FLAKED GRAIN VARIABLES: CONTROL POINTS AND EVALUATION OF FLAKED GRAINS
Jim Drouillard, Chris Reinhardt
Kansas State University
Manhattan, KS
jdrouill@k-state.edu

INTRODUCTION
With recent increases and the volatility in the costs of feed grains and of natural gas (Figure 1), it is more important than ever for feedyards and their consultants to scrutinize their steam-flaking operation for potential sources of inefficiency.

![Figure 1. Price (dollars per thousand cubic feet) of natural gas, Kansas (http://tonto.eia.doe.gov/dnav/ng/hist/n3020ks3m.htm).](http://tonto.eia.doe.gov/dnav/ng/hist/n3020ks3m.htm)

Perhaps the most obvious direction to look for cost-return optimization is in flake density. Studies evaluating feedlot performance at various flake densities of corn, sorghum, and wheat date back through several decades (Potter et al., 1971; Martin and Wagner, 1974; Theuer, 1986). However, the economic feasibility of flaking to any particular degree changes with fluctuating energy costs, so this topic warrants re-examination. With an increased degree of processing, starch availability increases both for corn (Zinn et al., 1990a; Sindt et al., 2006b) and sorghum grain (Reinhardt, et al., 1997; Swingle et al., 1999; Figure 2).
Figure 2. Starch degradability with increasing flake density of corn and sorghum (Zinn, 1990a: corn; rumen disappearance; Swingle et al., 1999: sorghum using enzymatic reactivity; Reinhardt et al., 1997, sorghum; differential scanning calorimetry; Sindt et al., 2006b, corn; *in vitro* gas production).

Theoretically, this should translate into improved feed efficiency for the more highly processed grain. However, while Xiong et al. (1991) observed a linear decrease in feed:gain (increased efficiency) when sorghum grain flake density was increased from 20 to 30 lb/bu [VALUES IN FIGURE 2 FROM XIONG DO NOT MATCH VALUES FROM JAS 69:1711], Reinhardt et al. (1997) reported a linear increase in F:G (decreased efficiency) from 22 to 28 lb/bu (Figure 3).

Figure 3. Effects sorghum grain flake density on feed:gain (Swingle et al., 1999; Reinhardt et al., 1997; Xiong et al., 1991)
Swingle et al. (1999) reported no change in feed efficiency from 20 to 28 lb/bu, but a 4.9% increase in F:G (decreased efficiency) from 28 to 32 lb/bu. When feeding corn, Zinn (1990a) reported a quadratic response in feed conversion, with an improvement in efficiency from 20 to 24 lb/bu and a subsequent increase in F:G (decrease in efficiency) from 24 to 28 lb/bu (Figure 4). Likewise, KSU researchers (unpublished) have observed a linear increase in F:G (decrease in efficiency) from 28 to 36 lb/bu.

Figure 4. Effects of corn flake density (lb/bu) on feed:gain (Zinn et al., 1990a; KSU, unpublished).

The optimum level of grain processing also may change with different costs for grain, natural gas, and electricity. Reinhardt et al. (1997) reported that mill throughput was increased by 66% when sorghum grain flake density was increased from 22 to 28 lb/bu, and KSU researchers (unpublished) recently found a 63% increase in tonnage processed through the mill when corn flake density was increased from 28 to 36 lb/bu (Figure 5).

Figure 5. Effect of steam-flake density of corn (KSU, unpublished) or sorghum grain (Reinhardt et al., 1997) on mill throughput (tons/hr) and utility costs ($/ton).
These increases in milling throughput correspond to 40 and 35% reductions in utility cost for flaking. With increasing processing input costs, the performance benefits of flaking to a given density may give way to opportunity costs of reducing the overall cost of the milling operation. Conversely, escalating grain costs may justify greater utility input costs to optimize efficiency of grain conversion.

Another concern within some feeding operations is the effect of storage conditions on changes in nutritive value of flaked grains. The temperature of the grain on the fringe of a pile of flaked grain cools very rapidly, rarely exceeding 140°F, and falls to below 100°F within 12 hours (Figure 6; Sindt, 2004).

![Figure 6. Temperature change of flaked corn during storage (Sindt, 2004).](image)

However, the temperature at the core of the pile may remain above 140°F for more than 17 hours, permitting insoluble protein-sugar complexes to form (Figure 7). Also, the trapped moisture along with the relatively slow decline in temperature may permit retrogradation of the starch, where starch chains re-align and create a less available form of starch than present in freshly flaked grain (Donovan, 1979).

