Influence of flake density and tempering on the feeding value of steam-flaked corn for feedlot cattle

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ABSTRACT
A feedlot growth-performance trial was conducted to evaluate the relative response to tempering when flake density (FD) of corn is increased from 0.31 kg/L (24 lb/bushel) to 0.39 kg/L (30 lb/bushel). Treatments were (1) non-tempered, FD = 0.31 kg/L; (2) non-tempered, FD = 0.39 kg/L; (3) tempered, FD = 0.31 kg/L and (4) tempered, FD = 0.39 kg/L. Tempering prior to flaking increased (21%, P < .01) the moisture content of corn as it exited the rolls and decreased (14%, P = .02) the starch enzymatic reactivity. Increasing roll tension to reduce FD decreased flake thickness (24%, P < .01) and increased starch reactivity (43%, P < .01). Increasing FD decreased (P = .03) estimated dietary NEm and NEg, and the estimated NEm and NEg values of steam-flaked corn by 2.3% and 2.9%, respectively. We conclude that whereas tempering corn grain before steam flaking increases the moisture content of corn as it exits the rolls, it has minimal influence on the feeding value for corn for feedlot cattle. Increasing FD from 0.31 to 0.39 kg/L decreases starch reactivity and the net energy value of corn, but does not affect daily weight gain or carcass characteristics.

1. Introduction
Tempering is a chemically facilitated process by which moisture is added to grain prior to further processing. Primary benefits to tempering include (1) softening the grain and thereby reducing the energy cost of rolling and (2) improving the integrity of the kernel as it leaves the rollers, and reducing dustiness and fines. In the absence of steaming, the improvements in physical characteristics of grain may be achieved by tempering, although limited data (Wilson et al. 1973; Zinn 1990a) indicate that moisture content of corn (15–35%), per se, may not have an important influence on its energy value. Applying moisture by tempering grain before flaking is an effective means of adding moisture to flaked corn and may decrease the need for long periods of steam conditioning (Sindt et al. 2006a).

Flake density (FD, kg flaked corn/L) is generally considered one of the most important quality controls of the steam-flaking process (Zinn et al. 2002; Sindt et al. 2006b). Changes in FD are linearly related to the total tract and postruminal digestibility of starch when grain is flaked (Zinn 1990b; Theurer et al. 1999). The objective of this study was to determine the influence of FD and tempering prior to steam flaking on the feeding value of corn for feedlot cattle.

2. Material and methods
All procedures involving animal care and management were in accordance with and approved by the University of California, Davis Animal Use and Care Committee.

One hundred crossbred (approximately 25% Brahman blood with the remainder represented by Hereford, Angus, Shorthorn and Charolais breeds in various proportions) steers (310 ± 14 kg) were used in a 137-day trial to evaluate the relative response to tempering when the FD of corn is increased from 0.31 kg/L (24 lbs/bushel SFC24) to 0.39 kg/L (30 lbs/bushel SFC30). Steers were blocked by weight and randomly assigned within weight groups to 20 pens (5 steer per pen). Pens were 43 m² with 22 m² overhead shade, automatic waterers and 2.4-m fence-line feed bunks. Four dietary treatments were compared: (1) not tempered, SFC24 (FD = 0.31 kg/L); (2) not tempered, SFC30 (FD = 0.39 kg/L); (3) tempered, TSFC24 (FD = 0.31 kg/L) and (4) tempered, TSFC30 (FD = 0.39 kg/L). Composition of the basal diet is shown in Table 1. 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®) was applied to the corn with the water at the rate of 0.165 mL/kg corn. Steam-flaked corn was prepared as follows: A chest situated directly above the rollers (46 × 61 cm corrugated) was filled to capacity (441 kg) with corn and then brought to a constant temperature (102°C) at an atmospheric pressure of using steam. The corn was steamed for approximately 20 min prior to starting the rollers. The first approximately 441 kg of SF corn was allowed to pass from the rollers before material was collected for use in the trial. This preliminary period served for warming the rollers and for adjusting the tension of the rollers to provide a flake with the desired density (0.31 or 0.39 kg/L). The retention time of corn in the steam chamber was maintained at roughly 34 min for
by the equation: \( EM = 0.077W^{0.75} \) (Lofgreen & Garrett, 1968). The \( NEm \) and \( NEg \) value of the diets were obtained by means of the equation: \( EG = ADG^{1.095} \).

