IN VIVO AND *IN VITRO* EVALUATION OF HIGH MOISTURE PROCESSING OF MILO AND MILO-WHEAT COMBINATIONS

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INTRODUCTION

In recent years there has been a tremendous increase in size and number of major cattle feeding operations in Oklahoma as well as elsewhere in the Southwest. This rapid growth of feedlot operations has resulted in an ever-increasing demand for feed grains.

Since many fattening rations today contain in excess of 80% grain, any improvement in the feeding value of grains would be of great benefit to the cattle industry. Milo is the most widely used feed grain in the Southwest. Recently, there has also been an increased interest in the use of wheat in feedlot rations due to its decreasing market value and ready availability.

Chemical composition of milo indicates that it has potential energy comparable to other cereal grains. Milo, however, is not as efficiently utilized as corn or wheat by feedlot cattle. Previous research indicates that the feeding value of milo can be improved by high moisture harvesting and reconstitution. This moist fermentation of milo apparently alters the chemical and physical structure of the grain to a form cattle can more readily utilize.

Recent research has also indicated replacement of a portion of the milo with wheat in high energy rations results in a more efficient utilization of both grains. There have been no reports, however, on the value of moist wheat in fattening rations.

The purpose of this study, therefore, was to evaluate several high moisture methods of processing milo and milo-wheat combinations. The processing methods were evaluated by feedlot performance, carcass merit, net energy, and *in vitro* digestibilities.

CHAPTER II

LITERATURE REVIEW

High Moisture Harvested Grain

It was reported as early as 1904 by Kennedy et al. that corn containing 35% moisture compared favorably with mature corn for fattening cattle. Thornton et al. (1966) reported that corn could be physiologically mature when it contained 30 or 40% moisture. As nutritive value of early harvested grain is at least equal and possibly superior to dry grain, storage and physical form of the moist grain are the major concerns of the cattle feeder.

Bechtel et al. (1942) used burlap lined pit silos for the storage of corn and sorghum which had been harvested "wet" due to early frosts. The grain was ensiled in this manner as a means of preventing spoilage and not in any attempt to improve efficiency. Current high moisture harvesting on the otherhand, is done in an attempt to increase efficiency as well as reduce field losses.

Corn

Beeson et al. (1957, 1958) found that cattle fed high moisture (32% moisture) ground ear corn which had been stored in glass lined silos gained essentially the same as those fed dry ground corn. However, the high moisture ear corn produced a 12 to 15% saving in total feed. Culbertson et al. (1957) likewise reported similar savings in feed with no significant reduction in gain when cattle were fed high moisture ear corn.

Attempts to increase the feeding value of shelled corn by high moisture harvesting have not been as successful as those when the ground ear corn was utilized. Mohrman et al. (1958) reported no significant differences in any of the digestion coefficients when corn harvested at 14.5% moisture was compared to corn harvested at 25, 30 and 35% moisture, respectively. Heuberger et al. (1959) conducted three experiments to compare field shelled corn stored in concrete stave silos at moisture contents of 24, 29 and 36% with dry shelled corn (14.5% moisture). Feed intake and daily gain were similar for all treatments, except 36% moisture corn. The 36% moisture corn produced significantly lower gains as well as less efficient gains than the other treatments. Perry et al. (1959, 1960) reported no advantage for high moisture harvesting shelled corn. The high moisture corn produced slightly lower gains and feed efficiency than dry shelled corn from the same source. This was due to the fact that although the cattle eating moist corn consumed less, they also showed a lower average daily gain. Martin et al. (1970), however, reported that steers fed high moisture harvested shelled corn not only gained faster, but required .95 and 1.43 lb. less feed per lb. of gain than dry shelled corn and high moisture harvested ear corn fed cattle, respectively.

Milo

Riggs et al. (1959) compared two forms of early harvested (23% moisture) milo with dry ground milo in approximately 50% grain rations. When moist ensiled grain was fed whole, it failed to produce satisfactory gain or finish on yearling steers during a 126 day feeding trial. Steers fed moist ground milo required 331 lb. less grain per 100 lb. of gain than similar steers fed whole moist milo. Ground moist grain produced gains equal to dry ground grain. Steers fed the ground moist grain required 18% less dry matter from grain and 12% less total dry matter than steers fed dry ground milo. Brethour and Duitsman (1961, 1962) found that milo harvested from 27 to 40% moisture, stored in concrete lined pits and sealed with 6mm plastic, produced more efficient gains than dry milo, regardless of whether the grain was ground prior to or after ensiling. Gains were similar for all treatments, but a 8 to 9% improvement in feed efficiency was observed in cattle receiving moist grain treatments. Brethour and Duitsman (1963) compared high moisture harvested milo with finely ground and coarsely rolled milo from the same source. The high moisture grain was ensiled at two different moisture levels (27% and 36%). Both high moisture levels were ground prior to ensiling in trench silos. Less dry matter was required per unit of gain with 36% moisture harvested milo than with 27% moisture milo. Both moist grains required less feed per lb. of gain than the dry forms. Daily gains and feed conversion ratios for 36% moisture, 27% moisture, finely ground and coarsely rolled milo were: 2.78, 5.44; 2.78, 5.85; 2.73, 6.43; and 3.03, 6.51, respectively.

Franke _et al._ (1960) found that sorghum grain harvested at 31% moisture, stored whole in glass lined silos and ground prior to feeding produced more efficient gains in steers during a 140 day feeding period than did dry ground grain from the same source. The groups fed dry sorghum gained 1.97 lb./day and were 17.6 percent less efficient than groups fed moist grain which gained 1.95 lb./day. No significant differences in carcass grades and dressing percentage were noted.

Neuhaus (1968) conducted *in vitro* studies to determine the effect of length of storage time, moisture level, and temperature on digestibilities of high moisture harvested grain. Moisture levels of 13, 17, 22, 26, 30 and 36 percent, temperatures of 40, 75 and 110 degrees Fahrenheit, and storage periods of 10, 20 and 30 days were studied in a three factor factorial design. All treatments were stored whole and ground prior to *in vitro* digestion. No significant difference in length of time stored was found, but interaction was found between time and moisture. It was suggested that increased moisture was required to maintain or increase starch availability with increased time. Data showed time and temperature to be independent. Temperature had a significant effect in that it seemed detrimental at low moisture levels (below 26%) and beneficial at high levels. It was suggested, therefore, that higher moisture grains (above 26%) may be more efficiently utilized if stored anaerobically in the summer months. Moisture had a significant effect on dry matter disappearance. Dry matter disappearance increased only slightly at 17 and 22% moisture levels compared to 13% moisture grain, but there was a substantial increase in digestion occurring between 22 and 26% moisture at all time and temperature levels. The highest dry matter disappearance occurred at 35% which also suggests that *in vitro* digestibility increases as moisture content of grain increases.

Riggs *et al*. (1963) ensiled sorghum grain heads which contained 37% moisture and 70% grain which contained 31% moisture. When this form of high moisture grain was fed in fattening rations, it produced gains equivalent to rations containing milo which was 23% moisture, harvested by combine, and ground after oxygen free storage.

Wagner et al. (1970) reported higher gains on fattening cattle receiving high moisture head chop cut and ensiled similar to that described by Riggs et al. (1963) when compared to dry rolled milo containing rations. Steers averaged 2.56 lb. of gain/day on head chop compared to 2.19 lb. of gain/day on rations containing dry rolled milo harvested from the same field. It is difficult to compare efficiencies of head chop sorghum with dry sorghum grain, however, due to different fiber levels of the rations, as well as different supplementation requirements.

Reconstituted Grain

By the mid 1960's it had been fairly well established that certain forms of high moisture harvested milo and corn were more efficient than the dry processed grain. Grains were then reconstituted in an effort to duplicate the chemical and physical properties of the high moisture harvested grain which make it more efficient than the dry form.

Milo

Buchanan-Smith et al. (1968) conducted digestion trials with 12 steers and 12 wethers in which they compared coarse ground, fine ground, steam processed and rolled and reconstituted sorghum grain all from one source. All diets contained 78.26% and 21.74% milo and protein-mineral-vitamin supplement, respectively. The high moisture form of grain was prepared by bringing moisture content up to 25.5% and storing anaerobically for three weeks prior to rolling.

As shown in Table I digestibility of the high moisture form of grain was higher for all components for cattle than any other treatment

TABLE I

DIGESTION COEFFICIENTS OBTAINED FOR SORGHUM GRAIN FED TO CATTLE AND SHEEP AS REPORTED BY BUCHANAN-SMITH ET AL. (1968)

	Cattle				Sheep			
	Treatment Groups							
Item	Coarse Grind	Fine Grind	Steam Processed & Rolled	Reconstituted & Rolled	Coarse Grind	Fine Grind	Steam Processed & Rolled	Reconstituted & Rolled
Dry Matter	76.0[a]	75.7[a]	79.9[a,b]	81.6[b]	80.8	80.4	79.8	81.7
Organic Matter	77.0[a]	76.7[a]	81.6[a,b]	82.8[b]	82.0	81.8	81.3	83.0
Nonprotein Organic Matter	79.1[a]	79.1[a]	84.7[b]	85.2[b]	83.8	83.8	84.2	85.0
Nitrogen	66.4	64.7	65.6	71.0	73.1[c]	71.6[c]	66.8[d]	73.2[c]
Starch	91.3	91.9	94.3	94.6	92.6	92.8	93.7	93.0
Starch and reducing sugars	89.8[a]	90.6[a,b]	94.1[b]	94.5[b]	92.5	92.6	93.6	93.0

[a,b]Values for cattle on the same line bearing different subscripts differ significantly ($P < .05$).

[c,d]Values for sheep on the same line bearing different subscripts differ significantly ($P < .01$).

and significantly higher than both dry forms for dry matter, organic matter and non-protein organic matter digestibilities. The moist grain also was significantly higher in starch and reducing sugar digestibility than the coarse ground form when fed to cattle. These results are in agreement with work done by McGinty _et al_. (1967) in which a 17% increase in digestibility was noted for all components except protein, which showed 22% improvement.

Neuhaus (1968) conducted an _in vitro_ study to determine the effect of moisture, temperature and length of storage on reconstituted ensiled milo, using a three factor factorial design. The following factors were studied: moisture levels of 15, 18, 23, 26, 30 and 34%; temperatures of 40, 75 and 110 degrees Fahrenheit; and lengths of oxygen free storage of 10, 20 and 30 days. All treatments were stored in both whole and ground forms prior to the _in vitro_ study. Analysis of moisture levels showed moisture had a significant effect on percentage of dry matter disappearance. Dry matter disappearance was not greatly increased by reconstituting the grain to 18 or 23% moisture, however, there was a substantial increase (approximately 4%) when moisture level was increased to 26% and further increases at the 30 and 34% moisture levels, indicating maximum utilization at the highest moisture levels studied. Time had a significant effect on dry matter disappearance. All samples tested had higher dry matter disappearance at 20 days than at 10. Additional time after reconstitution beyond 20 days (30 days) increased dry matter digestibility only at moisture levels of 30% and above, suggesting moisture time interaction. Dry grain reconstituted to 30% improved 11.1% in dry matter disappearance after 10 days oxygen free storage; whereas it only improved 3.7% during the following 20 days. Temperature significantly effected dry matter disappearance. Analysis showed a temperature-moisture interaction as grain containing 15, 18 and 23% moisture was affected very little by temperature during storage, while those containing 26% moisture or more showed a considerable increase in dry matter disappearance with each increase in temperature.

