

COMPLETION REPORT

January, 1982

PROJECT: The Effects of Mechanical Processing, Alkali Treatment and Moisture Level on the Nutrient Availability of Grain Sorghum to Ruminants.

OBJECTIVES: To determine the extent of ruminal digestion of sorghum at various moisture levels when subjected to dry rolling, steam flaking and/or chemical treatment. To determine the wetting rate of the grain when reconstituted with water, wetting agent solutions or dilute sodium hydroxide solutions at various temperatures.

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The Effects of Mechanical Processing, Alkali Treatment and Moisture Level on the Nutrient Availability of Corn and Grain Sorghum to Ruminants

Laboratory and animal experiments have been completed to determine the effects of physical and chemical treatments of corn and grain sorghum on parameters stated in the objectives. Procedures which have been completed include: wetting rates of whole corn and grain sorghum; in situ dry matter disappearance from nylon bags of whole, rolled or steam flaked corn and grain sorghum; ruminal digestibility of corn and grain sorghum in vitro; nutrient digestibility and nitrogen retention in growing lambs fed sodium hydroxide treated or reconstituted grain sorghum; and feedlot performance by growing lambs fed sodium hydroxide or reconstituted grain sorghum.

Laboratory evaluations of the wetting rate of air dry whole corn and grain sorghum in various grain conditioner solutions have been completed. Treatments evaluated include: technical-grade sodium hydroxide (1,2,3,6 and 9% solutions); Temper (Carnation); Grain-wet (Bill Barr); KEM-FLAK (Kemin); E-Z Flake (Loveland Industries) and E-Z Flake-4 (Loveland Industries); Wet Digest1 and Wet Digest2 enzymes (Creative Research Labs) used at the rate of 2 or 4 oz. per ton in combination with CRL-SI surfactant at the rate of 2 or 4 oz. per ton. The following basic procedure was used in conducting the evaluations. Twenty-five gram samples of air dry whole grain were weighed into 250 ml. glass centrifuge bottles. The grain was then immersed with 100 ml. of the appropriate wetting solution and the bottles were placed in a water bath adjusted to the desired temperature. All commercial grain conditioners were used as freshly made stock solutions from the concentrate supplied by the manufacturer. Concentrations of the stock solutions were based on manufacturers' recommendations for a typical application with rates ranging from 4 to 32 oz. concentrate per ton of grain. Dilution of the concentrate was based on the manufacturers' guidelines of the addition of 4% moisture to typical air dry grain (12-14% moisture) or approximately 10 gal. of water added per ton of grain. Wetting rate evaluations were conducted at 20 C (68 F), 40 C (104 F), 60 C (140 F), 80 C (176 F) and 95 C (204 F). Bottles were removed from the water bath after 5, 10, 15, 30, 45, 60, 75 and 90 minutes and the wetting solution-grain mixture was immediately filtered through a sintered glass crucible under strong suction. The crucible and grain were weighed immediately to determine the weight increase of the grain sample reflecting the amount of moisture absorbed. The raw data (percent moisture) was then fitted to a line by linear regression methods and the slope of the line expressed as percent moisture uptake per hour, thus giving an expression of wetting rate of the grain. Regression lines with correlation coefficients below .90 were not used and the wetting rate determinations were repeated. The wetting rate of each treatment at each temperature was compared to the water control using a t-test for homogeneity of regression described in Steel and Torrie (1980).

Wetting rate determinations of whole corn and sorghum at 20 C are shown in Table 1. With sorghum, there were no treatments which produced significantly higher wetting rates than the water control. With corn, all levels of sodium hydroxide treatment produced significant wetting rates as well as the lower application level of Wet Digest2. Shown in Table 2 are the wetting rates of corn and sorghum at 40 C. With sorghum, 3 or 6% sodium hydroxide and the high application level of Wet Digest1 produced significant wetting rates. With corn, eight treatments produced signif-

