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EFFECT OF PROCESSING VARIABLES ON CHARACTERISTICS OF STEAM-FLAKED CORN

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Summary

We evaluated tempering moisture concentration, addition of a surfactant to improve moisture uptake, steam conditioning time, and flake density to determine their impact on characteristics of steam-flaked corn. Increasing steam conditioning time from 20 to 40 minutes or adding a surfactant during tempering did not increase final flake moisture concentration, but moisture content of flaked corn was linearly increased by increasing tempering moisture concentration. Addition of Grain Prep® surfactant during tempering decreased ($P<0.05$) the amount of moisture lost during flaking. Flake durability was increased by increasing tempering moisture concentration, but only if corn was steamed for 40 minutes (tempering moisture × steam time interaction; $P<0.10$). Decreasing flake density linearly increased both starch availability ($P<0.01$) and flake durability ($P<0.05$). In this experiment, tempering moisture concentration had the largest impact on flake moisture content, and flake density was the most influential variable altering flake durability and starch availability.

Introduction

Steam-flaking is a common method of processing grain for cattle fed in confinement. Feedlot mill operators, cattle feeders, and nutritionists emphasize the importance of flake quality, which often is measured in terms of consistency of flake thickness, moisture level, durability, and degree of starch gelatinization.

Moisture is commonly added to whole corn prior to steaming to aid in the flake manufacturing process by reducing mill electrical consumption, to allow steam conditioning to "cook" the corn rather than to transfer moisture, and to reduce fines during flaking. There is little data available about either preprocessing conditions involving moisture application to corn or methods that impact quality attributes of flakes. Our goal was to characterize how some of the variables involved with the steam-flaking process alter flake quality, which we quantified in terms of flake durability and susceptibility of starch to fermentation.

Experimental Procedures

The variables used in this experiment were tempering moisture level (6, 10, or 14% moisture), addition of a surfactant to increase moisture uptake (0 or 0.09 oz of Grain Prep® surfactant/gallon of added water, providing for 2.2 oz of surfactant/ton of flaked corn, considering 10% water added), steam conditioning time (20 or 40 minutes), and flake density (28, 26, or 24 lb/bushel) in a 3×2×2×3 factorial arrangement of treatments. The surfactant was provided by Agrichem, Inc., Ham Lake, MN.

Whole shelled corn (11% moisture) was weighed into 1-gallon glass jars (n=12; 4.5 lb each) and 6, 10, or 14% water by weight containing 0 or 0.09 oz/gallon of Grain Prep surfactant was added. Jars containing corn samples were immediately placed on a mechanized rotary device to allow for continuous contact of moisture and corn and were tempered for 2 hours. After tempering, samples were steam conditioned for 20 or 40 minutes in a pilot steam table under atmospheric pres-

sure. Following steam conditioning, samples were flaked to a common bushel weight. This procedure was repeated three times daily to obtain samples with flake densities of 28, 26, and 24 lb/bushel and replicated over 3 days to obtain triplicate representation of each treatment. Samples were collected following tempering, steam conditioning, and flaking and were frozen daily. Tempered, steamed, and flaked samples were analyzed for moisture after completion of the study. To estimate starch availability, flaked corn samples (ground to pass through 1-mm screen) were incubated *in vitro* for 3 hours, and total gas production was measured. Additionally, flaked samples (0.55 lb) were placed into a multi-chambered rotary box tester and tumbled for 10 minutes with (modified) or without (unmodified) ½ inch hexagonal nuts. Tumbling flakes with the hexagonal nuts was thought to simulate a more aggressive handling/mixing procedure to better understand how the different variables affect the resiliency of the flakes. The percentage of flakes retained on a 0.37-inch screen was measured to estimate flake durability.

Results and Discussion

The effects of tempering moisture level and surfactant on dry matter of whole corn samples are presented in Table 1. As expected, increasing tempering moisture concentration linearly increased corn moisture concentration ($P<0.0001$). However, tempering with Grain Prep did not alter corn moisture concentration ($P=0.36$). Tempering moisture concentration was the only tested variable that affected steamed corn moisture content. Like tempering, moisture concentration of corn after steam conditioning was not increased by Grain Prep. Surfactants are thought to increase the rate or amount of water that penetrates the corn kernel. In our experiment, moisture uptake was not improved by adding a surfactant to the water during the tempering process. Moisture concentration of flaked corn was increased ($P<0.0001$) by increasing water concentration during tempering. Grain Prep ($P=0.38$), steam time ($P=0.17$), and flake density ($P=0.86$) did not alter moisture content of flaked corn. However, addition of Grain Prep during tempering increased ($P<0.05$) moisture gain during flaking.

We expected a longer steam time to increase flake moisture content but this was not the case. Longer conditioning times (40 vs 20 minutes) may not further increase moisture content when corn is previously tempered with at least 6% moisture. Moisture gain in corn can be accomplished via tempering or steaming and either can substitute for the other. When less moisture is applied during tempering more moisture can be accumulated during steam conditioning, and when greater quantities of moisture are applied during tempering, less moisture will be taken up via steam. Adequate quantities of moisture (>6% added) may allow for the steam to more thoroughly and efficiently "cook" the starch rather than to transfer moisture to the starch.

By more thoroughly "cooking" the grain prior to flaking, gelatinization of starch should be increased. However, gas production (Table 2; a measure of starch availability) was not altered by tempering moisture ($P=0.62$), Grain Prep ($P=0.31$), or steam time ($P=0.33$). Decreasing flake density linearly increased ($P<0.01$) gas production during a 3-hour *in vitro* incubation.

