INFLUENCE OF TEMPERING ON THE COMPARATIVE FEEDING VALUE OF ROLLED AND STEAM-FLAKED CORN FOR FEEDLOT STEERS

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ABSTRACT

Two trials were conducted to evaluate the influence of tempering and flaking on the (comparative feeding value of corn for feedlot cattle. Four dietary treatments were compared: 1) rolled corn; 2) rolled plus tempered corn; 3) steam flaked corn and 4) steam flaked plus tempered corn. The basal diet contained (dry matter basis) 6% alfalfa hay, 6% sudangrass hay, 69% corn, 4.7% cottonseed meal, 4% fat. 7% molasses and 3.3% vitamin-mineral supplement. Both tempering and steam-flaking increased the moisture content of the corn (P<.0l). Tempering alone, increased the moisture content of corn 7.5%, corresponding closely with the amount of water added to the grain. Steam-flaking increased the moisture content of the grain 4.5%. The combination of tempering and steam flaking increased the moisture content of corn 9%. Reactivity of starch to amyloglucosidase was increased 102% by steam-flaking (P<.0l). Nevertheless, gelatinization of starch with steam-flaking was low, averaging 10.8%. Tempering did not influence reactivity of starch to amyloglucosidase (P>.10). Treatment effects on animal performance and estimated net energy value of the diet were evaluated in a 126-d comparative slaughter trial involving 78 crossbred steers (228 kg). There were no interactions between tempering and corn processing method (P>.10). Steam-flaking resulted in a 7.1% reduction in dry matter intake and a 4.8% improvement in feed efficiency (P<.05). Steam-flaking increased the net energy value of the diet for maintenance (NEm) and gain (NEg) by 5.3 and 6.9%, respectively (P<.01). Steam-flaking increased the NEm and NEg value of corn 6.7 and 8.2%, respectively. Tempering corn tended to reduce dry matter intake and improve feed conversion (P>.10). Tempering increased the NEm and NEg value of the diet 3.7 and 4.4%, respectively (P<.05). Tempering increased the NEm and NEg value of corn 3.9 and 5.0%, respectively. Dietary treatment effects on ruminal and total tract digestion were evaluated in a metabolism trial involving 4 ruminally and intestinally cannulated steers (213 kg). Steam-flaking increased (P<.0l) ruminal and total tract digestion of starch 14.3 and 7.6%, respectively. Steam-flaking increased (P<.05) the digestible energy (DE) *value of* the diet 5.7%. Steam-flaking increased the DE value of corn 11.l%, compared with dry-rolling. Tempering did not influence (P>.10} ruminal digestion of starch. Tempering improved (P<.05) ruminal microbial efficiency 15.8%.There was an

interaction (P<.10) between tempering and corn processing method on DE value of the diet. Tempering did not influence the DE value of the steam-flaked corn diet. However, it increased the DE value of the rolled corn diet 5.2%.

Introduction

Restoring moisture back to grain prior to rolling is generally thought to be beneficial. By softening the grain it may reduce the energy cost of rolling as well as help to maintain the integrity of the kernel as it leaves the rollers and thereby reduce dustiness and fines while maintaining some of the "roughage" characteristics of whole grain. However, limited data (Wilson et al. .1973) indicates that moisture content of corn (15 to 35%), per se, may not have an important influence on its energy value. The objective of this study was to determine the influence of tempering prior to rolling or steam-flaking on the feeding value of corn for feedlot cattle.

Experimental Procedures

Trail 1. Seventy eight crossbred (approximately 25% Brahman blood with the remainder represented by Hereford. Angus, Shorthorn and Charolais breeds in various proportions) steers with an average weight of 228 kg were used in a 126-d comparative slaughter trial to evaluate the influence of tempering and flaking on the feeding value of corn. Four corn processing treatments were compared: 1) rolled; 2) tempered and rolled; 3) steam-flaked and 4) tempered and steam-flaked. Tempering consisted of applying 7.5% water to the corn and then allowing it to set for 2 h prior to further processing. A commercial tempering agent (SarTemp[1]) was applied to the corn with the water at the rate of .165 ml/kg corn. Rolled corn was prepared by passing corn through rollers which had been adjusted so that approximately 95% of the kernels had been broken. Steam-flaked corn was prepared by exposing corn to steam at atmospheric pressure for approximately 15 minutes and then passing it through rollers which were adjusted to provide a flake with a density of approximately 340 g/l. Composition of the basal diet to which corn was added is shown in Table 1. Six steers were selected at random and slaughtered to determine initial body composition. The remaining steers were blocked by weight and randomly allotted to 12 pens (6 steers/pen) equipped with automatic waters and fence-line feed bunks. Upon initiation of the study and then subsequently at day 70 ,steers were implanted with Synovex-S[2]. Diets were prepared at weekly intervals and stored in plywood boxes located in front of each pen. Steers were fed twice daily approximately 110 % of appetite. Hot carcass weights were obtained from all steers at time of slaughter. After the carcasses were chilled for 48 h. The following measurements were