Feeding trials by Parrett et al. (1966) comparing high moisture harvested (28% moisture) milo, dry milo reconstituted to 29.72% moisture, and dry milo, showed no significant difference in daily gain, however, cattle fed reconstituted grain were 15% more efficient than those fed dry ground milo and only 2% less efficient than those fed the high moisture harvested milo. McGinty et al. (1967) summarized seven feeding trials in which dry milo was compared to either early harvested or reconstituted milo. Early harvested grain fed cattle on the average required approximately 22% less grain and 11.5% less total dry matter per kg. of gain; whereas reconstituted grain fed cattle were approximately 15.5% more efficient on grain consumption and 11.5% more efficient on total dry matter consumed. McGinty suggested that the improved efficiencies of the high moisture forms of milo were due to an alteration in protein structure and/or the starch molecule to such an extent that it is more readily fermented by the rumen micro-organism or more highly digested in the small intestine.

Brethour et al. (1970) compared dry rolled milo, high moisture harvested (30% moisture) milo and reconstituted (30% moisture) milo. Both high moisture forms of the grain were rolled prior to ensiling in cement lined trench silos. When fed to yearling steers, average daily gains and lb. of feed/lb. gain were: 2.77, 9.25; 3.09, 8.31; and 3.18, 7.90 for the dry rolled, high moisture harvested and reconstituted milo, respectively. This improved utilization of milo ensiled after the kernel was broken is contrary to previous findings by Texas and Oklahoma workers in which little or no improvement in feed utilization was obtained from reconstituted milo that was not ensiled in the whole form.

McGinty et al. (1968) compared reconstituted milo which was ground prior to adding water and oxygen free storage for 30 days, reconstituted milo which was ground after 30 days of oxygen free storage and dry milo. Cattle fed the post-ground reconstituted milo required 13 and 18 percent less dry matter/kg. gain than the dry ground and pre-ground reconstituted milo fed cattle, respectively. Penic et al. (1968) reported similar results when 48 hd. of yearling steers were divided into 3 groups and fed a ration containing 91% milo in one of the following forms: dry ground 10% moisture, reconstituted whole with 30% moisture, stored oxygen free for 21 days and ground prior to feeding, or ground milo which was reconstituted to 30% moisture and then stored oxygen free for 21 days. There were no significant differences in gains or carcass data, however, reconstituted whole milo was 11% more efficient than dry ground milo, and no significant difference in efficiency was noted in the ground reconstituted milo when compared to the dry ground control. Schake et al. (1969) using 450 cattle in commercial lots compared pre- and post-rolled reconstituted milo (30% moisture) along with steam flaked milo and reported the following feed per lb. of gain ratios: 7.08, 6.42 and 6.70, for steamed flaked, whole reconstituted rolled and rolled reconstituted milo, respectively.

White et al. (1969) compared the following three milo processing methods: (1) fine ground dry milo, (2) reconstituted whole milo, followed by storage for 21 days, ground before feeding (reconstituted ground) and (3) ground dry milo followed by reconstitution and storage for 21 days before feeding (ground-reconstituted). Average daily intake of calves fed the respective treatments was not significantly different. However, a 9% increase in feed efficiency for reconstituted-ground milo fed cattle over those fed dry rolled milo was noted, while a 3.5% decrease in feed efficiency was observed in cattle fed milo ground prior to reconstitution.

In vitro fermentation data reported by Neuhaus (1968) coincides with Texas and Oklahoma feeding trials. It was reported that there was little or no increase in dry matter disappearance for grain ground prior to reconstitution and oxygen free storage when compared to dry ground milo. This was in contrast to substantial increases of dry matter disappearance when reconstituted grain ground after storage was compared to the same control. Martin *et al*. (1970) found, however, that whole milo that was soaked for three days (allowing considerable sprouting to occur) and ground prior to ensiling, resulted in approximately 1.7 lb. less feed required per lb. of gain in fattening cattle than milo which was ensiled immediately after grinding and reconstitution.

Oklahoma research indicates that method of breaking the milo kernel after reconstituting and storing also effects the utilization of the grain. Totusek *et al*. (1967) found that reconstituted milo which was rolled or steam rolled prior to feeding produced significantly better feed conversion than coarsely rolled milo. Reconstituted steam rolled milo was 11.9% more efficiently utilized than coarsely rolled milo, while conventionally rolled reconstituted milo was 8.2% more efficient than the dry rolled grain. Newsom *et al*. (1968) reported from the same station that steers fed reconstituted rolled milo gained essentially the same as those eating the same moist milo ground. Steers fed reconstituted rolled milo, however, consumed significantly less total feed than reconstituted ground milo fed cattle. When the conversion ratios for the reconstituted treatments are compared to dry coarsely ground milo, a 5% and 14% improvement was noted for reconstituted ground and reconstituted rolled milo, respectively. White et al. (1969) reported that cattle fed reconstituted rolled milo needed only 5.92 lb. of feed to produce a lb. of gain, while those receiving reconstituted ground milo consumed 6.60 lb. of feed for every lb. of gain.

Storage facilities for reconstituted grain represent a substantial investment by the cattle feeder. Therefore, minimum storage time and consequently maximum utilization of these facilities is necessary. Researchers in Texas and Oklahoma have conducted laboratory, as well as feedlot experiments in an effort to determine minimum storage time necessary.

Neuhaus (1968) reported that of the 15% increase in dry matter disappearance of reconstituted milo over the dry form in in vitro fermentations, 6% occurred in the first day of oxygen free storage. Pantin et al. (1969) conducted a digestibility study in which grains reconstituted to 28% moisture were stored for either 10 days or 20 days. It was reported that although somewhat higher coefficients of digestibility were noted for milo stored 20 days, the difference was nonsignificant. McGinty et al. (1968) had previously reported similar findings in a feeding trial. It was found that heifers fed reconstituted milo which was ground after 10 and 20 days, respectively, did not perform significantly different. Feed conversion ratios were 5.21 and 5.10 for milo stored 10 days and 20 days, respectively.

Ely _et al_. (1967) reported from Kansas that milo which was merely soaked 24 hr. prior to feeding reduced gains, but did not significantly alter feed efficiency when compared to dry rolled milo. White (1969) reported similar results on milo which was soaked for approximately 10 hr. and then stored for one day prior to rolling and feeding. The soaked grain did not produce any significant differences in performance of fattening heifers when compared to dry rolled milo. These results would indicate more than one day of anaerobic storage is required to alter the composition of milo to a more utilizable form.

Corn

Attempts to increase the feeding value of shelled corn by reconstitution have been less successful than those with reconstituted milo. Larson _et al_. (1966) compared dry shelled corn and reconstituted high moisture corn (28% moisture) which was stored in air tight silos for 23 days. Each type of corn was rolled prior to feeding. It was reported that both average daily gain and feed conversion for the moist and dry forms were not significantly different. Matsushima and Stenquist (1967) reported that as the moisture in shelled corn is increased, daily consumption and rate of gain decrease. Ground shelled corn reconstituted to 30% just prior to feeding was compared to the dry form. The moist grain produced an average of 0.24 lb. less gain per day, and required 0.7 lb. more feed/lb. of gain.

Henderson and Bergen (1970), on the otherhand, reported favorable results from high moisture forms of corn. Using 96 head of steers the following treatments were compared: (1) 20% ground hay - 80% rolled, dry, shelled corn; (2) 20% ground hay - 80% rolled, high moisture (33%)

harvested, shelled corn; (3) an ensiled mixture of direct cut alfalfa and 80% ground, dry, shelled corn. The hay-dry corn fed steers gained 4% faster but required 13% more feed to produce a lb. of gain than the ensiled mixture fed group. Gain and feed efficiency differences were not significantly different between ensiled mixture and high moisture harvested corn fed groups. One must keep in mind, however, that part or all of the improvement in the ensiled mixture may have been due to the fact that a different form of forage was also utilized.

Wheat

Although at least one commercial feedlot has utilized rations containing reconstituted wheat, no published data on the subject is available at this time. Kansas and Oklahoma researchers, however, have reported on the value of wheat as a replacement for sorghum grain in high energy rations.

Brethour (1966) reported on a feeding trial in which steers were used to evaluate wheat in fattening rations. The rolled grain portion of the three rations evaluated consisted of 100% milo, 100% wheat or a 50:50 ratio of milo and wheat. Average daily grain intake and lb. grain/lb. of gain were: 18.1, 5.40; 16.6, 4.76; and 14.3, 4.53, respectively for the milo, mixed and wheat rations. Although feed efficiency was noticeably better in both wheat rations, it was noted that cattle receiving wheat as the only grain scoured frequently and were difficult to keep on feed. In a subsequent trial, Brethour (1966) used the same 3 types of rations plus a 50:50 wheat-milo treatment and a 100% milo treatment both of which were fed without protein supplement. These additional treatments were added to determine the protein value of the wheat. Results were similar to the previous trial. The feeding of wheat as the only grain again resulted in reduced intake and slower gains. Protein supplementation was satisfactorily omitted from the wheat-milo ration, but daily gain was reduced $\frac{1}{4}$ of a lb. when protein supplement was omitted from the sorghum grain ration. Therefore, it was suggested that wheat may be used as a protein supplement replacement in fattening rations.

Totusek et al. (1968) conducted a feeding experiment in which steam rolled wheat, wheat-milo and milo rations were compared. Steer calves were randomly allotted into three groups, receiving 100% milo, equal parts of milo and wheat and 100% wheat, respectively as the grain portion of their ration. Although slight differences were noted, gains and feed conversions favored milo, followed by wheat and the combination of the two. These respective values were: 2.25, 6.65; 2.07, 6.96; 2.05, 7.08. When rumen samples which were obtained for each treatment were analyzed, no significant difference for total or individual volatile fatty acids were noted.

Richardson et al. (1967) compared the following combinations of wheat and milo in fattening rations: all milo, 75% milo and 25% wheat, 50% milo and 50% wheat, 75% wheat and 25% milo and 100% wheat. All grain combinations were fed free choice while roughage was fed at the rate of 4 lb./hd./day. Average daily gains were similar for all treatments. Average daily grain consumption and feed conversion ratios were: 17.8, 6.26; 17.6, 6.26; 16.1, 5.81; 14.0, 5.18; and 14.4, 5.48, respectively as milo was decreased from 100% to 0% of the grain fed. As stated above, average daily gain was maintained while grain consumption was reduced in rations containing 50% and 75% wheat. This data also suggests, however, that wheat is not as efficiently utilized by itself as when mixed with sorghum grain in fattening rations.