icantly higher wetting rates than the water control. Shown in Table 3 are the wetting rates of corn and sorghum at 60 C. All treatments except Grain-wet produced significant wetting rates with sorghum. With corn, 1, 3 and 9% sodium hydroxide, Grain-wet, E-Z Flake-4, Wet Digest1 (low level) and Wet Digest2 (high level) produced significant wetting rates. Shown in Table 4 are the wetting rates of corn and sorghum at 80 C. With sorghum, 1% and 2% sodium hydroxide, Grain-wet, E-Z Flake-4, and Wet Digest1 (low level) all produced significantly higher grain wetting rates than the water control. With corn, sodium hydroxide at levels of 2, 6 and 9%, E-Z Flake-4, Wet Digest1 (low level) and Wet Digest2 (low level) produced significant wetting rates. Wetting rates of the two grains at 95 C are shown in Table 5. Sodium hydroxide at all levels except 9% in sorghum produced significant wetting rates as well as Grain-wet and E-Z Flake. With corn, 1, 2 and 3% sodium hydroxide, Grain-wet, KEM-FLAK and Wet Digest2 (low level) produced significant wetting rates.

In order to examine overall effects of treatment, time and temperature on moisture content of corn and grain sorghum, models were proposed and tested. The data was analyzed by least squares regression methods using Statistical Analysis Systems procedures. Shown in Table 6 are the results of computer analysis of the data for two such models. The first model examined the simple relationship between water content of the grain and treatment. Only at 95 C with sorghum was treatment not a significant source of variation meaning basically that other variables such as time were greater sources of variation. As can be seen by the R-square values decreasing with increasing temperature, treatment was not a highly contributing factor to grain moisture at the higher temperatures. The second model shown in Table 6 examined the relationship between grain moisture and three sources of variation: treatment, time and the treatment by time interaction. The data was pooled across both grains and analyzed at each temperature. This model appeared to explain the data best with R-square values ranging from .88 to .95. A significant F value for the trt.xtime interaction source of variation would indicate that on the average the wetting solution treatments are definitely altering the rate at which the grain absorbs moisture. With this model, the treatment F values were highly significant at all temperatures and as expected, time was a highly significant source of variation at all temperatures. The treatment by time interaction effect was not significant at 20 C or 95 C which can probably be interpreted to mean that although the grain conditioners overall may be aiding moisture uptake there are probably few differences between the treatments at these temperatures. At 40 C, 60 C and 80 C the treatment by time interaction was highly significant meaning that there were some differences between treatments on rate of moisture uptake at these temperatures. This would tend to indicate that some of the treatments respond more to temperature changes than others. All of the sodium hydroxide treatments appear to respond well to temperature as well as several of the commercial products such as E-Z Flake-4 and Wet Digest2. Other models examining the effects of temperature and its interactions with other variables were tested. Temperature itself was a significant source of variation, however the interaction of temperature with treatment was not significant indicating that although a few treatments appeared to respond better to increased temperature on the average all treatments responded similarly to temperature. A model examining the interaction of temperature with time was also tested. As expected this interaction was significant, meaning that time and temperature are additive effects on the moisture content of grain.

Although these wetting rate determinations may appear confusing because of the large data base generated and the extensive statistical analyses conducted, we can draw some practical conclusions and make some recommendations on their use in the industry. First, we can conclude that overall the grain conditioners tested in these experiments do seem to improve the rate of moisture uptake by corn and grain sorghum. Secondly, the action of several of these grain conditioners is somewhat dependent on temperature and that overall temperature is an important factor in moisture absorption. Lastly, we can probably conclude that if grain conditioners are applied to grain, there may be some benefit to using heated water instead of cold water to apply the solution to aid the action of the grain conditioners.

The primary purpose of using grain conditioners is to aid in the addition of moisture to the grain. However, it is the opinion of many people in the industry that the grain conditioners by their chemical action and softening of the grain may improve the digestibility of the grain in the rumen. A series of experiments was conducted to examine this question. Samples of whole corn or grain sorghum were treated with the various grain conditioners according to the manufacturers' recommendations and allowed to react for at least 2 hrs. The treated samples were then cold rolled or steam flaked using laboratory scale equipment, with portions of the grain left intact as whole grain. Samples of the treated grain in the three process forms were weighed into 6 by 15 cm. dacron mesh bags, using approximately 3.5 gms of sample dry matter. The bags were tied to a heavy nylon cord with the bags location randomized on the cord and a sinker weight attached to prevent flotation of the bags in the rumen. The prepared bags and cord were suspended in the rumen of a fistulated steer for 24 hrs. The steer was fed twice daily a diet consisting primarily of 75% cracked corn, 20% cottonseed hulls and 5% supplement. This diet was offered at the rate of approximately 2% of the body weight daily. The 24 hr. incubation time was chosen because it is thought to be a good approximation of the retention time in the rumen of high concentrate diets. The procedure was repeated to provide at least 4 replicates of each treatment.