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1 SarTec Corp. Anoka, MN
2 Syntax Corp. Des Moines, IA

obtained: 1) longissimus muscle area (ribeye area), taken by direct grid reading of the eye muscle at the twelfth rib; 2) subcutaneous fat over the eye muscle at the twelfth rib, taken at a location 3/4 the lateral length from the chine bone end (adjusted by eye for unusual fat distribution); 3) kidney, pelvic and heart fat (KPH) as a percentage of carcass weight; 4) marbling score (USDA, 1965) and 5) carcass specific gravity. Empty body weight and empty body and carcass composition (percentage water, protein, fat and energy) were based carcass weight and carcass specific gravity, respectively, as outlined by Garrett and Hinman (1969). Net energy content of the diet for maintenance (NEm, Mcal/kg) and gain (NEg. Mcal/kg) was calculated assuming a constant fasting heat production of .077 $W^{.75}$ Mcal/day (Lofgreen and Garrett, 1968), where W is empty body weight (kg). From estimates of energy retention (ER) and energy expended for maintenance (MQ), the NEm and NEg values of the diets were obtained by process of iteration to fit the relationship: NEg = (.877NEm)-.41 (adapted from NRC, 1984). The comparative NEm and NEg value of corn using the various processing methods was determined using the replacement technique. It is assumed that the net energy value of tempered, flaked and tempered plus flaked corn is equal to the net energy value of the dry rolled corn they replaced plus the change in net energy content of the complete diet brought about by the replacement. Given that the NEm, NEg values for the rolled corn (IFN 4-02-931) used in the replacement, were 2.24 and 1.55 mcal/kg, respectively (NRC, 1984), the NEm and NEg values for corn as a result of tempering, flaking and tempering plus flaking were estimated as follows:

Test corn NEm=(((NEm test diet - NEm rolled corn diet)/.69)+2.24,

Test corn NEg=(((NEg test diet - NEg rolled corn diet)/.69)+1.55.

This trial was analyzed as a randomized complete block design experiment with a 2X2 factorial arrangement of treatments (Hicks, 1973).