In Vitro

Several in vitro cellulose or dry matter digestion techniques using mixed cultures of rumen bacteria have been utilized in the evaluation of forages as reported by Tilley and Terry (1963), Johnson (1966) and numerous others. Use of such techniques, however, has been somewhat limited in evaluating high energy mixed rations or various processed grains.

Albin et al. (1966) compared digestibility of all concentrate rations in vitro with the performance of feedlot steers receiving the same rations. The technique utilized both whole rumen fluid and resuspended bacterial cells as the inoculum. Samples were placed in 50 ml. test tubes and incubated at 39°C for 24 hr. Criteria for detecting differences in the rate of fermentation of various rations were digestion of dry matter, ether extract, starch and gross energy. When in vitro data was compared to in vivo data the most consistent correlation coefficients were between in vitro percent digestible dry matter and daily feedlot gain ($r = 0.88$), and in vitro percent digestible dry matter and feedlot efficiency of feed utilization ($r = 0.99$).

Kumeno et al. (1967) used an in vitro procedure to evaluate rations containing concentrates in varying proportions up to 75% of the total. The technique involved the use of 0.75 grams of substrate per 50 ml. fermentation medium. Dry matter disappearance and acid production were the parameters measured. These in vitro trials were run simultaneously with in vivo evaluations utilizing twelve sheep. The correlation coefficient for the resulting *in vitro* dry matter disappearances and *in vivo* digestibility data (r = 0.85) is highly significant ($P < .01$).

Klett and Ralson (1967) compared nylon bag (NB) *in vitro* (strained rumen juice) and *in vivo* digestion techniques using rations consisting of various ratios of alfalfa and steam rolled barley (4:0, 3:1, 2:2, 1:3, 0:4). When the means across rations were pooled, no significant differences were found among 48 hr. fermentations with the NB, 24 hr. fermentations *in vitro* and *in vivo* dry matter disappearances. *In vitro* dry matter disappearances at 12 and 24 hr. were significantly correlated with *in vivo* digestion of ether extract, energy, dry matter, cellulose and crude fiber. When *in vitro* dry matter disappearance was used to predict actual *in vivo* dry matter disappearance of several reference substrates, the differences between the actual and predicted dry matter disappearances were non-significant.

Neuhaus (1967) demonstrated that a definite relationship existed between *in vitro* fermentation digestibilities of processed grains and feed efficiency of feedlot cattle receiving the same grains in high concentrate rations, although no correlations were calculated due to lack of numbers.

Trei *et al*. (1969) described an *in vitro* system employing gas production by rumen micro-organisms to evaluate processed grains. A mixed suspension of rumen micro-organisms was used as a source of inoculum and calibrated manometric tubes were used to measure gas production. High correlations were found between gas production and dry matter disappearance (r = 0.95), volatile fatty acid production, and *in vitro* starch digestion.

CHAPTER III

MATERIALS AND METHODS

General

One cattle feeding trial and three *in vitro* experiments were conducted to determine the effect of high moisture processing on milo and milo-wheat combinations. Evaluation of the processing methods was based on feedlot performance, carcass merit, net energy, and *in vitro* fermentation digestibilities. The *in vivo* feeding trial will be referred to as Trial I, and the *in vitro* experiments will be denoted as Experiments I, II and III, respectively.

In Vivo - Trial I

Forty choice Angus and ten choice Angus-Hereford crossbred heifers were started on trial June 27, 1969 to compare five types of processed milo in a high-concentrate ration. The initial average weight of the heifers was 200.5 kg.

At the beginning of a three week preliminary period, the animals were vaccinated for IBR, blackleg-malignant edema, leptospirosis and parainfluenza. Stilbestrol was implanted at the 12 mg. level prior to placing animals on the experimental rations.

The feeding trial was conducted at the Oklahoma State University campus where animals had access to an open-sided shed, outside lot and automatic waterers.

Allotment

A complete randomized block design was utilized. The experimental design is shown in Table II.

TABLE II

TRIAL I: EXPERIMENTAL DESIGN SHOWING NUMBER OF ANIMALS PER TREATMENT

	Processed Milo					
Blocks	Dry Roll	Recon. 5 days	Recon. 10 days	Recon. 20 days	Steeped	Total Number
1	5	5	5	5	5	25
2	5	5	5	5	5	25
	10	10	10	10	10	50

Each treatment included two pens of four Angus heifers and one crossbred heifer. The heifers were blocked independently on weight and randomly allotted forming one light-weight and one heavy-weight pen for each treatment.

Feeding

The five types of processed milo were fed in a 90% concentrate mixture. The non-milo ingredients in the ration were combined into a premix. The composition of the premix and complete ration is shown in

Table III. The proximate analyses of the premix and the processed milo are shown in Table IV.

TABLE III

TRIAL I: RATION COMPOSITION

Ingredient	Percent
Milo	84.0
Dehydrated Alfalfa Meal Pellets (17% C.P.)	4.93
Cottonseed Hulls	4.93
Soybean Meal (44% C.P.)	4.30
Urea (45% Nitrogen)	0.64
Salt	0.60
Bonemeal	0.60
	100.00

Added per lb. of ration:

Vitamin A	1600 I.U.
Aureomycin	5 mg.

The heifers were gradually adapted to a high-concentrate ration over the three week preliminary period.

Upon initiation of the actual feeding experiment, animals were fed approximately 10 lb. per head of their respective experimental ration

TABLE IV

TRIAL I: PERCENT PROXIMATE ANALYSES OF FEEDS

Feedstuff	Dry Matter[a]	Dry Matter Basis				
		Ash[b]	Crude Protein[b]	Ether Extract[b]	Crude Fiber[b]	N.F.E.[c]
Milo						
Dry Rolled	87.0	1.5	10.4	3.2	2.0	82.9
Recon. 5 days	69.1	1.6	10.7	3.4	1.9	82.4
Recon. 10 days	70.0	1.6	10.8	3.1	2.1	82.4
Recon. 20 days	71.4	1.6	10.6	3.3	2.0	82.5
Steeped	60.7	1.5	10.1	3.4	2.1	82.9

[a]Average of 12 determinations.

[b]Average of 2 determinations.

[c]100 - (sum of values reported for ash, crude protein, ether extract and crude fiber).

(on a 90% dry matter basis) and were given incremented, increasing amounts over the next five days, at which point they were receiving all they would clean up prior to the following feeding.

The five rations were processed and fed daily in quantities to assure availability of feed until the next feeding. Unconsumed feed was removed and weighed back daily to assure that fresh feed was available at all times.

Processing

The milo for each treatment was processed as follows:

1. Dry rolled.
2. Reconstituted in whole form at 30 percent moisture - stored 5 days and rolled.
3. Reconstituted in whole form at 30 percent moisture - stored 10 days and rolled.
4. Reconstituted in whole form at 30 percent moisture - stored 20 days and rolled.
5. Steeped in water for 48 hours, drained 24 hours and rolled.

All reconstituted milo was produced daily by submerging air-dry milo in water and mixing in a cement mixer for approximately 50 minutes, followed by draining of excess water. The reconstituted milo was then placed in air-tight plastic bags containing approximately 41 kg. per bag for the number of days indicated previously. Steeped milo (approximately 38% moisture) was produced by soaking air-dry milo in 190 l. barrels for 48 hours, followed by draining in 1.08 m. x .60 m. x .24 m. perforated containers for 24 hours.

All milo treatments were rolled through a 12 x 18 inch Ross Roller

Mill with a roller tolerance in excess of .027 mm. prior to feeding.

The relative density and particle size of the processed grains are shown in Table V.

TABLE V

TRIAL I: PARTICLE SIZE[a] AND DENSITY[b] OF PROCESSED MILO

Process	Screen Size 4.0 mm	2.0 mm	1.0 mm	500 micron	250 micron	250 micron	lb. per Bu.
	Percent Retained on Screen					Percent Through Screen	
Dry Rolled	0	16.1	67.1	8.7	6.9	1.2	41.6
Recon. 5 days	61.8	31.5	2.2	3.4	1.1	0.0	28.4
Recon. 10 days	60.0	35.6	2.2	2.2	0.0	0.0	29.6
Recon. 20 days	63.7	27.5	3.3	4.4	1.1	0.0	29.4
Steeped	59.3	36.3	2.2	1.1	1.1	0.0	25.0

[a]Particle size determined by three 100 gm. samples of each grain being sieved.

[b]Test weights reported are the average of three determinations and are on a 90% dry matter basis.

Dry matter of feeds was determined several times during each 28 day period. These determinations were averaged and used to adjust ration treatments to an equal dry matter content.

All milo used in this study was obtained from the Stillwater Milling Company in one or two ton quantities as needed.

Data Obtained

Performance data was summarized after cattle were fed 114 days. Performance data obtained were average daily gain, average daily feed intake, and feed per kg. of gain calculated both on a live shrunk weight basis and on an empty body weight basis. Empty body weight gain per kilogram of feed and energy gained per kilogram of feed were calculated so that a comparison of weight gain and energy gain could be made. Daily feed consumption records were kept. Initial and final weights were taken at 28 day intervals with water removed 16 hours prior to weighing.

All animals were slaughtered at the end of the feeding trial. Following a 24-hour chill, carcass data obtained included carcass grade, marbling, ribeye area, fat thickness over the ribeye, chilled carcass weight and percent kidney fat. From this data, dressing percentage and cutability[1] were calculated.

The right side of the carcass was then quartered, weighed first in

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[1] Cutability, or percent boneless retail cut yield, was estimated by the equation of Murphey et al. (1960), which is:

$$Y = 51.34 - (5.78 \times A) - (0.462 \times B) + (0.740 \times C) - (0.0093 \times D)$$

where,

Y = boneless retail cuts, as % of carcass
A = average fat thickness over ribeye (in.)
B = % kidney fat
C = ribeye area (sq. in.)
D = chilled carcass weight (lb.)

air, and then in water to allow calculation of carcass specific gravity.

Individual heifer data was analyzed for average daily gain and carcass merit, while pen averages were used in net energy, feed intake and feed conversion analyses. All variables were subjected to analyses of variance, the components of which are shown in Table VI.

TABLE VI

TRIAL I: ANALYSES OF VARIANCE

Source	df
For Feed Intake, Feed/Kg. Gain and Net Energy Values:	
Total	9
Blocks	1
Treatments	4
Block x Treatment[a]	4
For Average Daily Gain and Carcass Data:	
Total	49
Blocks	1
Treatments	4
Block x Treatment[a]	4
Within Pen	40

[a]Error term used to test treatments.

Duncan's new multiple Range Test (Steele and Torrie, 1960) was used to compare treatment means whenever a significant F value was obtained.

Net Energy Determinations

The slaughter group used for estimating initial body composition was the same as for Trial III (White, 1969).