Shown in Table 7 are the dry matter disappearances (24 hrs.) of whole corn and grain sorghum. With whole corn, there were trends toward improved digestibility over the untreated control (water only added) but due to high variability between samples, the differences were not statistically significant. With milo, E-Z Flake and Wet Digest¹ produced significantly higher dry matter disappearance than the water control. Shown in Table 8 are the 24 hr. dry matter disappearances for cold rolled corn and grain sorghum. With grain sorghum, there was no apparent treatment effect, but this may have been due to extremely small particle size with these samples causing some "washout" of the samples from the dacron bags. With corn, the only significant treatment effect was that the reconstituted and ensiled corn had higher digestion than all other treatments. Shown in Table 9 are the 24-hr. dry matter disappearances for steam flaked corn and grain sorghum. With grain sorghum, there were no significant treatment effects but with corn there were some significant differences. In order to examine the effects that differences in particle size might have on the digestibility of the treated grain, samples were treated and ground through a 20-mesh screen to take out the particle size effect. The samples were then subjected to a 48-hour single stage in vitro fermentation with rumen fluid from a steer on a high concentrate diet. Results of this experiment are shown in Table 13. With corn, all digestibilities were extremely high and were not significantly different. With grain sorghum the main differences were that sodium hydroxide and E-Z

Flake had lower digestibility than the water control and additionally these two and Grain wet were lower than both Wet Digest enzymes. The reason for this apparently lower digestibility with these treatments is unclear.

In order to evaluate the effects of some of these treatments on animal performance, two lamb studies were conducted. The purpose of these studies was to evaluate the performance of lambs fed reconstituted or sodium hydroxide treated grain sorghum and to determine the feasibility of sodium hydroxide treated grain sorghum for use in cattle rations. The first experiment conducted was a lamb metabolism study using eight 45 kg. wether lambs allotted to wooden metabolism crates in a double 4x4 latin square design. The lambs were fed grain and a cottonseed hull based supplement at a ratio of 80:20 on a dry matter basis twice daily with feed refusal recorded and sampled for analysis. Each period of the trial consisted of 10 days adjustment to treatment and intake followed by 7 days total collection of feces and urine. The four treatments were as follows: Treatment 1, air dry grain sorghum ground to pass through a 3.2 mm. screen and considered to be the positive control; Treatment 2, reconstituted sorghum, prepared by adding water to dry grain to a moisture level of 30-35% followed by ensiling for at least 21 days before rolling; Treatment 3, sodium hydroxide treated and rolled grain sorghum, prepared by treating the grain with a 4% NaOH solution to a final concentration of 1.5% NaOH followed by rolling after 21 days; Treatment 4, was the same as trt. 3 but was fed as the whole grain instead of rolled. Shown in Table 10 are the compositions for the treated grain for dry matter, starch, crude protein, neutral detergent fiber and acid detergent fiber. There were no differences in starch content of the grain but all three treated grains had lower crude protein than the dry control possibly indicating some volatile loss of nitrogen from this grain. We are unable to explain the apparently higher NDF content of the NaOH treated grain except that the treatment could be making some non-fiber fractions less soluble and they are appearing in the NDF residue. Shown in Table 11 are the total tract digestibilities of the four treatments for dry matter, starch, crude protein, NDF and ADF. The sodium hydroxide treated and rolled grain had significantly lower starch digestibility than the dry ground control possibly due to a high rate of passage of the grain caused by the NaOH. This treatment also had the highest NDF digestibility but this may have just been due to the artificially high NDF content of this grain. There were no treatment differences in dry matter or crude protein digestibility.