Trial 2. Four crossbred steers (213 kg) of similar breeding to those used in trial 1, with "T" cannulas in the rumen, and proximal duodenum (6 cm from the pyloric sphincter) were used to evaluate treatment effects on characteristics of digestion and rumen function. Dietary treatments were as indicated for trial 1 with the inclusion of .42% chromic oxide as a digesta marker. Dry matter intake was restricted to 2.2% of body weight. Diets were fed at 0800 and 2000 h daily. Following a two week diet adjustment period, duodenal and fecal samples were taken from all steers, twice daily over a period of 4 successive days as follows; d 1. 0750 and 1350 h; d 2. 0900 and 1500 h; d 3, 1050 and 1650 h and d 4. 1200 and 1800 h. Individual samples consisted of approximately 500 ml duodenal chyme and 200 9 (wet basis) fecal material. Samples from each steer and within each period were composited for analysis. Upon completion of the trial, ruminal fluid was obtained from all steers and composited for isolation of ruminal bacteria, via differential centrifugation (Bergen et al. , 1968) Samples were subjected to all or part of the following analysis: dry matter (oven drying at 105 C until no further weight loss); ash, Kjeldahl N, ammonia N (AOAC, 1975); gross energy (adiabatic bomb calorimeter); ADF (Goering and Van Soest, 1970): purines (Zinn and Owens, 1986) and chromic oxide (Hill and Anderson, 1958). Starch was assayed as follows: 1) place 200 mg ground sample in 20 ml screw cap culture tube along with 10 ml H_2O and gently mix; 2) tightly cap tube and incubate at 100 C in a shaking water bath for 3 h (gelatinization step); 3) allow tube to cool and then add 10 ml buffer {9.91 g sodium acetate (anhydrous) plus 7.27 ml glacial acetic acid in 1 liter H_2O), 80 units amyloglucosidase (1 mg enzyme) and 1 drop toluene; 4) tightly cap, gently mix and incubate at 55 C for 2 h in shaking water bath; 5) transfer 1 ml of starch hydrolyzate solution to a 10 ml centrifuge tube, add 4 ml TCA solution (30 g trichloroacetic acid in 1:l H_2O), vortex and let stand for 5 minutes; 6) Centrifuge a 6000 rpm for 10 minutes; 7) Transfer 4 ml o-toluidine (solution of 6% ortho-toluidine in glacial acetic acid)[3] into a separate test tube, add 150 ul TCA supernatant solution, cover with marble and incubate at 100 C in water bath for 10 minutes; 8) remove tubes and place in ice bath for 5 minutes; 9) read absorbance at 630 nm (adapted from Macrae and Armstrong, 1968). Gelatinization of starch as a result of processing was determined by first grinding dry grain samples in a Wiley mill to pass through a 60 mesh screen and then proceeding as indicated for starch analysis except for the deletion of step 2. Microbial organic matter (MOM) and N (MN) leaving the abomasum was calculated using purines as a microbial marker (Zinn and Owens, 1986). Organic matter fermented in the rumen (OMF) was considered equal to organic matter (OM) intake minus the difference between the amount of total OM reaching the duodenum and MOM reaching the duodenum. Feed N escape to the small intestine was considered equal to total N leaving the abomasum minus ammonia-N and MN and, thus, includes any endogenous contributions. The trial was analyzed as a 4 x 4 Latin square design experiment with a 2 x 2 factorial arrangement of treatments (Hicks, 1973).

Results and Discussion

The influence of tempering on corn moisture content and starch reactivity to amyloglucosidase (a measure of gelatinization or disruption of the starch granule) is shown in Table 2. Both tempering and steam-flaking increased the moisture content of the grain (P<.01). Tempering alone, increased the moisture content of corn 7.5%, corresponding closely with the amount of water added to the grain. Steam-flaking increased the moisture content of the grain 4.5%, consistent with findings of Johnson at al (1968), who noted a 5% increase in moisture content

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3 Stanbio Lab, Inc. San Antonio, TX

of corn that was steam-flaked under conditions similar to those used in this study. There was however, an interaction between tempering and flaking ($P<.05$). The combination of tempering and steam flaking increased the moisture content of corn 9%.

Reactivity of starch to amyloglucosidase was increased 102% by steam-flaking ($P<.01$). Nevertheless, gelatinization of starch with steam-flaking was low, averaging 10.8%. Tempering did not influence reactivity of starch to amyloglucosidase ($P>.10$).

The influence of corn processing techniques on feedlot performance and estimated net energy (NE) value of the diet is shown in Table 3. There were no interactions between tempering and corn processing method ($P>.10$). Steam-flaking corn resulted in a 7.1% reduction ($P<.05$) in feed intake and a 4.8% improvement (P(.05) in feed conversion. Estimated NE value of the diet for maintenance and gain was increased 5.3 and 6.9%, respectively ($P<.01$), as a result of steam-flaking the corn. Because steam flaked corn was substituted for an equal quantity of rolled corn in the diet, it may be assumed that the NE of steam-flaked corn is equal to the NE of the rolled corn it replaced plus the change in the NE of the complete diet brought about by the replacement. Accordingly, steam flaking improved the NE value of corn 6.7 and 8.2%, respectively, for maintenance and gain (Table 4). These estimates are in very close agreement with tabular values for rolled versus steam-flaked corn as reported in NRC (1984). However, they reflect a much smaller improvement then would be expected based on results of previous studies (Matsushima and Montgomery, 1967; Lee et al., 1982; Ramirez et al., 1985: Zinn, 1987).

Tempering corn also tended to reduce dry matter intake and improve efficiency, however, differences were not statistically significant ($P>.10$). Tempering corn increased ($P<.05$) the NE_m and NE_g of the diet 3.7 and 4.4%, respectively. Tempering increased the net energy value of the corn 3.9 and 5.0%, respectively (Table 4).