In determining steer performance, weights were reduced 4% to remove estimated fill. Energy gain (\( EG \)) was calculated by breaking the flake approximately in half and measuring the thickness in mm (using a micrometer) at the flattest spot near the centre of the flake. Estimates of thickness represent an average value for 10 whole flakes randomly selected from the air-dry subsamples of each batch (total of 7 batches per treatment) of processed corn. Diets were prepared at weekly intervals and stored in plywood boxes located in front of each pen. Steers were allowed ad libitum access to experimental diets. Fresh feed was provided twice daily (roughly 0730 and 1400 h). Steers were implanted with Synovex-S® (Zoetis, Kalamazoo, MI) upon initiation of the trial and then again at day 140 h. Steers were allowed ad libitum access to experimental diets. Fresh feed was provided twice daily (roughly 0730 and 1400 h). Steers were implanted with Synovex-S® (Zoetis, Kalamazoo, MI) upon initiation of the trial and then again at day 140 h.

### Table 1. Composition of basal diets fed to steers.

| Item                  | Flaked SFC24 | SFC30 | Tempered-flaked* SFC24 | SFC30 | SEM | Flaked vs tempered-flaked | SFC24 vs SFC30 | Interaction |
|-----------------------|--------------|-------|------------------------|-------|-----|---------------------------|----------------|-------------|
| Ingredient composition, % dry matter |              |       |                        |       |     |                           |                |             |
| Alfalfa               | 8.00         | 8.00  | 8.00                   | 8.00  |     |                           |                |             |
| Sudangrass hay        | 4.00         | 4.00  | 4.00                   | 4.00  |     |                           |                |             |
| Tempered-flaked corn  | –            | –     | 77.30                  | 77.30 |     |                           |                |             |
| Steam-flaked corn     | 77.30        | 77.30 | –                      | –     |     |                           |                |             |
| Yellow grease         | 2.50         | 2.50  | 2.50                   | 2.50  |     |                           |                |             |
| Cane molasses         | 4.00         | 4.00  | 4.00                   | 4.00  |     |                           |                |             |
| Limestone             | 1.78         | 1.78  | 1.78                   | 1.78  |     |                           |                |             |
| Urea                  | 1.17         | 1.17  | 1.17                   | 1.17  |     |                           |                |             |
| Trace mineral saltb   | 0.50         | 0.50  | 0.50                   | 0.50  |     |                           |                |             |
| Sodium bicarbonate    | 0.75         | 0.75  | 0.75                   | 0.75  |     |                           |                |             |
| Vitamin A^c           | +            | +     | +                      | +     |     |                           |                |             |
| Monensin^d            | +            | +     | +                      | +     |     |                           |                |             |
| Nutrient composition^e |              |       |                        |       |     |                           |                |             |
| Net energy, Mcal/kg   | 2.20         | 2.20  | –                      | –     |     |                           |                |             |
| Maintenance           | 1.53         | 1.53  | 1.53                   | 1.53  |     |                           |                |             |
| Crude protein, %      | 13.00        | 13.00 | 13.00                  | 13.00 |     |                           |                |             |
| Ether extract, %      | 6.00         | 6.00  | 6.00                   | 6.00  |     |                           |                |             |
| Calcium, %            | 0.80         | 0.80  | 0.80                   | 0.80  |     |                           |                |             |
| Phosphorous, %        | 0.28         | 0.28  | 0.28                   | 0.28  |     |                           |                |             |