After completing the feeding trial, all animals were slaughtered and specific gravities were calculated by the following formula:

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

All net energy calculations and equations used for body composition were essentially the same as those used by Newsom (1968).

The NE_{m+p} and NE_m values of the premix were estimated to be 978.9 (Morrison, 1969) and 1108.9 (Lofgreen and Garrett, 1967) kcal. per kg., respectively.

Feed intake was on a pen basis, therefore, net energy values are valid only for a pen of animals. The computer program was designed to use the mean intake of a pen of animals to compare with the caloric gain and maintenance requirement of each animal. Final net energy values were obtained by averaging the mean values of the two pens of cattle on each respective treatment.

In Vitro

Two laboratory experiments were conducted to study differences in *in vitro* digestibilities of various forms of moist sorghum grain. A third *in vitro* experiment was conducted to compare dry matter digestibilities of various combinations of reconstituted wheat and milo.

Technique

A modification of the first phase of the Tilley and Terry procedure, using dry matter disappearance for evaluation of treatment difference, was utilized in all three experiments. This technique permitted the fermentation of large numbers of samples concurrently with a minimum of experimental error.

The basic technique used to determine *in vitro* digestibility is given in Table VII.

TABLE VII

IN VITRO TECHNIQUE

Element	Level
Grain Sample	0.4 g.
Artificial Saliva	22.0 ml.
Rumen Inoculum	8.0 ml.
Temperature	39°C.
Time of Incubation	24 hr.

Prior to inoculation with fermentation media, all grain samples regardless of experimental treatment were prepared in the following manner:

(1) Dried at 100°C. for 16 hr. and ground through laboratory Wiley Mill (20 mesh screen);

(2) Weighed into numbered 50 ml. centrifuge tubes which were oven dried and weighed to the nearest .001 gm. in amounts of approximately .4 grams;

(3) Tube plus sample were then oven dried again at 100°C. to obtain an actual 100% dry matter weight of the grain by subtracting dried tube weight from dried tube plus sample weight.

The artificial saliva used was based on work by McDougal (1949) and is given in Table VIII.

TABLE VIII

COMPOSITION OF ARTIFICIAL SALIVA

Ingredient	Gm./liter of distilled H_2O
$NaHCO_3$	9.8
$Na_2HPO_4 \cdot 12H_2O$	9.3
KCl	0.57
NaCl	0.47
$MgSO_4 \cdot 7H_2O$	0.12
$CaCl_2$	0.04

Two-liter quantities of the above solution were mixed, saturated with CO_2 and warmed to 39°C. prior to mixing with whole rumen inoculum.

While artificial saliva was being warmed to 39°C. (in a water bath) a quantity of rumen fluid was recovered from a fistulated steer on a ration of 84% grain. The grain portion of the ration was all milo through experiments I and II, but was changed to 40% wheat and 60% milo two weeks prior to experiment III. The steer was fed twice daily at the rate of approximately 1.5 times the maintenance requirement. The rumen sample was dipped from the rumen through a fistula and placed into a thermos jug and immediately taken to the laboratory where it was filtered through four and then six layers of cheesecloth, respectively. This was accomplished as quickly as possible to minimize bacterial loss. Seven hundred twenty-six milliliters of the liquid portion were then mixed with the two liters of warmed artificial saliva and CO_2 was bubbled through the mixed media until all feed samples were inoculated. Temperature was maintained at 39°C. and solids kept in suspension by a heated magnetic stir plate.

Five ml. of the mixed media was pipetted into each substrate containing tube to moisten feed and prevent floating of feed particles when greater quantities were added. An additional 25 ml. of the buffered inoculum was then pipetted into each tube. Following inoculation, the unfilled portion of each tube was immediately flooded with CO_2 and stopped with a #6 stopper. All stoppers had a 2mm. hole drilled through them to allow gas which was produced to escape. The tubes upon being stopped, were immediately suspended into a pulsating water bath which was thermostatically controlled at 39°C. The samples were incubated in the dark for 24 hr. and stirred three times during this period. Six or more pre-weighed tubes containing 30 ml. of the saliva-rumen inoculum mixture only were incubated at the same time to obtain an average of dry matter constituents after fermentation not attributable to the grain samples. Both the "blank" and substrate containing tubes were removed from the water bath in the same random order they were entered and centrifuged at 2500 rpm for five minutes. Supernatent solution was then decanted off, 25 ml. of distilled water added and the centrifugation procedure repeated. After the fluid portion was again decanted, tubes were placed in a drying oven at 100°C. for 24 hr.

The tubes containing undigested matter were removed from the oven after 24 hr., cooled in dessicators and again weighed to the nearest .001 gm. Undigested dry grain weight was determined by the following formula:

(Dry tube + total dry matter) - (Dry weight of tube + average dry matter weight of contents of tubes containing only buffered inoculum).

Percent dry matter disappearance was then calculated by dividing dry undigested grain weight by the original dry grain sample weight.

Duncan's new multiple Range Test (Steele and Torrie, 1960) was used to compare treatment means in each of the three experiments.

Experiment I

This experiment was conducted to determine the effect of treatments imposed on milo in feeding trial I on *in vitro* dry matter digestibility. A randomized complete block design as shown in Table IX was used.

TABLE IX

EXPERIMENT I: EXPERIMENTAL DESIGN SHOWING NUMBER OF SAMPLES PER TREATMENT

	Processed Milo					
Blocks	Dry Rolled	Recon. 5 days	Recon. 10 days	Recon. 20 days	Steeped	Total Number
1	12	12	12	12	12	60
2	12	12	12	12	12	60
3	12	12	12	12	12	60
4	12	12	12	12	12	60
	48	48	48	48	48	240

This experiment was blocked on 4 rumen samples and each block represented a separate *in vitro* trial consisting of 12 samples of each treatment. The analysis of variance components are shown in Table X.

The five grain treatments were the same as those described in the cattle feeding trial. All samples were taken from the actual milo prepared for the cattle in feeding trial I. It was insured, however, that all reconstituted-stored forms came from bags which had not been damaged by rodents or exposed to oxygen by any other means during storage. After rolling at the feeding facility, all samples were returned to the laboratory where they were dried and ground as described earlier and placed in small sealed glass jars until used.

TABLE X

EXPERIMENT I: ANALYSES OF VARIANCE

Source	df
Total	239
Block	3
Treatment	4
Block x Treatment	12
Sampling[a]	220

[a]Error term used to test treatments.

The source and variety of the milo is unknown as it was purchased on the commercial market.

Experiment II

This experiment was designed to determine the difference in *in vitro* dry matter disappearance of twelve different forms of high moisture grain which were from the same source.

Various natural moisture levels, reconstitution, and physical form at time of storage are factors which differentiate treatments. The specific grain treatments and respective abbreviations to be used in future discussions are as follows:

(1) Harvested at 19% moisture and stored ground (19% SG);

(2) Harvested at 19% moisture and stored whole (19% SW);

(3) Harvested at 19% moisture, reconstituted to 30% moisture and stored ground (19% RSG);

(4) Harvested at 19% moisture, reconstituted to 30% moisture and stored whole(19% RSW);

(5) Harvested at 22% moisture and stored ground (22% SG);

(6) Harvested at 22% moisture and stored whole (22% SW);

(7) Harvested at 22% moisture, reconstituted to 30% moisture and stored ground (22% RSG);

(8) Harvested at 22% moisture, reconstituted to 30% moisture and stored whole (22% RSW);

(9) Harvested at 30% moisture and stored ground (30% SG);

(10) Harvested at 30% moisture and stored whole (30% SW);

(11) Harvested at 36% moisture and stored ground (36% SG);

(12) Harvested at 36% moisture and stored whole (36% SW).

The grain used in all treatments was harvested from one irrigated field of NK-222 sorghum grain. The composite sample for each unreconstituted moisture level was obtained by harvesting at different times as the grain matured, starting when the grain contained 36% moisture. The grain containing 36% moisture was threshed by hand while all lower moisture level grains were threshed by a conventional field combine.

All reconstituted grains were obtained by adding the amount of water required to obtain a 30% moisture product.

Grain which was stored in the ground form was ground through a laboratory Wiley Mill using a 2mm. screen prior to oxygen free storage. The reconstituted ground forms were ground prior to the addition of water.

All treatments regardless of form or moisture were then placed in 250 ml. plastic air-tight bottles, flooded with CO_2 and stored for 20 days. After 20 days of storage at room temperature (22.2^{o}C.), grain stored in the whole form was ground through a Wiley Mill using a 2mm. screen. All samples were then dried and ground through a 20 mesh screen as previously described, and placed in small sealed glass jars until used.

A randomized complete block experimental design as shown in Table XI was used.

TABLE XI

EXPERIMENT II: EXPERIMENTAL DESIGN SHOWING NUMBER OF SAMPLES PER TREATMENT

	Processed Milo												
Blocks	19% SG	19% SW	19% RSG	19% RSW	22% SG	22% SW	22% RSG	22% RSW	30% SG	30% SW	36% SG	36% SW	Total Number
1	5	5	5	5	5	5	5	5	5	5	5	5	60
2	5	5	5	5	5	5	5	5	5	5	5	5	60
3	5	5	5	5	5	5	5	5	5	5	5	5	60
4	5	5	5	5	5	5	5	5	5	5	5	5	60
	20	20	20	20	20	20	20	20	20	20	20	20	240

The analysis of variance components when all 12 treatments were considered is shown in Table XII.

TABLE XII

EXPERIMENT II: ANALYSES OF VARIANCE

Source	df
Total	239
Block	3
Treatment	11
Block x Treatment[a]	33
Sampling	192

[a]Error term used to test treatments.

When only the eight treatments which were not reconstituted were considered, the analyses of variance components shown in Table XIII were used to determine if interaction existed between milo's physical form and moisture level during storage.

Experiment III

Experiment III was conducted to compare *in vitro* digestibilities of reconstituted milo, wheat and milo-wheat combinations. The various ratios of milo to wheat studied were: 100:0, 75:25, 50:50, 25:75 and

0:100, respectively.

TABLE XIII

EXPERIMENT II: ANALYSIS OF VARIANCE FOR THE DETERMINATION OF INTERACTION OF PHYSICAL FORM AND MOISTURE LEVEL

Source	df
Total	159
Block	3
Treatment	7
A (physical form)	1
B (moisture)	3
AB	3
Block x Treatment[a]	21
Sampling	128

[a]Error term used to test treatments.

The milo used was NK-222 grown at the Fort Reno experiment station and the wheat was of a hard red winter variety (Triumph) grown at the same station. Field dry samples were collected and returned to the laboratory. Samples were analyzed for moisture. After both specie of grain were ground through a Wiley Mill, using a 2mm. screen, the grains were combined in the respective ratios on a 100% dry matter basis. After thorough mixing, water was added to bring moisture level of the grains, or mixtures of grains to 30%. All samples were firmly packed in 250 ml. air-tight bottles and stored for 20 days at room temperature.