The influence of corn processing techniques on carcass merit is shown in Table 5. There were no treatment effects on carcass merit or body composition ($P>.10$).

The influence of processing techniques on characteristics of digestion is shown in Table 6. Steam-flaking did not influence ruminal or total tract digestion of fiber. Steam-flaking increased ruminal and total tract starch digestion 14.3 and 7.6%, respectively ($P<.01$). Similar improvements in ruminal and total tract starch digestion with steam-flaking have been reported by Zinn (1987). Steaming, alone, probably does not account for this improved utilization of starch (Johnson et al., 1968; Osman et al., 1970). Increased digestibility appears to results largely from physical changes that occur during flaking (French, 1973). Because disruption of the starch granule and gelatinization of starch also occurs to some varying degree with flaking it has been generally assumed that the efficiency of the steam-flaking process is directly proportional to the degree of gelatinization. However, studies indicate that the feeding value of corn for ruminants may actually be depressed at higher levels of gelatinization (Johnson et al., 1968; Mudd and Perry, 1969). Thus, it is interesting that in this trial total tract starch digestion was nearly complete (98.4%) with steam-flaked corn containing only 10 to 11% gelatinized starch (Table 2). Steam-flaking tended (P>.10) to increase non-ammonia N flow to the small intestine, reflecting an increase in ruminal microbial protein synthesis (P<.0l). Prigge et al (1978) also noted increased ruminal microbial protein synthesis with steam-flaked corn diets. In contrast, Zinn (1987) did not observe changes in microbial synthesis with steam-flaked as compared to rolled corn based diets. Apparent total tract N digestion was also greater (P<.01) for the steam-flaked corn based diet. Zinn (1987) noted no change apparent N digestion with steam flaking while Prigge et al (1978) reported decreased total tract N digestion with steam-flaked as compared to rolled corn diets. Changes in apparent N digestion may reflect extent of post-gastric fermentation rather than digestibility of corn protein, per se. Ruminal organic matter digestion was not influenced (P>.10) by processing method. However, steam-flaking increased total tract organic matter digestion 5.7% (P<.01) and digestible energy {DE, Mcal,kg) value of the diet 5.7% (P<.01).

Tempering corn did not influence ruminal digestion of organic matter, starch or N (P>.10). However, ruminal fiber digestion tended (P>.10) to be depressed. The most notable effect of tempering on ruminal digestion was a 15.8% increase (P<.05) in microbial efficiency. This response may have resulted from the yucca extract contained in the tempering agent. Other researchers (Grobner et al., 1982; Zinn et al., 1983) have noted increased ruminal microbial efficiency with yucca extract supplementation. Although not as yet verified, saponins contained in the yucca extract are thought to be the biologically active components in this regard.

Total tract digestion of organic matter and fiber were not affected by tempering. Although ruminal digestion of starch was not affected, tempering improved total tract starch digestion 3.5% (P<.10). This improvement in starch digestion was most noted with the rolled corn treatments where tempering increased starch digestion 6.5%. Apparently, the tempered corn had a greater intestinal digestibility than dry-processed corn. There was an interaction (P<.10) between tempering and corn processing method on DE value of the diet. With rolled corn, tempering improved the DE value of the diet 5.2%. In contrast, with the steam-flaked corn treatments, tempering did not influence the DE value of the diet. Thus, while tempering did not influence the DE value of steam-flaked corn, it increased the DE value of rolled corn 6% (Table 4). The digestible energy value of steam-flaked corn was 11.1% greater than that of rolled corn.

Net energy value of the diets can be estimated from DE using the following equations:

$NEm = -.661 + .736DE$

$NEg = -.410 - .87NEm$

(adapted from NRC, 1984). In this manner the corresponding NEm and NEg values for the rolled, tempered plus rolled, steam-flaked and tempered plus steam-flaked corn diets in trial 2 are 1.75, 1.11; 1.87, 1.22; 1.97, 1.30; 1.93, 1.27, respectively. Based on the results of the metabolism trial (trial 2), the expected improvement in NEm and NEg for steam-flaked versus dry rolled corn would be 14.4 and 18.0%, respectively. These improvements in estimated NE value of corn as a result of steam-flaking are higher (110%) than those estimated from the comparative slaughter trial (trial 1), but are in closer agreement with estimates obtained from previously reported studies comparing dry-processed and steam-flaked corn (Matsushima and Montgomery, 1967; Johnson and et al., 1968; Lee et al., 1982; Ramirez et al., 1985; Zinn, 1987).