![Figure 7. Starch availability (refractive index following 15-min incubation in glucoamylase) of steam-flaked corn stored in a pile as affected by time of storage (Sindt, 2004).](image)
When dry-rolling or grinding, increasing the surface area available for microbial and enzymatic digestion is the goal; therefore, particle size reduction is critical for improving ruminal digestion. Such is not the case with steam-flaking. We measured particle size distribution of corn flaked to a density of 28 lb/bu and determined that greater than 75% of the particles exceeded 4.75mm. In the case of dry rolled corn, more than 75% of grain had a particle size of less than 4.75 mm (Figure 8).

![Graph of particle size distribution](image)

**Figure 8.** Distribution of grain sizes for dry rolled or steam-flaked corn (KSU, unpublished).

However, *in vitro* gas production for large particles of flaked grain was similar to that of small particles of either dry-rolled or steam-flaked corn; in contrast, large particles of dry-rolled corn (whole or half kernels) were associated with much lower gas production than the smaller particles (Figure 9).

![Graph of gas production](image)

**Figure 9.** Effects of particle size on *in vitro* gas production of steam-flaked corn (SFC) and dry-rolled corn (DRC; KSU, unpublished).
While insufficient mixing will cause reductions in efficiency due to inconsistent nutrient intake, excessive mixing of the final diet containing flaked grain will cause flake damage and reduction of particle size of the steam-flaked grain; this may cause digestive upsets. Sindt (2006b) found that mixing steam-flaked corn for 15 minutes reduced average particle size (Figure 10). DMI was numerically reduced (19.4 vs. 20.5 lb; \( P = 0.13 \)) when grain was mixed for 15 additional minutes compared to no additional mixing time. While no differences were observed in ADG or F:G, the percentage of cattle grading Prime and Choice was reduced (42% vs. 65%; \( P = 0.10 \)). More extensive ruminal digestion of starch may markedly reduce the supply of starch flowing to the small intestine. This reduced supply of glucogenic compounds may ultimately affect quality grade.

![Figure 10. Effects of mixing on particle size reduction of steam-flaked corn portion of finishing diet (Sindt, 2006b).](image)

Moisture content of flaked grain also can alter ruminal digestibility of grain. In one study, Sindt and coworkers (2006a) tempered corn with 0, 6, or 12% (wt/wt) water and flaked the grain to 24 or 28 lb/bu. Flaking to the lighter test weight increased starch availability, and increasing tempering moisture content also linearly increased starch availability. However, while increasing moisture content increased DMI and reduced F:G for cattle fed grain flaked to 28 lb/bu, the 12% moisture level actually caused a 0.8 lb reduction in DMI and a 1 unit increase in F:G (\( P < 0.01 \)) compared to the 6% level in cattle fed the grain flaked to 24 lb/bu. In a separate study, Sindt et al. (2006b) found that when corn had a final post-flaking moisture content of 36%, DMI (17.6 vs 18.9 lb; \( P = 0.02 \)) and ADG (3.44 vs 3.70 lb; \( P = 0.05 \)) both were lower when compared to those of cattle fed flaked corn containing 18% moisture.

Sindt and co-workers (2006b) evaluated the following grain processing treatments: tempering to 6, 10, or 14% moisture pre-steaming, addition of a yucca-based surfactant, steaming for 40 minutes vs. 20 minutes, or flaking to 24, 26, or 28 lb/bu. While only flake density affected starch availability, increased tempering moisture level, the addition of the surfactant, longer steaming time, and lighter
flake density all positively affected flake durability ($P < 0.10$). Increasing the steaming time also can increase the moisture content of the flakes (Zinn, 1990b), but that change is relatively small when compared to adding water in the tempering step. These data suggest that any method for optimizing moisture content of the final flaked grain may improve flake durability, diminish the particle size reduction during diet mixing, and ideally, improve animal performance. Interactions between moisture content and flake density on starch availability may impose practical limits to the improvements in animal performance based on moisture content of the flaked grain.

In summary, increasing the degree of processing increases ruminal availability of starch, but this increase does not always translate into improved feed efficiency. This may reflect an inability of some animals to deal with the rapid acid accumulation in the rumen during fermentation of highly processed grain. While particle size reduction is essential for improving digestion of dry-processed grain, fine particles of flaked grain may increase the incidence of digestive upsets and reduce performance. For this reason, flake durability becomes an important consideration. Increasing the moisture content of flaked grain can improve the durability or “toughness” of flaked grain and reduce the amount of flake damage during mixing and feeding. Once again, with respect to steam-flaking of grain, “optimization” may be more important than “maximization.”

**LITERATURE CITED**


**QUESTIONS AND ANSWERS**

Q: Would you comment on the role of surfactants in grain processing?

A: Other people here could answer that question better than me. Surfactants have been studied for many years. Jim Drouillard has generated some nice data regarding flake durability that matches information on moisture uptake and gelatinization. These factors all can alter the ability of the flake to hold together.