After oxygen free storage all samples were dried at 100°C. and ground through a 20 mesh Wiley Mill screen prior to being subjected to *in vitro* fermentation.

A randomized complete-block experimental design was used and is shown in Table XIV. Analysis of variance components are shown in Table XV.

TABLE XIV

EXPERIMENT III: EXPERIMENTAL DESIGN SHOWING NUMBERS OF SAMPLES PER TREATMENT

	Ratio of Milo to Wheat					Total
Blocks	100:0	75:25	50:50	27:75	0:100	Number
1	10	10	10	10	10	50
2	10	10	10	10	10	50
3	10	10	10	10	10	50
4	10	10	10	10	10	50
	40	40	40	40	40	200

Treatment means were subjected to orthoganol regression comparisons as well as Duncan's new multiple Range Test (Steele and Torrie, 1960) to determine the nature of the response curve as levels of wheat increased.

TABLE XV

EXPERIMENT III: ANALYSES OF VARIANCE

Source	df
Total	199
Block	3
Treatment	4
Block x Treatment[a]	12
Sampling Error	180

[a]Error term used for testing treatments.

CHAPTER IV

RESULTS AND DISCUSSION

In Vivo - Trial I

Feedlot Performance

Feedlot performance of the heifers fed the five types of processed milo is shown in Table XVI.

Although significant F values were not obtained for kg. feed/kg. gain, or kg. milo/kg. gain, a comparison of treatment means indicates that feed efficiency for all moist forms tended to be somewhat superior to the dry rolled milo. The reconstituted 20-day treatment was most efficiently converted, requiring .76 kg. less feed per kg. gain than the dry rolled treatment. This represents a 11.3% increase in feed utilization over dry rolled milo. The reconstituted 20-day milo was followed in efficiency of feed utilization by steeped, reconstituted 5-day, and reconstituted 10-day milo, respectively. The respective feed conversion ratios and percent improvement over dry rolled milo for 20-day, steeped, 5-day and 10-day treatments were 6.50, 8.7; 6.75, 5.2; and 6.78, 4.8. The improvements in efficiency of the moist grains are a result of nearly identical daily gains on significantly ($P < .05$) less dry matter. The average daily gains (kg.) and intakes (kg.) for 20-day, steeped, 5-day, 10-day and dry milo were 1.22, 7.45; 1.20, 7.76; 1.14, 7.61; 1.18, 7.97; and 1.23, 8.52, respectively.

TABLE XVI

TRIAL I: FEEDLOT PERFORMANCE (114 DAYS)

Item	Dry Rolled	Recon. 5 Day	Recon. 10 Day	Recon. 20 Day	Steeped	$S_{\bar{x}}$[a]	F[b]
No. Heifers	10	10	10	10			
Initial live shrunk wt., kg.	200.03	203.21	199.13	201.85	198.67		
Final live shrunk wt., kg.	339.97	332.94	334.07	340.88	335.66		
Av. daily gain, kg.	1.23	1.14	1.18	1.22	1.20	0.04	0.15
Av. daily intake, kg. (total)[d]	8.52[1]	7.61[2]	7.97[2]	7.45[2]	7.76[2]	0.13	10.55[c]
Av. daily intake, kg. (grain)[d]	7.17[1]	6.37[2]	6.69[2]	6.28[2]	6.52[2]	0.11	10.78[c]
Total feed/kg. gain, kg.	7.12	6.75	6.78	6.19	6.50	0.42	0.69
Grain/kg. gain, kg.	5.97	5.65	5.70	5.21	5.46	0.35	0.68
Initial empty body wt., kg.	197.46	200.45	196.61	199.17	196.18		
Final empty body wt., kg.	329.28	322.66	323.72	331.24	325.22		
Av. daily EBW gain, kg.	1.16	1.07	1.12	1.15	1.13	0.04	0.16
Total feed/kg. EBW gain, kg.	7.55	7.16	7.20	6.56	6.90	0.45	0.69
Grain/kg. EBW gain, kg.	6.35	6.00	6.05	5.53	5.80	0.37	0.68

[a]Standard error of treatment means.

[b]Calculated F value from analysis of variance.

[c]Significant ($P < .05$).

[d]Any two means without a common number differ significantly (P .05).

Results indicate that intake and utilization of milo were apparently partially dependent on reconstitution. These results are in agreement with work done by Franke _et al_. (1960) and White _et al_. (1969) in that feed consumption was decreased and feed efficiency improved by increasing the moisture content of milo. The milo was obviously eaten at a constant energy intake regardless of moisture, as rate of gain was constant among all treatments. This suggests the starch portion of the grain was in a form more efficiently utilized by the heifers when milo was in the ensiled or steeped form.

The results also indicate that 20 or more days of oxygen free storage are required to get maximum energy utilization of 30% moisture milo. However, data also show that of the 11.2% increase in feed efficiency obtained with moist milo stored 20 days, approximately half (5.2%) of the benefit is obtained with five days of storage or less. Comparable results were obtained in Texas by Bowers _et al_. (1968). It was reported that a 22% increase in feed efficiency was obtained when milo reconstituted to 28% moisture and stored ten days was compared to dry ground milo. Only 5% additional improvement was noted when storage was extended to 20 days. This increase in improvement of utilization of milo at a decreasing rate effect was also illustrated _in vitro_ by Neuhaus (1968), when milo reconstituted to 30% moisture improved 11.1% in dry matter disappearance in 10 days and further improved only 3.7% during the next 20 days of storage. Similar _in vitro_ data are noted in experiment I which will be discussed later.

It is of interest that steeped milo produced performance in fattening heifers comparable to the ensiled grains. There are conflicting reports from this station which both support and refute the idea that merely increasing moisture level and exposing to the atmosphere for a number of hours, imparts some characteristic to the starch structure of milo which is beneficial to its utilization. White (1969) found _in vitro_ digestibilities were considerably improved for reconstituted milo exposed to the atmosphere for one day, while the same treatments fed to beef cattle proved to be of very little benefit. Experiment I of this study complicates interpretation further, in that _in vitro_ dry matter disappearance of steeped milo which was processed for cattle in Trial I was not significantly different from dry rolled milo.

Rodents were a problem during the course of the feeding trial. Many of the sealed bags containing reconstituted grain were broken by these rodents, resulting in considerable spoilage in isolated bags. An attempt was made by feed handlers to discard all such spoiled grain, however, a "musty" odor persisted in grain which was observably unspoiled in these same damaged bags. Logically, feed intake and utilization could be affected by such abnormalities. Care was taken to avoid such broken bags completely when samples for _in vitro_ work were collected. As a result two different populations of ensiled grain were being tested with respect to Trial I and Experiment I.

Part of the increased benefit resulting from reconstitution may be due to the fluffy flake-like physical form which is acquired upon rolling of the moist grains. Both the ensiled and steeped grain, while similar in density, were considerably lighter than dry rolled grain. The average wt./bu. for reconstituted grains was 29.1 lb. while steeped milo weighed 25.0 lb. and dry rolled milo weighed 41.6 lb. per bushel. This decrease in density resulted in an increase in surface area which may enhance utilization of the starch portion of the grain by feedlot cattle (White, 1969).

Feed efficiency values expressed on an empty body weight basis produced results which reflected those previously discussed on a shrunk weight basis (Table XVI).

Net Energy

The calculated net energy values of the five types of processed milo are shown in Table XVII. Significant F values were obtained only for NE_{m+p} of the total ration. Comparison of these same treatment means indicated that the NE_{m+p} of the total ration was significantly higher for all moist forms than for the dry control, but no significant ($P > .05$) difference was noted among the moist forms.

As shown by the data (Table XVII), NE_{m+p} and NE_p values of the various processed grains followed trends similar to the NE_{m+p} of the total rations. Differences among both the NE_{m+p} and NE_p values for the grains were approaching significance.

The NE_p value of 112.91 megcal./100 kg. estimated for dry rolled milo falls midway between mean estimates of similar dry forms of sorghum grain reported by Newsom (1968) and White (1969). Their estimates ranged from 106.5 to 124.3 megcal./100 kg. NE_p values for the other four processed milos are as follows: recon. 20 day, 134.61; recon. 10 day, 119.43; recon. 5 day, 132.30; and steeped 132.68. These NE_p values reflect improvements in feed efficiency in that both the feed efficiency and NE_p values increased simultaneously.

Carcass Merit

Carcass characteristics and dressing percentage were not signifi-

TABLE XVII

TRIAL I: NET ENERGY VALUES OF PROCESSED MILO

Net Energy Value	Dry Rolled	Recon. 5 Day	Recon. 10 Day	Recon. 20 Day	Steeped	$S_{\bar{x}}$[a]	F[b]
NE_{m+p} of Total Ration[c,g]	133.76[1]	147.23[2]	138.69[1,2]	148.53[2]	147.51[2]	2.56	6.585[h]
NE_{m+p} of Milo[d]	140.51	156.78	146.49	159.206	156.94	3.36	5.79
NE_m of Milo[e]	169.37	198.45	179.15	201.92	199.02	--	--
NE_p of Milo[f]	112.91	132.30	119.43	134.61	132.68	5.02	3.69

[a]Standard error of treatment means.

[b]Calculated F value from analysis of variance.

[c]Energy for gain and maintenance ÷ intake of total ration.

[d]Any two means without a common number differ significantly ($P < .05$).

[e]NE_p x 1.50, (1.50 = ratio of NE_m to NE_p on basis of ave. crude fiber content).

[f]Determined by dividing maintenance requirement and energy gained between milo and premix on basis of ratio in ration (84% milo, 16% premix).

[g]Any two values without a common number differ significantly ($P < .05$).

[h]Significant ($P < .05$).

TABLE XVIII

TRIAL I: CARCASS MERIT

Item	Dry Rolled	Recon. 5 Day	Recon. 10 Day	Recon. 20 Day	Steeped	$S_{\bar{x}}$[a]	F[b]
No. Heifers	10	10	10	10	10		
Dressing %[c]	59.9	59.4	59.9	59.4	58.9	0.2	0.7
Carcass grade[d]	10.9	10.5	10.9	10.5	10.3	0.2	0.5
Ribeye area, sq. in.[e]	9.9	10.1	10.7	9.9	9.5	0.2	1.4
Fat thickness, in.[f]	0.6	0.7	0.6	0.6	0.6	0.0	1.4
Marbling[g]	17.3	15.9	17.5	17.1	15.0	0.4	1.2
Cutability, %[h]	51.2	51.2	52.0	51.2	51.1	0.2	1.1

[a]Standard error of treatment means.

[b]Calculated F value from analysis of variance.

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

[d]U.S.D.A. grades converted to following numerical designations: high prime-15, ave. prime-14, low prime-13, high choice-12, ave. choice-11, low choice-10, high good-9, ave. good-8, low good-7.

[e]Determined by measurements of ribeye tracings at the 12th rib.