The improvements in estimated NEm and NEg of tempered versus dry rolled corn (trial 2) are 7.9 and 10.5%, respectively. The estimated NE response to tempering rolled corn was 95% higher for trial 2 compared to trial 1.

The NE estimates for the diets used in trials 1 and 2 were in reasonably close agreement. The average difference between estimates based on the comparative slaughter trial and those based on the digestion trial was 2.3%. Most notable exceptions between estimates obtained from the two trials are the lack of interaction in trial 1 (tempering response was similar for rolled and steam-flaked corn) and the higher (5.1%} estimated NE value of the dry-rolled corn diet for trial 1 compared to trial 2.

More work is needed to adequately assess the merits of tempering corn, particularly in combination with other processing techniques such as rolling and flaking. The trials reported here were designed to provide preliminary information on the influence of tempering on the energy value of the corn. Since tempered and steam-flaked corn diets were allowed to air-dry prior to diet formulation, the trials do not consider the influences of the added moisture on diet palatability and nutrient utilization. Furthermore, the discrepancy between results of trials 1 and 2 with respect to influence of tempering on the energy value of steam-flaked corn indicates that some component of the tempering compound may be influencing animal performance indirectly or independently of starch digestion. Changes in microbial efficiency with tempered corn (trail 2) support this contention.

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Table 1. COMPOSITION OF BASAL DIET (TRIALS 1 AND 2)[a]

Item	%
Corn	68.91
Sudangrass hay	6.00
Alfalfa hay	6.00
Cottonseed meal	4.72
Molasses	7.00
Fat	4.00
Dicalcium phosphate	.27
Limestone	1.85
Urea	.75
Trace mineral salt[b]	.50
Monensin[c]	+
Vitamin A[d]	+

[a]Dry matter basis.

[b]Trace mineral salt contained: $CoSO_4$, .068%; $CuSO_4$, 1.04%; $FeSO_4$, 3.57%; ZnO, .75%; $MnSO_4$, 1.07%; KI, .052%; and NaCl, 93.4%.

[c]31 mg/kg.

[e]2200 IU/kg.

Table 2. INFLUENCE OF TEMPERING ON MOISTURE CONTENT AND IN VITRO STARCH DIGESTION OF ROLLED AND STEAM-FLAKED CORN

Item	Rolled Corn		Flaked Corn		SD^a
	Control	Tempered	Control	Tempered	
Dry matter, %					
Original	88.5	88.5	88.5	88.5	1.4
Leaving rollers[bcd]	88.5	81.0	84.0	79.5	2.7
Gelatinized starch, %[ce]	5.46	5.26	11.13	10.48	.92

[a] Standard deviation.

[b] Main effect of control versus tempered corn ($P<.01$).

[c] Main effect of rolled versus steam flaked corn ($P<.01$).

[d] Tempering by corn processing interaction ($P<.05$).

[e] Starch which is susceptible to enzymatic digestion by amyloglucosidase.

Table 3. INFLUENCE OF CORN PROCESSING TECHNIQUES ON FEEDLOT PERFORMANCE AND ESTIMATED NET ENERGY VALUE OF THE DIET (TRIAL 1)

Item	Rolled Corn		Flaked Corn		SD[a]
	Control	Tempered	Control	Tempered	
Empty body weight, kg					
Initial	227	229	228	230	6
Final	427	420	415	424	13
Empty body gain, kg/d	1.58	1.52	1.48	1.54	.09
Dry matter intake, kg/d[b]	8.40	7.87	7.48	7.63	.33
Dry matter conversion[b]	5.33	5.20	5.05	4.97	.04
Diet net energy, Mcal/kg					
Maintenance[cd]	1.84	1.91	1.94	2.01	.05
Gain[cd]	1.21	1.26	1.29	1.35	.04

[a]Standard deviation.
[b]Main effect of rolled versus steam flaked corn, $P<.05$.
[c]Main effect of rolled versus steam flaked corn, $P<.10$.
[d]Main effect of control versus tempered corn, $P<.05$.

