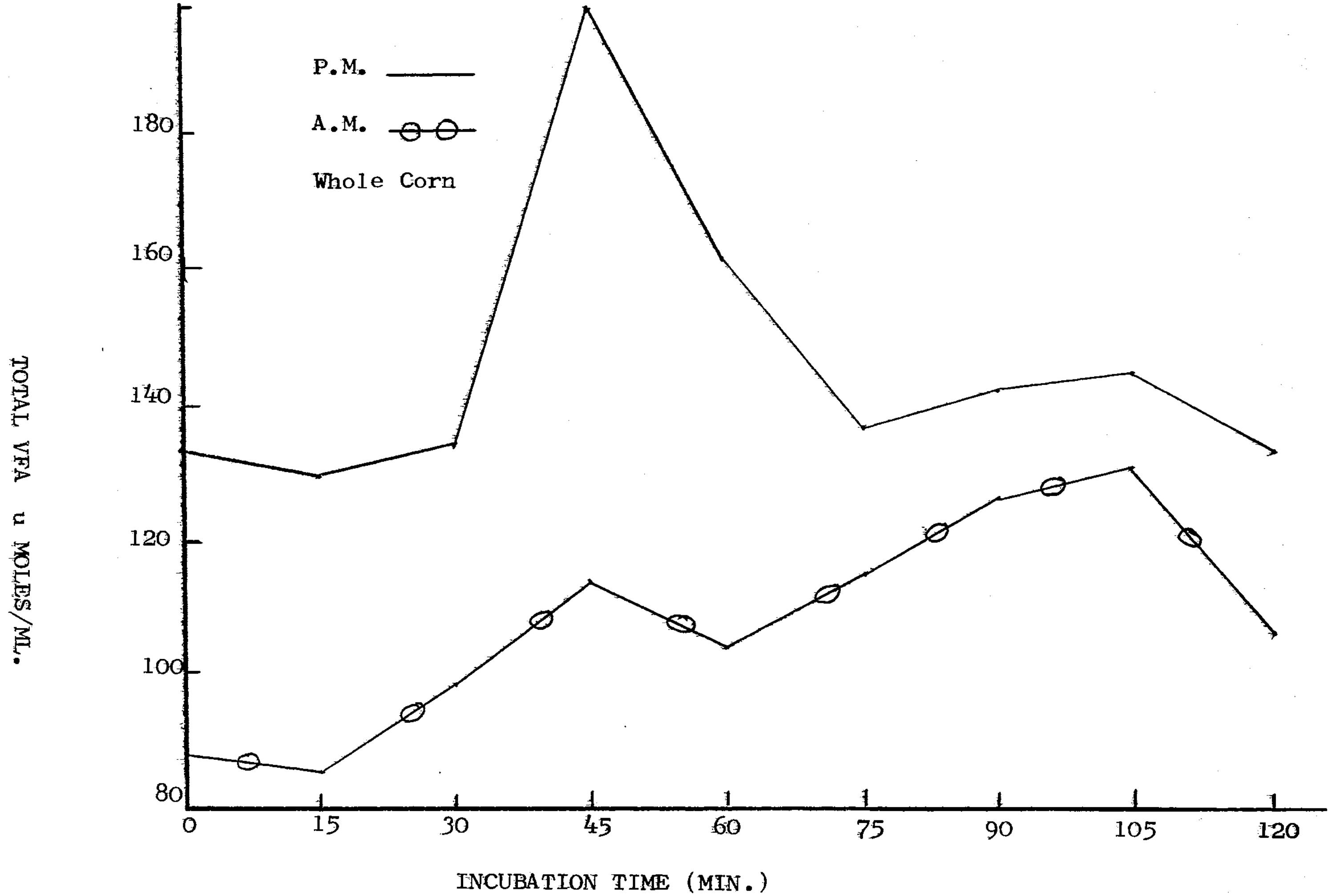

Figure 3. Concentration of Total VFA Over Incubation Period for Whole Corn Ration

No explanation is offered for the decline in total VFA on the whole corn ration during the first 15 minutes of incubation, or the decrease in concentration between 45 and 75 minutes incubation. Lower values for samples taken at 120 minutes are explainable, assuming there was insufficient ingesta in the incubation flask at 120 minutes to give a representative sample.

Figure 4 was constructed using only incubation times of zero and 120 minutes, for both rations and two different sampling times. From these data based only on the slope of the line connecting zero incubation time with 120 minutes, whole corn shows a slightly increased rate of production in the morning; however, ground corn shows a slightly greater rate of production during the afternoon. These differences, however, were not significant ($P > .05$).

The analysis of samples taken at zero time and the mean concentration of individual acids can be found in Tables XXXI, XXXII, and XXXIII.