[f]Average of three measurements on ribeye tracings.

[g]Marbling scores, 1=devoid minus to 30=abundant plus, with 3 scores per classification (minus, ave., plus).

[h]Percent of boneless trimmed retail cuts on carcass basis=51.78-5.78 (fat thickness)-4.62 (% kidney fat)+.740 (ribeye area)-.0093 (chilled carcass wt.).

cantly ($P > .05$) affected by processing method (Table XVIII).

In Vitro - Experiment I

The same grain processing methods used in feeding Trial I were investigated in this laboratory experiment using *in vitro* dry matter digestibility as the criterion on which evaluation was based.

The analysis of variance is presented in Table XIX. Mean values for percent dry matter digestibility were: 42.16, 46.41, 53.05, 56.29 and 42.84, respectively, for dry rolled milo, reconstituted milo stored five days, reconstituted milo stored ten days, reconstituted milo stored twenty days and steeped milo. Comparison of treatment means and standard error of the mean are illustrated graphically in Figure 1.

TABLE XIX

ANALYSES OF VARIANCE, EXPERIMENT I

Source	df	M.S.	F
Total	239	1888.47	
Blocks	3		
Treatments	4	1888.47	285.69[1]
Block x Treatment	12	9.73	
Sampling[2]	220	6.61	

[1]Significant ($P < .01$).

[2]Error term used to test treatments.

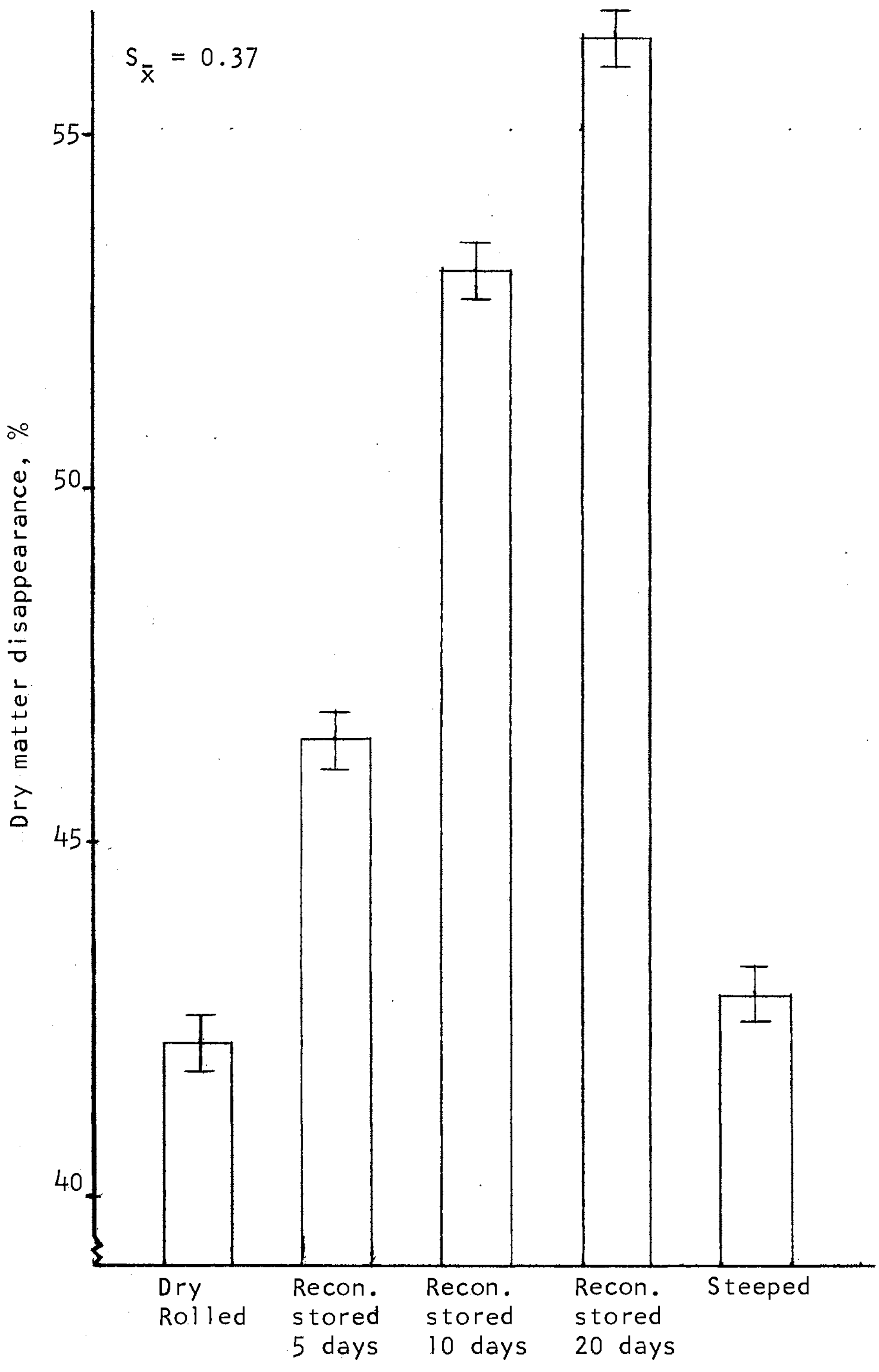

Figure 1. Effect of Reconstitution and Storage Time of Milo on *In Vitro* Digestion

Comparisons of *in vitro* dry matter digestibility and efficiency of utilization by fattening heifers of dry rolled, reconstituted 30% 5 day, reconstituted 30% 10 day, reconstituted 30% 20 day and steeped milo are shown in Figure 2.

Although 48 samples were used to calculate each *in vitro* digestibility mean, correlations were not calculated as efficiency values are the average of only two means. Even though such correlations could not be calculated, a relationship between the two measurements is apparent.

Analysis of the five treatment means showed a significant difference ($P < .01$) between all treatments except for dry rolled and steeped milo which were essentially the same in *in vitro* digestibility.

No complete explanation can be given for the lack of *in vivo* and *in vitro* agreement between the dry rolled and steeped milo treatments. One possible reason for this phenomenon could be the chance involved in allotting of heifers in the feeding trial, as feed conversion ratios of 6.43 and 6.48, respectively, for pens of steeped milo fed cattle fell intermediate to conversion ratios of 6.12 and 8.03 for respective pens of cattle fed dry rolled grain.

As length of storage for reconstituted ensiled grain increased, *in vitro* digestibilities also increased. The percent improvement noted in reconstituted milo after 5, 10 and 20 days of storage, respectively, was 10.1, 25.8 and 33.5. The greatest improvement is noted in the second five days of storage, where a 15.7% increase in dry matter disappearance is noted over that improvement obtained in the first five days of storage. The improvement noted in the first 10 days was improved yet another 7.7% with the extension of storage time to 20 days. Although *in vitro* data reported by Neuhaus (1968) revealed a similar

Treatments:

1 - Dry rolled
2 - Recon. 30% stored 5 days
3 - Recon. 30% stored 10 days
4 - Recon. 30% stored 20 days
5 - Steeped

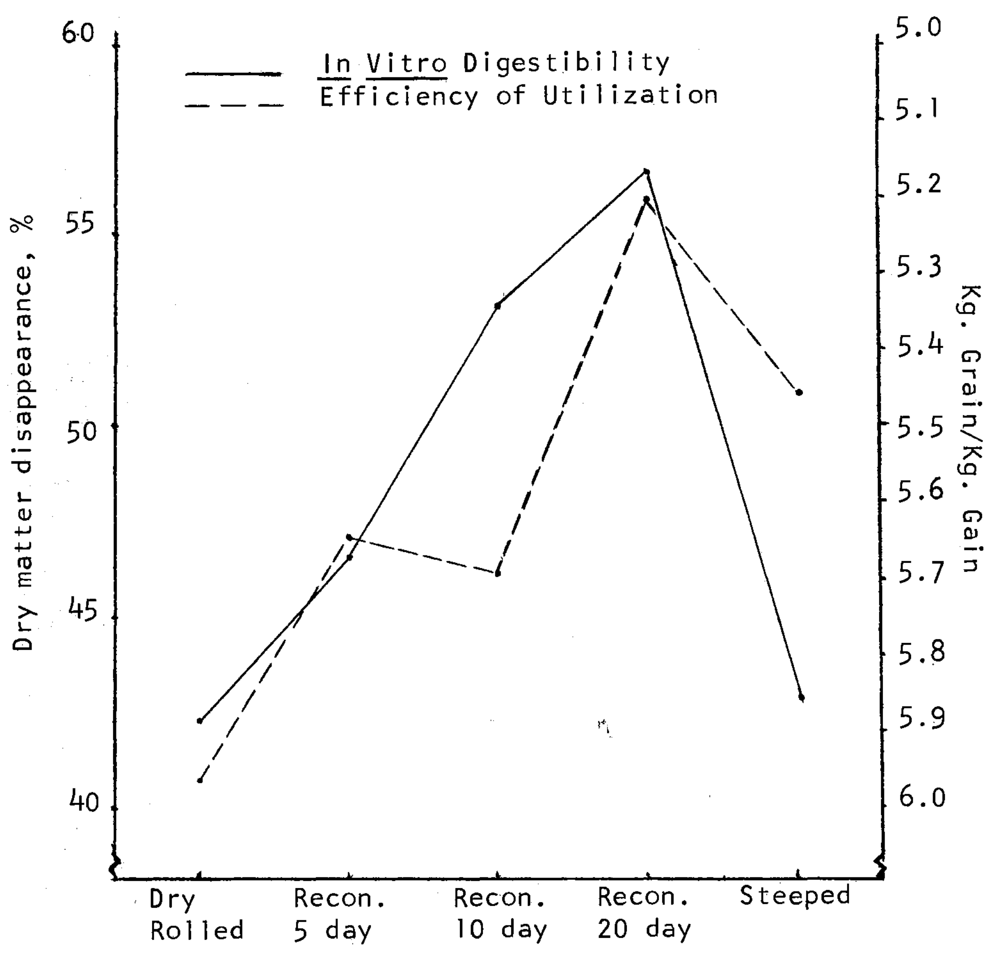

Figure 2. Comparison of *In Vitro* Dry Matter Disappearance to Effeciency of Utilization by Fattening Heifers

trend, much smaller increases in dry matter disappearance were noted in extended periods of storage, as only 3.7% improvement was noted when storage time was increased from 10 days to 30 days.

The process whereby the digestibility of grain by rumen bacteria is improved via reconstitution and extended storage is possibly due to both partial germination and fermentation, during which the starch portion may be altered to a more usable form.

In Vitro - Experiment II

Twelve methods of processing milo were evaluated in this experiment on the basis of *in vitro* dry matter disappearance. The moisture levels for all treatments investigated ranged from 36% to 19%. A comparable range of moisture content is frequently observed in milo from the initiation of high moisture harvesting to its completion. The milo treatments which were all stored oxygen-free for 20 days prior to *in vitro* fermentations are listed below with abbreviations which will be used in later discussion.