Steaming the corn longer (40 vs 20 minutes) did improve flake durability (Table 3), but only if tempering moisture concentration increased (tempering moisture × steam time interaction; $P<0.10$). Additionally, decreasing flake density linearly increased ($P<0.05$) durability of flakes, and Grain Prep addition to water during tempering slightly increased ($P<0.05$) the amount of flakes retained on a 0.37-inch screen after modified tumbling (Table 4). Improving flake durability by decreasing flake density is likely explained by the production of larger diameter flakes that are

retained to a greater degree on the 0.37-inch screen.

Flake moisture content was most affected by tempering moisture concentration. Increasing moisture concentration of corn prior to flaking improved flake durability when corn was steamed for at least 40 minutes. In our experiment, a commercial surfactant did not alter moisture content, but it did increase moisture gain during flaking, and it also marginally increased flake durability. Decreasing flake density increased starch availability and increased flake durability. Flake density was the most influential factor that affected laboratory estimates designed to measure differences in flake quality and feeding value.

Table 1. Effect of Processing Variables on Moisture Concentration of Tempered, Steamed, or Flaked Corn Samples. Corn Samples Were Tempered with 6, 10, or 14% Water and 0 or 0.09 oz/gallon of Grain Prep Surfactant for 2 Hours, Steam Conditioned for 20 or 40 Minutes, and Flaked to Densities of 28, 26, or 24 lb/Bushel. No Interactions Existed Among Treatments

Item	Initial Corn Moisture, %	Moisture Gain during Tempering, %	Tempered Corn Moisture, %	Moisture Gain during Steaming,. %	Steamed Corn Moisture, %	Moisture Gain during Flaking, %	Flaked Corn Moisture, %
Tempering moisture, %							
6	11.0	6.2	17.2	5.6	22.8	-0.3	22.6
10	11.0	10.4	21.4	4.7	26.1	-0.1	26.1
14	11.0	13.9	24.9	2.5	27.4	-0.4	26.8
SEM		0.31	0.31	0.47	0.47	0.67	0.63
P-value, linear effect		<0.0001	<0.0001	<0.0001	<0.0001	0.87	<0.0001
Grain Prep, oz/gallon[a]							
0.00	11.0	10.2	21.2	4.6	25.8	-0.8	25.0
0.09	11.0	10.1	21.1	4.0	25.1	0.3	25.3
SEM		0.30	0.30	0.39	0.39	0.62	0.61
P-value		0.36	0.36	0.25	0.16	<0.05	0.38
Steam time, minutes							
20	11.0	10.2	21.2	4.0	25.2	-0.3	24.9
40	11.0	10.1	21.1	4.6	25.7	-0.2	25.4
SEM		0.30	0.30	0.39	0.39	0.62	0.61
P-value		0.49	0.49	0.29	0.42	0.93	0.17
Flake density, lb/bushel							
28	11.0	10.2	21.2	4.2	25.4	-0.1	25.3
26	11.0	10.2	21.2	4.0	25.2	-0.1	25.1
24	11.0	10.1	21.1	4.7	25.8	-0.6	25.0
SEM		0.33	0.33	0.48	0.48	0.67	0.65
P-value		0.78	0.78	0.57	0.72	0.66	0.86

[a]To provide 2 oz of Grain Prep/ton of flaked corn.

Table 2. Effect of Processing Variables on Gas Produced During a 3-Hours In Vitro Fermentation of Flaked Corn. Corn Samples Were Tempered with 6, 10, or 14% Water and 0 or 0.09 oz/gallon of Grain Prep Surfactant for 2 Hours, Steam Conditioned for 20 or 40 Minutes, and Flaked to Densities of 28, 26, or 24 lb/bushel. No Interactions Existed Among Treatments

Item	Gas Volume, mL
Tempering moisture, %	
6	76.4
10	74.9
14	76.8
SEM	1.8
P-value	0.62
Grain Prep, oz/gallon	
0.00	75.2
0.09	76.9
SEM	1.6
P-value	0.31
Steam time, minutes	
20	75.2
40	76.9
SEM	1.6
P-value	0.33
Flake density, lb/bushel	
28	66.9
26	72.2
24	89.0
SEM	2.3
P-value, linear effect	<0.01

Table 3. Durability of Flaked Corn Samples After Tumbling With (Modified) or Without (Unmodified) Six Hexagonal, 0.5-inch Nuts for 10 Minutes in a Multi-Chambered Durability Tester. Flaked Corn Samples Were Tempered with 6, 10, or 14% Water and Steam Conditioned for 20 or 40 Minutes

	Steam Time	
Item	20 Minutes	40 Minutes
Unmodified	---------- % retained on 0.37 inch screen ----------	
Tempering moisture, %		
6	43.7	44.6
10	46.3	51.4
14	45.2	54.4
SEM	4.4	4.4
Tempering moisture × steam time interaction, $P<0.05$.		
Modified		
Tempering moisture, %		
6	8.2	11.8
10	17.3	20.4
14	17.1	25.2
SEM	3.2	3.2
Tempering moisture × steam time interaction, $P<0.10$.		

Table 3. Durability of Flaked Corn Samples After Tumbling With (Modified) or Without (Unmodified) Six Hexagonal, 0.5-inch Nuts for 10 Minutes in a Multi-Chambered Durability Tester. Flaked Corn Samples Were Tempered with 0 or 0.09 oz/gallon of Grain Prep Surfactant for 2 Hours and Flaked to Densities of 28, 26, or 24 lb/bushel

Item	Unmodified	Modified
Grain Prep, oz/gallon	---------- % retained of 0.37 inch screen ----------	
0.00	47.2	15.6
0.09	48.0	17.7
SEM	4.2	3.0
P-value	0.58	<0.05
Flake density, lb/bushel		
28	45.9	14.2
26	45.8	15.2
24	51.1	20.6
SEM	4.3	3.4
P-value, linear effect	<0.05	<0.01