Kansas Agricultural Experiment Station Research Reports

Volume 3
Issue 1 *Cattlemen's Day*

Article 22

January 2017

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Recommended Citation

Schwandt, E. F.; Hubbert, M. E.; Thomson, D. U.; Vahl, Christopher; Bartle, S. J.; and Reinhardt, C. D. (2017) "Flake Density, Roll Diameter, and Flake Moisture All Influence Starch Availability of Steam-Flaked Corn," *Kansas Agricultural Experiment Station Research Reports*: Vol. 3: Iss. 1. https://doi.org/10.4148/2378-5977.1356

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Flake Density, Roll Diameter, and Flake Moisture All Influence Starch Availability of Steam-Flaked Corn

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Introduction

Steam-flaked corn is commonly fed in feedlot finishing diets because steam-flaking improves starch availability and nutrient utilization, thus improving the overall feeding value of corn. In most operations which utilize steam-flaked corn, grain is processed to a pre-determined flake density by setting the rolls to a specific separation distance and using tension to hold rolls together. Flaked grain is most often produced to a bulk density between 24 and 32 lb/bu, with a common recommendation of 27 lb/bu for corn; however, flake density among steam-flakers within a single mill and among feedlots can vary greatly. Flaking to a similar density using 2 flakers does not ensure similar starch availability.

The degree of starch gelatinization or starch availability of steam-flaked corn can be estimated using analytical procedures such as enzymatic hydrolysis, gas production, and steam-flaked corn gelatinization methods. Routinely evaluating starch availability is used as a quality control method to standardize the steam-flaking process to ensure within-day and day-to-day manufacturing consistency. The concentration of readily available starch in steam-flaked corn is indicative of the rate of starch fermentation in the rumen. When starch is too readily available and is fermented at an excessively rapid rate, acid can accumulate in the rumen, reducing ruminal pH, and ultimately resulting in increased prevalence of digestive disturbances.

Factors that contribute to variation between feedlot operations with respect to steam-flaked corn quality include type and dimensions of flaking equipment, grain type, grain variety and moisture content, roll wear, and steam-flaking procedures. Sampling and handling procedures contribute to precision of results; therefore, sampling procedures need special attention, and consistency must be evaluated when attempting to determine starch availability of steam-flaked corn.

The objective of this study was to evaluate starch availability of steam-flaked corn comparing roll dimensions and steam-flaked corn flake densities among flaking systems and feedyards and to provide information on the equipment utilized, steam-flaked corn

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flaking procedures, and to define current manufacturing practices of steam-flaking in commercial feedlot operations.

Key words: flake density, starch availability, steam-flaked corn

Experimental Procedures

Commercial feedlots (n = 17) which regularly steam-flake grain in their operations were selected for inclusion in this study. Data were collected from August through October 2015. Each individual roll set (n = 49) within each feedlot was considered the observational unit; samples were collected during normal operating procedures after the mill had been in operation for a minimum of 2 hours.

Steam-conditioned whole corn samples were most commonly collected directly above the rolls located at the peg feeder. Investigators were unable to collect steam-conditioned grain from 2 flakers. Flaker design dictated that steam-conditioned corn samples from 14 flakers be collected below the rolls with the rolls separated and temporarily not in operation. Steam-flaked corn was collected directly below the rolls and across the entire length of the roll using a shovel. Flake density was measured 3 separate ways using a hand-held density tester: 1) measured by yard personnel using the feedyard's quart cup hand-held density tester under their normal operating procedures (Yard flake density); 2) measured by the investigator using the same procedure at every yard: steam-flaked corn sample was taken directly below the rolls using a shovel and immediately allowed to fall freely into the quart cup to over-fill, then steam-flaked corn was leveled off with a strike off stick in a zig-zag motion across the rim of the cup, and weighed (Hot flake density); and 3) measured by the investigator using the same procedure at every yard: steam-flaked corn sample was taken directly below the rolls using a shovel, immediately spread out on a clean, flat surface (thickness of approximately 1.2 in.), allowed to cool for 15 minutes, gently swept into a dust pan and allowed to freely fall into the quart cup to over-fill, then steam-flaked corn was leveled off with a strike off stick in a zig-zag motion across the rim of the cup, and weighed (Cooled flake density). Steam-flaked corn was collected directly below the rolls and across the entire length of the roll, immediately spread out onto a clean, flat surface (thickness of approximately 1.2 in.), allowed to cool for 15 minutes, gently swept into a dust pan, funneled into a 1.23 L plastic cylinder, leveled off with a strike off stick, and weighed (Volumetric). Flake Color Index System analysis was conducted on cooled steam-flaked corn samples from each roll set. The ground sample of steam-flaked corn used for the Flake Color Index System measurement was subsequently submitted for total starch and available starch using enzyme hydrolysis. Cooled steam-flaked corn samples were also analyzed for flake thickness. Twenty-five whole, intact flakes from each set of rolls were measured at the center of the flake, using a micrometer and thickness (mm) was recorded; average thickness values for each roll set were used in this analysis and were representative of spacing between rolls. Roll corrugations were measured by evaluating the number of grooves per inch from various whole flakes from each sample and roll corrugations were reported as either round-bottom vee or Stevens profile.