### 3. Results and discussion

The influence of tempering on corn moisture content flake thickness and starch reactivity to amyloglucosidase (a measure of gelatinization or disruption of the starch granule) is shown in Table 2. Compared with steam flaking alone, tempering prior to flaking increased (21%, \( P < .01 \)) the moisture content of corn as it exited the rolls. The moisture content of tempered steam-flake corn (TSFC) as it exited the rolls was increased by 3.7% units over that of steam-flaking corn (SFC) alone. This finding is consistent with previous studies (Johnson et al., 1968; Plascencia & Zinn, 1996; Zinn et al., 1998), where tempering prior to flaking increased the moisture content of corn by 3.5–5.0% units, respectively. Zinn et al. (1998) observed that tempering corn prior to rolling increased flake integrity over that of steam flaking alone. Likewise, TSFC appeared (not quantified) to have larger and more uniform flakes, with fewer fines, possibly due to the softening effect of tempering, resulting in less shattering as grain passes through the rolls (Zinn, 1990a; Christen et al., 1996).

However, tempering prior to flaking decreased (14%, \( P = .02 \)) the comparative reactivity of starch to amyloglucosidase (a measure of changes in starch solubility). This effect is consistent with the kernel softening effect of tempering, resulting in less energy transfer to the kernel as it passes through the rolls (Zinn et al., 1998, 2002). Also, Sindt et al. (2006a, 2006b) observed that simply increasing the moisture addition to corn

### Table 2. Relationship between density of steam-flaked corn and measurements of flake thickness and starch reactivity to amyloglucosidase.

| Item                  | Flaked SFC24 | SFC30 | Tempered-flaked* SFC24 | SFC30 | SEM | Flaked vs tempered-flaked | SFC24 vs SFC30 | Interaction |
|-----------------------|--------------|-------|------------------------|-------|-----|---------------------------|----------------|-------------|
| Replicates            | 7            | 7     | 7                      | 7     |     |                           |                |             |
| Dry matter, %b        | 82.4         | 82.9  | 79.1                   | 78.8  |     |                           |                |             |
| Flake thickness, mm   | 1.76         | 2.31  | 1.86                   | 2.44  |     |                           |                |             |
| Starch reactivity, %   | 20.3         | 14.0  | 17.3                   | 12.2  |     |                           |                |             |

Notes: SFC24: flake density = 0.31 kg/L (24 lb/bushel); SFC30: flake density = 0.39 kg/L (30 lb/bushel).

^aSARTemp* (Sartec Corp., Auoka, MN).

^bMeasurement taken on corn as it exited the rollers.

^cPercentage of starch that is reactive to amyloglucosidase.

^d20 mg/kg.

^e2200 IU/kg.

^fBased on tabular values for individual feed ingredients (NRC, 2000).