In order to compare these metabolic characteristics with actual animal performance, a lamb feeding trial was conducted using essentially the same treatments as in the metabolism trial. Seventy-two crossbred feeder lambs were vaccinated for enterotoxemia, wormed and slowly adjusted to a high concentrate lamb starter ration over 21 days prior to the start of the experiment. The lambs were allotted 6 head per pen to allow 3 pen replications per treatment. The lambs were fed a complete supplement at the rate of .3 kg. per head daily and grain sorghum free choice in self feeders. The treated grain was prepared in the same manner as in the first experiment except that moisture levels were reduced some to avoid handling problems encountered previously. The lambs were weighed at 29, 56 and after 84 days on test. Shown in Table 12 is the results of the lamb feeding trial for feed intake, average daily gain and feed efficiency. Treatment means for these three statistics were not significantly different. Extremely hot weather prevalent in the summer of 1980 when this trial was conducted caused a few bunk spoilage problems and erratic intakes and may explain the poorer feed efficiency with this treatment.

There was no apparent response from rolling the sodium hydroxide treated grain as compared to the whole grain. The results of these lamb studies indicate that whole grain sorghum treated with sodium hydroxide may be a feasible grain source for lambs. These studies also indicate that sodium hydroxide treatment of grain may offer some limited potential to the cattle feeding industry.

CONCLUSIONS:

Overall we have seen from these studies that grain conditioners do seem to aid moisture uptake by grain and can be a useful tool in softening grain prior to processing. This wetting action is highly temperature sensitive and there are some treatment differences in this response. The use of grain conditioners seems to have a slightly positive effect on ruminal digestibility possibly by softening the seed coat or initiating hydrolysis of the starch. In interpreting this data we have not attempted to "rank" these products as to their effectiveness but rather to examine the overall effects of grain conditioners. Choice of particular products should depend on the feedmill arrangement as the products have varying physical characteristics. Overall this study indicates that grain conditioners do have a place in the industry and should be considered for use.

TABLE 1. WETTING RATES
OF WHOLE CORN AND SORGHUM

Wetting Solution	Temperature, 20 C (68 F)			
	Corn	(%/hour)		SE ^a
		SE	Sorghum	
Water	6.3	.4	4.7	1.2
Sodium Hydroxide, 1%	6.5	1.0*	7.4	1.1
Sodium Hydroxide, 2%	9.1	1.0 *	7.5	2.0
Sodium Hydroxide, 3%	9.1	.5 *	10.2	1.1
Sodium Hydroxide, 6%	12.7	1.7 *	11.2	1.1
Sodium Hydroxide, 9%	8.9	1.4 *	10.6	1.1
Temper	7.8	.9	4.8	.5
Grain-wet	2.8	.9	2.7	.4
KEM-FLAK	4.6	.8	4.7	.7
E-Z Flake	5.3	1.2	11.8	2.1
E-Z Flake-4	5.0	1.4	7.5	1.8
Wet Digest 1 (low level)	5.8	.9	5.2	.8
Wet Digest 1 (high level)	6.2	.7	4.1	.6
Wet Digest 2 (low level)	7.1	1.2	4.2	.7
Wet Digest 2 (high level)	5.4	1.0	4.2	1.0

SE Standard error of regression coefficient

^a Treatment means not different from water control (P > .10)

* Significantly greater than water control (P < .05)

TABLE 2. WETTING RATES
OF WHOLE CORN AND SORGHUM

Temperature, 40 C (104 F)				
Wetting Solution	Corn	SE	(%/hour)	
			Sorghum	SE
Water	6.2	.6	7.9	.9
Sodium Hydroxide, 1%	16.8	1.5*	18.7	2.9
Sodium Hydroxide, 2%	14.6	2.7	21.2	3.2
Sodium Hydroxide, 3%	11.3	.7*	15.0	.8*
Sodium Hydroxide, 6%	15.3	1.8*	19.3	1.8*
Sodium Hydroxide, 9%	20.0	3.6	19.6	3.4
Temper	7.1	.9	5.5	.8
Grain-Wet	8.6	1.3*	2.0	1.9
KEM-FLAK	8.0	.7*	7.6	1.0
E-Z Flake	5.8	.9	10.4	2.6
E-Z Flake-4	10.9	2.7	10.6	3.0
Wet Digest1 (low level)	7.0	2.7	7.0	1.1
Wet Digest1 (high level)	7.8	1.0*	8.3	.9*
Wet Digest2 (low level)	7.4	.8*	7.8	.8
Wet Digest2 (high level)	8.0	.5*	7.2	.8