Data were analyzed as a multiple linear regression using the PROC MIXED procedure of SAS (SAS Institute, Inc., Cary, NC). Pearson's correlation coefficients (r) were determined for each pair of continuous variables considered for potential use as independent

variables in the multiple linear regression model using PROC CORR of SAS to determine potential collinearity ($r \geq 0.70$; $P<0.10$). For pairs of variables which were determined to be collinear, only 1 variable was selected to be tested in the regression model for significance. Manual forward selection was used to fit a regression model to the response variables and determine significant ($P<0.10$) explanatory variables. The ultimate model statement included starch availability measured using enzymatic hydrolysis as a response variable, and cooled flake density, steam-flaked corn moisture, and roll diameter ($P<0.10$) were used as fixed effects. Flaker was considered the experimental unit and feedyard and flaker within feedyard were used as random effects. The final significant variables were analyzed using the PROC REG procedures and PCORR2 function of SAS to determine partial R^2. A simple linear regression using the REG procedure of SAS was used to evaluate the following variables: Hot flake density vs. Yard flake density, Hot flake density vs. Cooled flake density, Yard flake density vs. Enzymatic, Flake thickness vs. Hot flake density, and Flake thickness vs. Cooled flake density.

Results and Discussion

Consulting nutritionists (n = 7) suggested names of feedlots (n = 17) to participate in this survey. Each individual flaker (n = 49) was considered an independent observational unit. Roll size varied considerably between feedyards. The most prevalent roll size was 24 × 48 in. (24.5%). Roll diameter ranged from 18 to 36 in., and roll length ranged from 24 to 68 in. In addition to roll size, the ratio of length to diameter was also reported and averaged 1.9 with a range of 1.33 to 2.33.

Flake density measured by yard personnel averaged 27.5 lb/bu; hot flake density averaged 27.7 lb/bu; and cooled flake density measured by the investigator was 24.1 lb/bu. Differences between Yard flake density and Hot flake density measurements were attributed to some yards sifting out fines prior to measuring hot flake density. Flake density measurements taken by the investigator were completed the same way at all feedyards. Roll corrugations ranged from 14 to 16 grooves per inch and were reported by mill personnel as either round-bottom vee or Stevens Tooth profile. Most feedyards assessed roll wear by physically evaluating flake quality and by looking at changes in enzymatic starch availability. Roll wear was not assessed in this survey and could have had an impact on the results of the analysis. Average flake thickness across all flakers was 1.76 mm with a range of 1.22 to 2.45 mm. Enzymatic hydrolysis starch availability values ranged from 37 to 65% with an average of 51%. The median starch availability value was 51% and the mode was 46%. All feedyards routinely submitted samples to commercial laboratories for starch availability analysis using the enzymatic hydrolysis method. Most of the feedyards surveyed submitted weekly (66.7%) samples, while the remaining feedyards submitted monthly (33.3%) samples. Two feedyards also routinely evaluated starch availability using the Flake Color Index System.

Significant ($P<0.10$) variables contributing to the final multiple linear regression model using Enzymatic as the dependent variable were: steam-flaked corn moisture, cooled flake density, and roll diameter (Enzymatic = 119.72 - (1.22 × steam-flaked corn moisture) - (2.42 × cooled flake density) + (0.47 × roll diameter); $R^2 = 0.5276$; $P<0.10$).

Implications

Manufacturing equipment and quality control measures vary greatly across commercial feedyards in the United States. Within each feedyard, each roll set should be managed as an individual unit given that no two units are the same. Each roll set is unique in roll wear, roll gap, mill load, steam cabinet temperature, retention time, etc. All of these variables can influence steam-flaked corn production capacity and quality. This study has identified cooled flake density, steam-flaked corn moisture, and roll diameter to be significant variables contributing to enzymatic starch availability in commercial feedyards located in the United States.

Table 1. Multiple linear regression coefficient estimates for variables related to changes in enzymatic starch availability of steam-flaked corn in 17 commercial feedyards surveyed in Nebraska, Kansas, Colorado, Texas, New Mexico, Arizona, and California

Variable	Estimate	Standard error	P<F	Partial R^2
Intercept	119.72	10.974	< 0.01	
Cooled flake density, kg/L[1]	-2.42	0.379	< 0.01	0.4764
Steam-flaked corn moisture, %	-1.22	0.441	0.02	0.1456
Roll diameter, cm	0.47	0.244	0.06	0.0749

[1]Cooled flake density was measured by the same investigator after cooling.