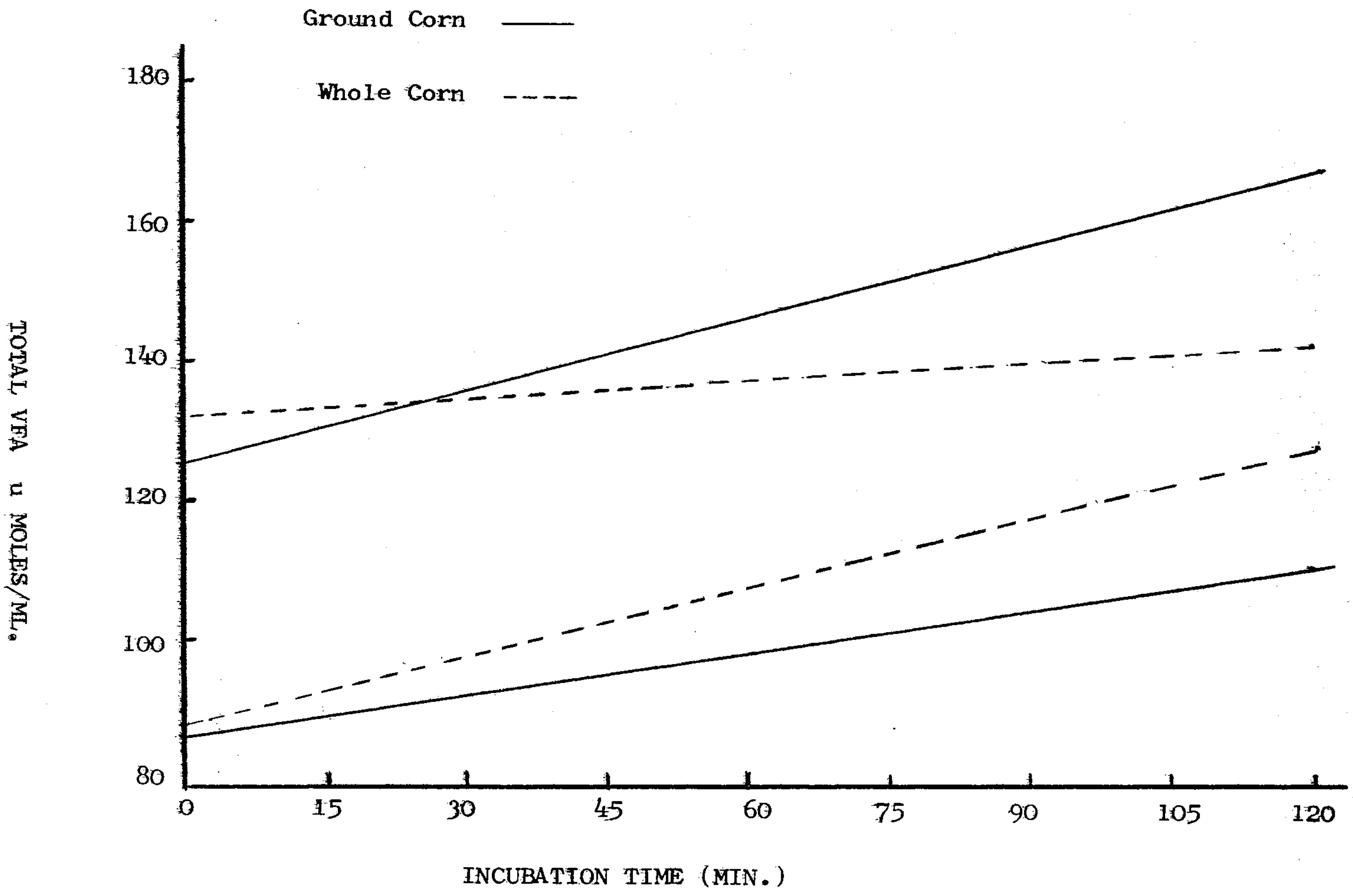

Figure 4. Concentration of Total VFA at Zero Time and 120 Minutes, Only.

TABLE XXXI

MOLAR PERCENT - ZERO TIME SAMPLES

Item	Whole Corn	Ground Corn
	Molar %	
Acetic Acid	43.33	39.22
Propionic Acid	38.78	39.83
Butyric Acid	12.10	16.75
Isovaleric Acid	2.79	1.20
Valeric Acid	2.99	2.99

TABLE XXXII

SAMPLE COMPOSITION*- ZERO TIME SAMPLES

Item	Whole Corn	Ground Corn
	ug/ul	
Acetic Acid	49.74	45.04
Propionic Acid	41.01	44.32
Butyric Acid	13.97	12.88
Isovaleric Acid	3.88	1.20
Valeric Acid	2.60	2.89

* ug/ul

TABLE XXXIII

MEAN CONCENTRATIONS FOR INDIVIDUAL ACIDS AVERAGED OVER 120 MINUTES INCUBATION TIME

Item	Whole Corn	Ground Corn
	ug/ul	
Acetic Acid	56.2	48.7
Propionic Acid	47.0	52.4
Butyric Acid	16.0	16.1
Isovaleric Acid	3.9	1.6
Valeric Acid	3.2	3.9

VITA

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Master of Science

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