SE Standard error of regression coefficient

* Significantly greater than water control (P < .05)

TABLE 3. WETTING RATES
OF WHOLE CORN AND SORGHUM

Wetting Solution	Temperature, 60 C (140 F)			
	Corn	SE (%/Hour)	Sorghum	SE
Water	8.4	1.0	9.0	1.4
Sodium Hydroxide, 1%	19.1	2.6*	22.3	2.4†
Sodium Hydroxide, 2%	21.1	3.4	28.4	3.0†
Sodium Hydroxide, 3%	16.4	1.1*	26.3	1.6*
Sodium Hydroxide, 6%	32.7	4.8	40.1	3.9*
Sodium Hydroxide, 9%	24.2	1.6*	31.2	1.4*
Temper	10.0	2.2	8.7	1.6†
Grain-wet	9.2	1.3*	3.5	2.7
KEM-FLAK	8.2	1.9	10.9	1.2*
E-Z Flake	8.2	1.4	13.3	1.9†
E-Z Flake-4	9.4	1.4*	11.9	1.4†
Wet Digest 1 (low level)	9.4	.9*	10.2	1.2*
Wet Digest 1 (high level)	8.6	1.2	10.9	1.6†
Wet Digest 2 (low level)	8.6	1.5	11.3	.8*
Wet Digest 2 (high level)	9.4	1.4*	11.3	2.1†

SE Standard error of regression coefficient

* Significantly greater than water control (P<.05)

† Significantly greater than water control (P<.10)

TABLE 4. WETTING RATES
OF WHOLE CORN AND SORGHUM

Wetting Solution	Temperature, 80 C (176 F)			
	Corn	SE	Sorghum	SE
Water	12.8	1.5	12.2	2.3
Sodium Hydroxide, 1%	31.4	5.2	22.5	2.7*
Sodium Hydroxide, 2%	32.5	3.9*	45.4	4.4†
Sodium Hydroxide, 3%	27.5	4.4	29.8	7.8
Sodium Hydroxide, 6%	26.5	3.0*	36.8	4.2
Sodium Hydroxide, 9%	30.7	3.0*	36.5	5.7
Temper	13.3	1.7	16.7	2.5
Grain-wet	11.3	1.0	13.5	1.4*
KEM-FLAK	10.6	2.0	13.0	2.0
E-Z Flake	12.5	1.0	10.4	1.6
E-Z Flake-4	19.9	1.4*	18.4	3.6†
Wet Digest 1 (low level)	21.2	2.7*	21.2	3.2†
Wet Digest 1 (high level)	11.1	3.2	13.9	3.3
Wet Digest 2 (low level)	15.9	2.1*	16.0	2.4
Wet Digest 2 (high level)	11.8	1.3	13.7	3.1

SE Standard error of regression coefficient

* Significantly greater than water control (P<.05)

† Significantly greater than water control (P<.10)

TABLE 5. WETTING RATES
OF WHOLE CORN AND SORGHUM

Wetting Solution	Temperature, 95 C (204 F)			
	Corn	SE	Sorghum	SE
Water	19.7	2.0	29.8	1.9
Sodium Hydroxide, 1%	25.7	2.2*	36.5	3.5*
Sodium Hydroxide, 2%	26.9	4.0*	41.2	3.6*
Sodium Hydroxide, 3%	38.7	4.3*	53.6	5.0*
Sodium Hydroxide, 6%	52.5	8.8	58.6	8.2*
Sodium Hydroxide, 9%	58.3	11.4	86.4	12.8
Temper	14.9	1.5	23.1	3.5
Grain-wet	25.1	3.3*	30.4	2.3*
KEM-FLAK	21.2	2.4*	29.3	3.0
E-Z Flake	16.7	1.8	29.8	2.8*
E-Z Flake-4	14.6	1.8	23.1	2.9
Wet Digest 1 (low level)	13.9	1.4	23.9	2.2
Wet Digest 1 (high level)	16.3	1.9	23.6	2.1
Wet Digest 2 (low level)	22.3	4.0*	27.0	3.0
Wet Digest 2 (high level)	17.6	1.7	23.4	1.8