Table 4. INFLUENCE OF TEMPERING ON THE COMPARATIVE DIGESTIBLE AND NET ENERGY VALUE OF CORN

Item	Digestible Energy[a]	Net Energy, Mcal/kg[b]	
		Maintenance	Gain
Rolled corn			
Control	3.97	2.24	1.54
Tempered	4.21	2.33	1.62
Flaked corn			
Control	4.41	2.39	1.67
Tempered	4.34	2.48	1.75
Improvement over dry rolled corn, %			
Tempered	6.0	4.0	5.2
Flaked	11.1	6.7	8.4
Tempered plus flaked	9.3	10.7	13.6

[a]Trial 2
[b]Trial 1

Table 5. INFLUENCE OF CORN PROCESSING TECHNIQUES ON CARCASS MERIT OF FEEDLOT STEERS (TRIAL 1)

Item	Rolled Corn		Flaked Corn		
	Control	Tempered	Control	Tempered	SD[a]
Dressing percentage	63.5	62.8	63.0	64.0	1.6
Rib eye area, cm^2	81.1	82.7	81.0	82.5	4.2
Fat thickness, cm	.89	.68	.80	.87	.17
KPH, %	2.36	2.11	2.33	2.22	.30
Marbling score, degrees	3.49	3.78	3.68	3.79	.38
Retail yield, %	51.6	52.5	51.9	51.9	.61
Empty body composition, %					
Water	55.8	56.0	55.9	55.6	1.5
Protein	16.8	16.8	16.8	16.7	.4
Fat	23.6	23.3	23.5	23.9	2.0

[a]Standard deviation.

Table 6. INFLUENCE OF TEMPERING ON CHARACTERISTICS OF DIGESTION OF ROLLED AND STEAM-FLAKED CORN DIETS (TRIAL 2)

Item	Rolled Corn		Flaked Corn		
	Control	Tempered	Control	Tempered	SD[a]
Intake, g/d					
Organic matter	4,356	4,348	4,357	4,362	
Starch	1,783	1,772	1,806	1,783	
Acid detergent fiber	402	411	384	384	
N	89	90	87	89	
Gross energy, Mcal/d	20.6	20.7	20.8	20.6	
Leaving abomasum, g/d					
Organic matter	2,362	2,629	2,323	2,463	230
Starch[b]	520	638	396	431	92
Acid detergent fiber	291	334	315	351	52
Non-ammonia N	98.9	103.7	104.5	107.8	7.1
Microbial N[b]	65.4	67.3	75.8	76.5	3.3
Feed N	33.5	36.4	28.6	31.3	8.1
Ruminal digestion, %					
Organic matter	45.8	39.5	46.7	43.5	5.3
Starch[b]	70.8	63.9	78.1	75.8	5.3
Acid detergent fiber	27.5	18.7	18.0	8.6	13.2
Feed N	62.4	59.7	67.0	64.9	8.9
Microbial efficiency[cde]	33.2	39.5	37.5	42.4	3.6
Fecal excretion, g/d					
Organic matter[b]	1,045	917	782	800	104
Starch[bf]	197.8	93.4	28.3	16.6	56.2
Acid detergent fiber	270	280	250	275	22
N[b]	31.8	30.5	24.7	27.0	2.6
Gross energy, Mcal/d[g]	5.41	4.67	4.21	4.25	.48
Total tract digestion, %					
Organic matter[b]	76.0	78.9	82.0	81.7	2.4
Starch[bf]	88.9	94.7	98.4	99.1	3.1
Acid detergent fiber	32.8	31.9	35.0	28.4	5.7
N[b]	64.2	66.2	71.6	69.8	2.8
Digestible energy, Mcal/kg[bh]	3.27	3.44	3.57	3.52	.10

[a] Standard deviation.
[b] Main effect of rolled versus steam flaked corn, P<.01.
[c] Microbial N, g/kg organic matter fermented.
[d] Main effect of control versus tempered corn, P<.05.
[e] Main effect of rolled versus steam flaked corn, P<.10.
[f] Main effect of control versus tempered corn, P<.10.
[g] Main effect of rolled versus steam flaked corn, P<.05.
[h] Tempering by corn processing interaction, P<.10.