(1) Harvested at 19% moisture stored ground (19% SG)

(2) Harvested at 19% moisture stored whole (19% SW)

(3) Harvested at 19% moisture, reconstituted to 30% moisture and stored ground (19% RSG)

(4) Harvested at 19% moisture, reconstituted to 30% moisture and stored whole (19% RSW)

(5) Harvested at 22% moisture and stored ground (22% SG)

(6) Harvested at 22% moisture and stored whole (22% SW)

(7) Harvested at 22% moisture, reconstituted to 30% moisture and stored ground (22% RSG)

(8) Harvested at 22% moisture, reconstituted to 30% moisture and stored whole (22% RSW)

(9) Harvested at 30% moisture and stored ground (30% SG)

(10) Harvested at 30% moisture and stored whole (30% SW)

(11) Harvested at 36% moisture and stored ground (36% SG)

(12) Harvested at 36% moisture and stored whole (36% SW)

The analysis of variance is presented in Table XX and comparisons of treatment means and standard error of the means are illustrated graphically in Figure 3.

TABLE XX

ANALYSES OF VARIANCE, EXPERIMENT II

Source	df	M.S.	F
Total	239	24.26	
Blocks	3	114.59	
Treatments	11	464.34	140.40[1]
Block x Treatment[2]	33	3.30	
Sampling Error	192	1.24	

[1]Significant ($P < .01$).

[2]Error term used to test treatments.

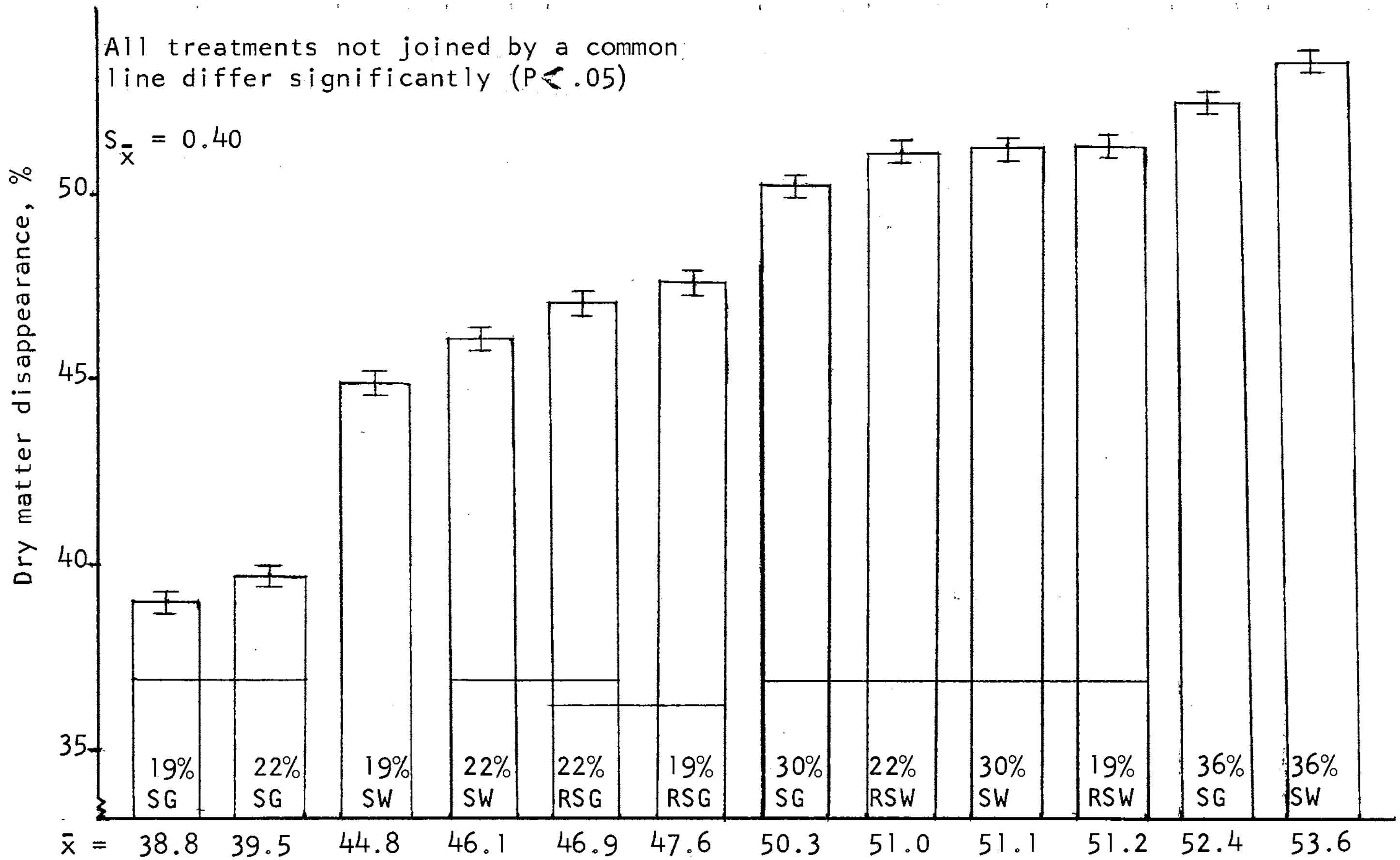

Figure 3. *In Vitro* Digestibilities of Twelve Forms of Moist Milo

Effect of Natural Moisture

When only whole, non-reconstituted treatments are considered, it is noted that there is a significant difference between all successive moisture levels. Dry matter disappearance percentages for the whole naturally harvested forms ranged from 44.8 for milo containing 19% moisture to 53.6 for milo containing 36% moisture at harvest. This represents nearly a 9% increase in *in vitro* digestibility, with 5% of the increase occurring when the moisture level increased from 22% to 30%. This same pattern is obtained when ground forms of the same moisture levels are compared, with the exception that 19% SG and 22% SG were not significantly different.

The fact that the major increase in *in vitro* dry matter disappearance occurs as the moisture content approaches 30% suggests that this may be the optimum moisture level for harvesting moist sorghum grain, as it can be readily combined by maintaining combine cylinder speed while reducing ground speed (Franke *et al*., 1960). Although milo at 36% moisture shows a greater percentage of total *in vitro* dry matter disappearance, this difference is slight (2.5%), and milo at this stage cannot be thrashed out readily by conventional combines (Brethour and Duitsman, 1960).

It would appear that although milo is physiologically mature at higher moisture levels, the starch may be in a form more readily utilized by rumen microflora than in drier grain.

A separate analysis of variance was calculated on all treatments which were not reconstituted for the purpose of determining if an interaction existed between moisture level and form at time of storage. This analysis (Table XXI) shows a highly significant interaction ($P < .01$)

exists between moisture level and physical form of milo at time of storage.

TABLE XXI

ANALYSES OF VARIANCE FOR THE DETERMINATION OF INTERACTION, EXPERIMENT II

Source	df	M.S.	F
Total	159		
Blocks	3		
Treatments	7	654.32	299.90[1]
A (physical form)	1	536.26	245.79[1]
B (moisture)	3	1255.15	575.28[1]
AB	3	92.83	42.55[1]
Block x Treatment[2]	21	2.18	
Sampling Error	128	1.19	

[1]Significant ($P < .01$).

[2]Error term used to test treatment means.

Reconstitution vs. High Moisture Harvesting

Figure 4 illustrates the improvement of *in vitro* dry matter digestibility resulting from reconstitution of 19 and 22% harvested sorghum grains, both whole and ground, to 30% moisture.

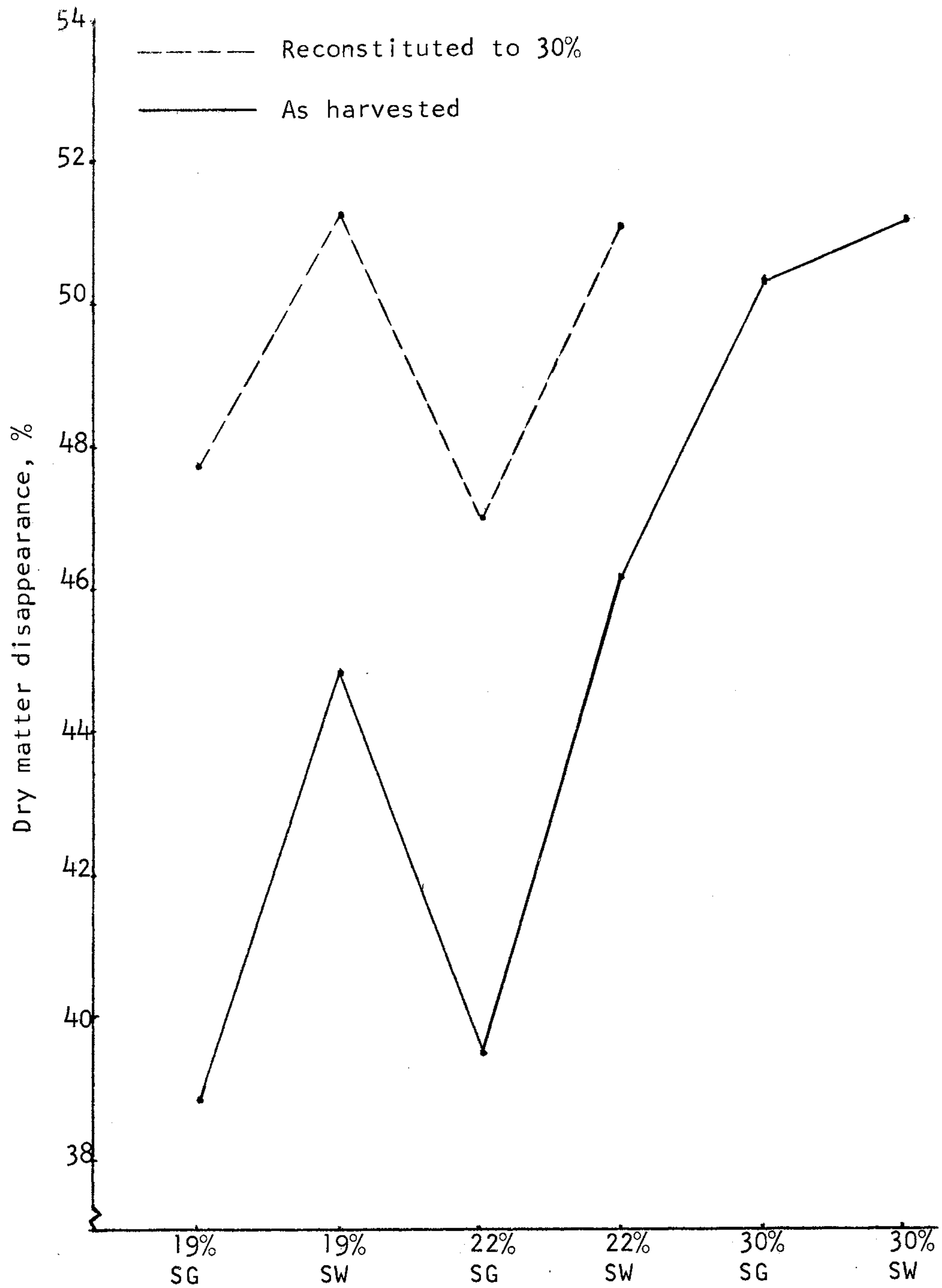

Figure 4. Comparison of Reconstituted and High Moisture Harvested Milo

Although both ground and whole forms of reconstituted milo had significantly higher in vitro dry matter disappearances than the unreconstituted forms, only those stored in the whole form reached the digestibility of milo harvested at 30% moisture. Neither 19% RSW nor 22% RSW were significantly different in in vitro dry matter disappearance than the milo treatments containing 30% natural moisture. Nineteen percent RSG and 22% RSG were both significantly lower in dry matter disappearance, however, than treatments containing 30% natural moisture. Nineteen percent RSG and 22% RSG digestibilities were 3.6 and 4.3% less respectively than the 30% SW.