SE Standard error of regression coefficient

* Significantly greater than water control ($P < .05$)

TABLE 6.
OVERALL ANALYSIS OF WETTING RATE DATA

Model Percent Water = Treatment

Temperature	DF	SS	F	R ²	Probability	
Corn (20 C)	15	4072.3	16.7	.69	.0001	SIG
Corn (40 C)	15	5805.4	10.9	.60	.0001	SIG
Corn (60 C)	15	9736.8	11.2	.60	.0001	SIG
Corn (80 C)	15	6929.8	3.9	.35	.0001	SIG
Corn (95 C)	15	6886.9	3.2	.32	.0002	SIG
Sorghum (20 C)	15	2388.5	11.6	.61	.0001	SIG
Sorghum (40 C)	15	5005.1	7.1	.49	.0001	SIG
Sorghum (60 C)	15	7219.9	6.2	.47	.0001	SIG
Sorghum (80 C)	15	8885.4	4.2	.37	.0001	SIG
Sorghum (95 C)	15	3502.8	1.0	.12	.4896	NS

Model Percent Water = Treatment Time Treatment X Time
(By temperature across both grains)

Temp. 20 C						
Treatment	15	5597.8	36.8	.88	.0001	SIG
Time	7	2546.7	35.9		.0001	SIG
Trt. X Time	105	490.7	.5		1.0000	NS
Temp. 40 C						
Treatment	15	10340.6	87.0	.95	.0001	SIG
Time	7	6474.0	116.7		.0001	SIG
Trt. X Time	105	1779.1	2.1		.0001	SIG
Temp. 60 C						
Treatment	15	16488.5	94.67	.95	.0001	SIG
Time	7	10433.1	128.36		.0001	SIG
Trt. X Time	103	3017.3	2.52		.0001	SIG
Temp. 80 C						
Treatment	15	15428.9	43.3	.93	.0001	SIG
Time	7	22048.9	132.7		.0001	SIG
Trt. X Time	103	4462.2	1.8		.0007	SIG
Temp. 95 C						
Treatment	15	11264.1	20.12	.92	.0001	SIG
Time	7	26673.4	102.12		.0001	SIG
Trt. X Time	98	3067.8	.84		.8150	NS

TABLE 7
In situ Digestibility - Whole Grain

<u>Wetting Solution</u>	Dry Matter Disappearance	
	<u>Corn</u>	<u>Milo</u>
Water	5.12	4.14 ^c
Sodium Hydroxide, 3%	7.90	5.04 ^{a,b,c}
Sodium Hydroxide, 6%	8.03	5.56 ^{a,b,c}
Sodium Hydroxide, 9%	6.96	5.97 ^{a,b,c}
Temper	6.32	4.72 ^{a,b,c}
Grain-wet	5.96	4.45 ^{b,c}
KEM-FLAK	8.76	4.48 ^{b,c}
E-Z Flake	8.93	6.82 ^a
Wet Digest 1	8.87	6.42 ^{a,b}
Wet Digest 2	8.74	6.09 ^{a,b,c}
Reconstituted	9.56	----

a,b,c Means in the same column with different superscripts differ ($P < .05$)

TABLE 8
In situ Digestibility - Cold Rolled Grain

<u>Wetting Solution</u>	Dry Matter Disappearance	
	<u>Corn</u>	<u>Milo</u>
Water	55.58 ^b	53.38
Sodium Hydroxide, 3%	54.08 ^b	49.51
Sodium Hydroxide, 6%	50.12 ^b	48.20
Sodium Hydroxide, 9%	52.88 ^b	49.06
Temper	54.06 ^b	51.21
Grain-wet	47.92 ^b	49.08
KEM-FLAK	54.89 ^b	46.93
E-Z Flake	56.59 ^b	52.47
Wet Digest 1	48.91 ^b	49.15
Wet Digest 2	48.29 ^b	50.90
Reconstituted	69.33 ^a	-----

a,b Means in the same column with different superscripts differ (P < .05)