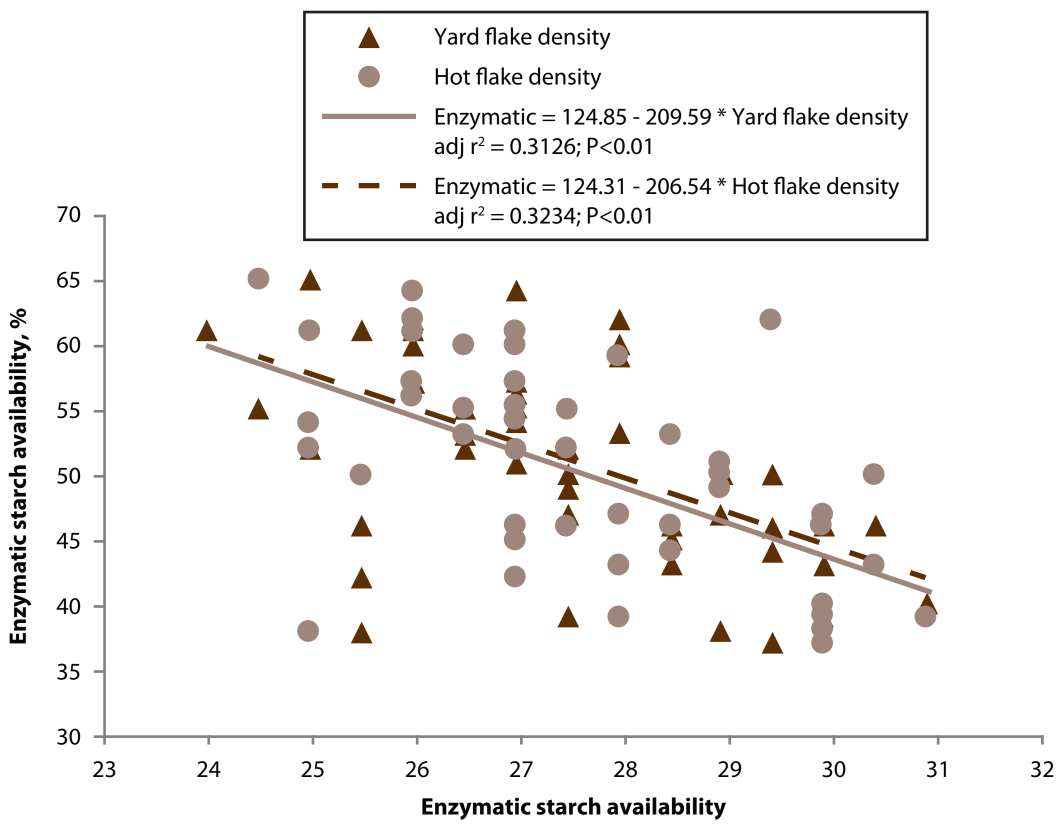

Figure 1. Simple linear regression model comparing the relationships between enzymatic starch availability (Enzymatic) and yard personnel flake density and Enzymatic and investigator flake density for 17 commercial feedyards surveyed in Nebraska, Kansas, Colorado, Texas, New Mexico, Arizona, and California. (Standard error of the mean = 2.188.)

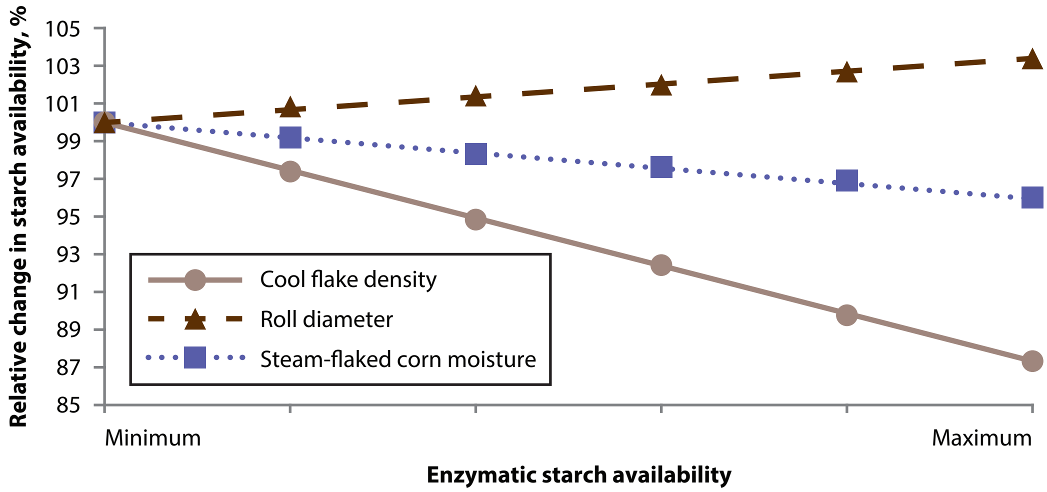

Figure 2. Multiple linear regression equation illustrating the relative effects of starch availability for the complete range of values within dataset for significant variables: Cooled flake density, roll diameter, and steam-flaked corn moisture for 17 commercial feedyards surveyed in Nebraska, Kansas, Colorado, Texas, New Mexico, Arizona, and California. (Enzymatic = 119.72 - (1.22 × steam-flaked corn moisture) - (2.42 × cooled flake density) + (0.47 × roll diameter) All variables but one were held constant at the mean of the data collected, and values for the third variable were entered from the minimum to the maximum values within the dataset. Then, the relative effect of each change was calculated as:

$$\frac{\text{change in starch availability}}{\text{original starch availability}} \times 100$$