The significantly greater improvement obtained by the addition of water to drier forms of whole milo, as opposed to the ground forms, indicates that some of the improvement may be due to the initial stages of germination, causing some starch hydrolysis. This starch hydrolysis may not take place, on the otherhand, if physical integrity of the whole kernel is disrupted by grinding (van Overbeek, 1966).

Obviously, however, there was significant benefit to merely adding moisture prior to storage. The ground forms of reconstituted 19 and 22% harvested milo were digested in vitro to a significantly greater extent than the unreconstituted forms. The improvement in digestibility may be due to softening the grains proteinacaceous matrix. Swelling or hydration may occur in the starch portion itself, causing a partial weakening or destruction of the matrix and cell walls (Penic et al., 1968).

The fact that both 19% SW and 22% SW milo were digested by rumen bacteria to a significantly greater extent than 19% SG milo and 22% SG milo (although moisture present was not sufficient to obtain maximum benefit of the germination process) lends support to the idea that partial germination may enhance starch availability.

It is interesting to note, however, that grain containing natural 30% moisture was not significantly affected by the physical form in which it was stored. This may imply that hydrolysis of the starch portion of milo harvested at 30% moisture may be by a mode of action other than the germination which apparently occurs in drier whole grains when water is added.

In Vitro - Experiment III

Experiment III was a pilot study for the purpose of determining effect of reconstituted wheat and milo-wheat combinations on rumen microflora digestibility.

Table XXII shows the analysis of variance. Mean values for percent dry matter digestibility were: 52.57, 53.45, 58.47, 61.42 and 63.03, respectively, as wheat made up 0, 25, 50, 75 and 100% of the grain. Comparison of individual treatment means and the standard error of the mean (±1.6) are illustrated graphically in Figure 5.

Although a significant difference ($P < .05$) was found only between those treatments containing 50% wheat or more and those groups containing 25% wheat or less, increasing digestibilities were noted as increasing amounts of wheat replaced milo. When treatment means were subjected to orthoganol comparisons, a highly significant ($P < .01$) linear response was indicated.

This increase in *in vitro* digestibility as percentage of wheat was increased tends to agree with feedlot work reported by Richardson *et al.* (1967). It was reported that grain/lb. of gain values for fattening steers increased successively as wheat (dry) replaced 25, 50 and 75% of the milo in fattening rations.

TABLE XXII

ANALYSES OF VARIANCE, EXPERIMENT III

Source	df	M.S.	F
Total	199	125.90	
Blocks	3	6736.95	
Treatments	4	872.64	8.90[1]
Block x Treatment[2]	12	98.02	
Sampling	180	.98	

[1]Significant ($P < .01$).

[2]Error term used for testing treatments.

Dry matter digestibility of 100% wheat was superior to all other grain combinations and was significantly ($P < .01$) higher than 75% milo-25% wheat or 100% milo treatments. This might suggest that any reduction in performance of cattle fed higher levels of wheat (Brethour, 1966) may be due to factors other than disruption of rumen microflora activity. The fact that wheat was digested *in vitro* more readily than the milo also indicates that the starch portion of wheat is in a more utilizable form than that of milo.

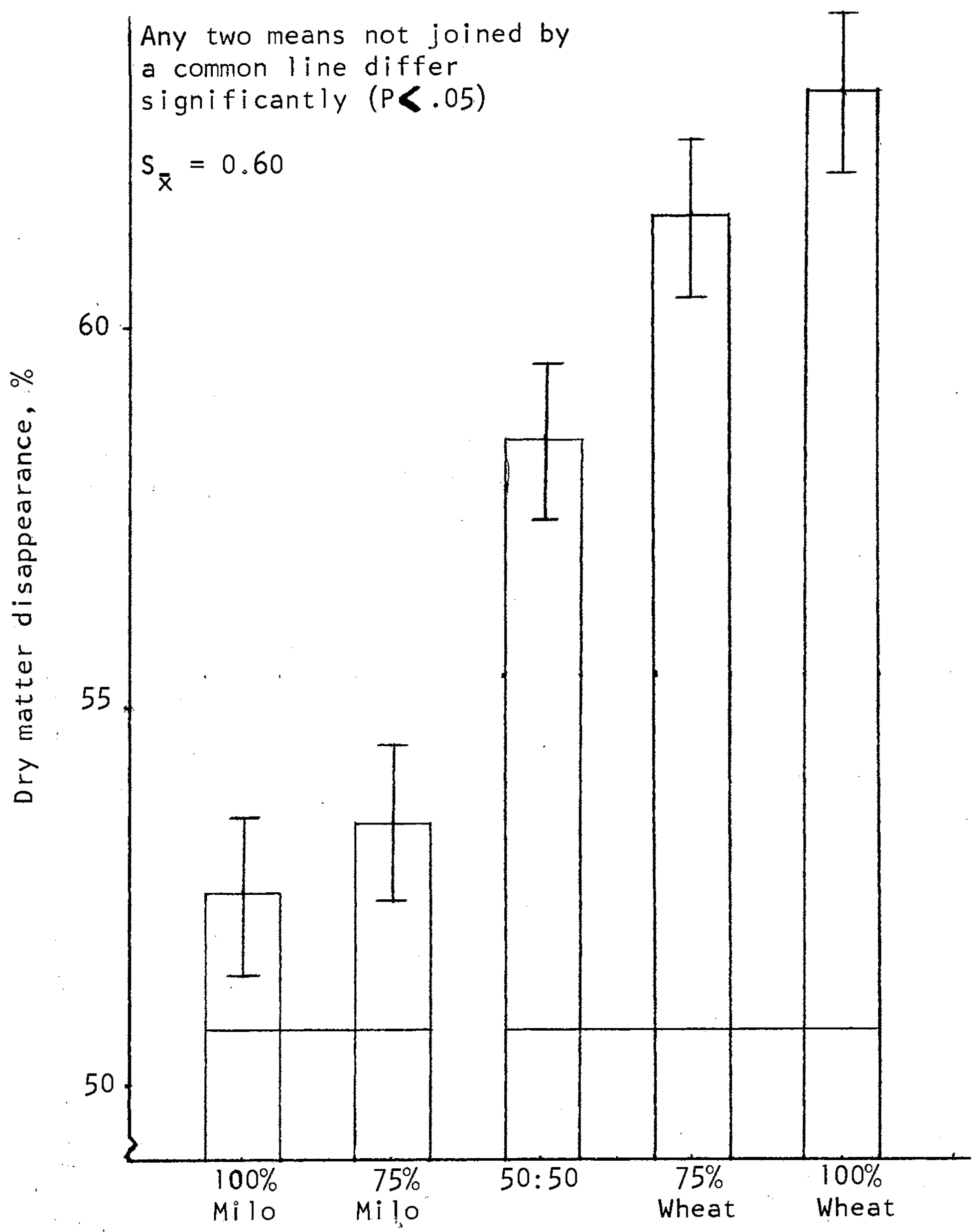

Figure 5. *In Vitro* Digestibilities of Reconstituted Milo, Wheat and Milo-Wheat Combinations

Assuming whole reconstituted wheat, like milo, produces performance equal or superior to the ground reconstituted form, one might surmise that it could be utilized in feedlot operations which feed reconstituted milo, with no alteration of equipment regardless of whether glass lined or trench silos are used as the means of storage.

CHAPTER V

SUMMARY

One feeding trial and three laboratory experiments were conducted to evaluate high moisture forms of milo and milo-wheat combinations.

Feeding Trial I was conducted to determine effect of steeping and length of storage of reconstituted milo on fattening cattle. Evaluation was based on feedlot performance, net energy, and carcass merit.

No significant difference was noted in daily gain regardless of treatment. There was a significant ($P < .05$) difference in efficiency of feed utilization between dry rolled and all moist forms, but no significant difference was noted among moist treatments. This difference between dry rolled milo and the moist forms is attributed to the fact that dry rolled milo fed cattle ate more feed ($P < .05$) while gains were comparable. Although differences of feed utilization were not significantly different among moist treatments, reconstituted milo stored 20 days produced 11.2% more efficient gains than dry rolled milo, while 5 and 10 days of storage resulted in approximately half that much improvement. Steeped milo produced an 8.7% increase in feed utilization over the control ration.

NE_p values and carcass merit were not significantly effected by processing method.

The three laboratory experiments were used to evaluate moist grains by measuring dry matter disappearance of the grains subjected to

fermentation in buffered rumen fluid for 24 hr.

Reconstituted ensiled treatments, sampled from milo used in the feeding trial were found to have higher *in vitro* dry matter disappearances ($P < .01$) than dry rolled milo. Milo reconstituted to 30% and stored 20 days had higher dry matter disappearance ($P < .01$) than that stored 10 days, and milo stored 10 days in turn was digested *in vitro* to a greater degree ($P < .01$) than milo reconstituted and stored 5 days. Steeping of milo did not noticeably improve *in vitro* digestibility.

As moisture level increased in high moisture harvested milo, it was found that *in vitro* dry matter disappearance also increased. Significant differences were found in *in vitro* dry matter disappearance between milo harvested at 22% and 30% and between that harvested at 30% and 36% regardless of physical form during storage.

While both ground and whole forms of milo reconstituted to 30% have *in vitro* dry matter disappearance values significantly higher than the same grain unreconstituted, that which was stored whole produced greater *in vitro* digestibilities ($P < .05$) than the ground form.

A linear response ($P < .01$) was found as wheat replaced increasing amounts of milo in reconstituted samples subjected to *in vitro* fermentation. As wheat increased in 25% increments from 0 to 100% of the total grain, *in vitro* dry matter disappearance also increased. When treatment means were compared, a significant ($P < .05$) improvement of *in vitro* digestibility was found in samples containing 50, 75 and 100% wheat over those samples containing 25% wheat or less.

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