TABLE 9
In situ Digestibility - Steam Flaked Grain

<u>Wetting Solution</u>	Dry Matter Disappearance	
	<u>Corn</u>	<u>Milo</u>
Water	37.86 ^{a,b}	35.41
Sodium Hydroxide, 3%	33.12 ^{b,c}	31.04
Sodium Hydroxide, 6%	37.99 ^{a,b}	35.67
Sodium Hydroxide, 9%	41.77 ^{a,b}	37.41
Temper	39.99 ^{a,b}	34.05
Grain-wet	38.98 ^{a,b}	33.59
KEM-FLAK	38.84 ^{a,b}	36.30
E-Z Flake	38.22 ^{a,b}	34.14
Wet Digest 1	36.03 ^{a,b}	37.09
Wet Digest 2	31.28 ^{b,c}	34.46
Reconstituted	45.03 ^a	-----

a,b,c Means in the same column with different superscripts differ (P < .05)

TABLE 10
Lamb Metabolism Study

Grain Composition (Dry Matter Basis)

	TREATMENT			
	Dry Ground	Reconstituted	NaOH-R	NaOH-W
Grain Dry Matter (%)	86.6 ^a	65.2 ^c	73.7 ^b	76.0 ^b
Starch (%)	65.55	65.28	64.43	65.43
Crude Protein (%)	9.79 ^a	8.63 ^b	8.64 ^b	8.24 ^b
NDF (%)	15.84 ^{b,c}	10.49 ^c	24.90 ^a	19.21 ^{a,b}
ADF (%)	8.50	7.30	7.94	6.36

a,b,c means in the same line with unlike superscripts are different (P < .05)

TABLE 11
Lamb Metabolism Study

	TREATMENT			
	Dry Ground	Reconstituted	NaOH-R	NaOH-W
Average Daily Feed (Kg)	1.126	1.008	1.105	1.092
Nutrient Digestibility - (Dry matter basis)				
Dry Matter Apparent Digestibility (%)	74.4	74.0	70.5	70.2
Starch (%)	86.69 ^a	82.99 ^{a,b}	79.60 ^b	82.76 ^{a,b}
Crude Protein (%)	41.84	35.17	38.49	29.51
N-Retention (Gm/day)	3.64	2.19	3.17	1.61
NDF (%)	50.17 ^b	33.88 ^c	58.89 ^a	47.35 ^b
ADF (%)	42.31	34.38	38.95	31.67

a,b,c Means in the same row with unlike superscripts are different (P < .05)

TABLE 12
Lamb Feeding Trial

	TREATMENT			
	Dry Ground	Reconstituted	NaOH-R	NaOH-W
Grain Dry Matter (%)	88.6	77.2	85.6	85.1
^a Average Daily Feed (Kg)	1.18	1.09	1.09	1.13
^a Average Daily Gain (Kg)	.192	.177	.176	.183
^a Feed Efficiency (F/G)	6.30	6.56	6.35	6.36

a Means not different ($P < .05$)

TABLE 13

24-HR. IN VITRO DIGESTIBILITY OF CORN AND GRAIN SORGHUM

Wetting solution	Dry Matter Digestibility (%)	
	Corn	Milo
Water	97.2	90.7 ^{ab}
Reconstituted	96.1	-----
Sodium Hydroxide, 3%	98.0	82.8 ^d
Temper	95.0	90.8 ^{ab}
Grain wet	94.7	89.1 ^b
KEM-FLAK	92.6	92.9 ^a
E-Z Flake	95.9	83.8 ^{cd}
Wet Digest1	92.3	92.1 ^a
Wet Digest2	94.8	93.3 ^a

a,b,c,d Means with different superscripts in the same column are significantly different (P < .05)