**quadratic equation:** \( x = (-b ± (b^2 - 4ac)^{0.5})/2c \), where \( a = -0.41EM \), \( b = 0.877EM + 0.41DMI + EG \), \( c = -0.877DMI \) and \( NEg = 0.877NEm - 0.41 \) (Zinn & Shen, 1998). For calculating steer performance, initial and final full weights were reduced 4% to account for digestive tract fill. Pens were used as experimental units. Hot carcass weights were obtained from all steers at time of slaughter. After the carcasses were chilled for 48 h, the following measurements were obtained: (1) Longissimus muscle area (ribs-eye 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 and (4) marbling score (USDA, 2016). The trial was analysed as a randomized complete block design experiment with a 2 × 2 factorial arrangement of treatments (Statistix 10, Analytical Software, Tallahassee, FL). Statistical effects of treatments are considered significant for \( P \leq .05 \), and considered as tendency for \( P > .05 \) and \( P \leq .11 \).
from 6% to 14% in conjunction with tempering did not affect starch availability of flaked corn. Increasing roll tension to reduce FD also decreased flake thickness (24%, \( P < .01 \)) and increased starch amylglucosidase reactivity (43%, \( P < .01 \)). This effect is consistent with previous studies (Plascencia & Zinn 1996; Theurer et al. 1999; Sindt et al. 2006a, 2006b; Hales et al. 2010), a characteristic of surfactant agents during tempering accelerates softening of the kernel, thereby increasing production rate (flow rate of grain through the steam chest to achieve a specified FD). Richardson et al. (2002) observed that application of tempering agents to bring corn moisture to 18% before introduction into the steam chest decreased processing time and energy usage by approximately 20%. Decreasing FD from 0.39 to 0.31 kg/L did not influence ADG (\( P = .23 \)) and DMI (\( P = .66 \)). However, consistent with Zinn et al. (2011), it tended to increase gain efficiency (\( P = .11 \)), and increased (\( P = .03 \)) the NE value of the diet. Compared with steam flaking alone, tempering corn prior to flaking did not affect estimated dietary NE (\( P = .41 \)). Decreasing FD from 0.39 to 0.31 kg/L increased (\( P = .03 \)) estimated dietary NEm and Neg. The ratio of observed vs expected dietary NEm and Neg averaged 1.00. But was 2% greater (\( P = .03 \)) for 0.31 vs 0.39 kg/L FD. Because the proportion of flaked corn in the diet was the same across flake densities (Table 1), it may be assumed that the relative change in NE of flaked corn brought about by the changes in FD is equal to the NE value of diet with corn flaked to a density of 0.31 kg/L minus NE value of the diet with corn flaked to a density of 0.39 kg/L divided by the level of inclusion (77.3%, Table 1). Accordingly, the relative change in NEm is 0.0583 Mcal/kg flaked corn [(2.225–2.180)/0.773]. Thus, given that flaked corn with a density of 0.31 kg/L has NEm and Neg values of 2.496 and 1.779 Mcal/kg, respectively (Zinn et al. 2011), then the corresponding NEm and Neg values for corn when flaked density of 0.39 kg/L would be 2.438 and 1.728 Mcal/kg, respectively.

### Table 3. Influence of density of steam-flaked corn and tempering on feedlot performance and estimated net energy value of diets fed to steers.

| Item                      | SFC24 Flaked | SFC30 Flaked | SFC24 Tempered-flaked | SFC30 Tempered-flaked | SE | Flaked vs tempered-flaked | SFC24 vs SFC30 | Interaction |
|--------------------------|--------------|--------------|-----------------------|-----------------------|----|---------------------------|----------------|-------------|
| Replicates, pens         | 5            | 5            | 5                     | 5                     |    |                           |                |             |
| Live weight, kg\(^{ab}\) |              |              |                       |                       |    |                           |                |             |
| Initial                  | 309.7        | 312.4        | 317.3                 | 305.3                 | 2.60 | .57                       | .30            | .05         |
| Final                    | 530.6        | 523.8        | 535.3                 | 517.8                 | 8.00 | .94                       | .15            | .52         |
| ADG, kg/day              | 1.61         | 1.54         | 1.62                  | 1.55                  | 0.05 | .90                       | .23            | .95         |
| DMI, kg/day              | 8.14         | 8.16         | 8.35                  | 8.11                  | 0.25 | .76                       | .66            | .61         |
| G/F                      | 0.20         | 0.19         | 0.19                  | 0.19                  | 0.003 | .74                      | .11            | .32         |
| Diet NE, Mcal/kg         |              |              |                       |                       |    |                           |                |             |
| Maintenance              | 2.24         | 2.18         | 2.21                  | 2.18                  | 0.02 | .41                       | .03            | .55         |
| Gain                     | 1.56         | 1.50         | 1.53                  | 1.50                  | 0.02 | .41                       | .03            | .55         |
| Observed/expected diet NE\(^c\) | 1.02 | 0.99         | 1.00                  | 0.99                  | 0.01 | .41                       | .03            | .55         |
| Gain                     | 1.02         | 0.98         | 1.00                  | 0.98                  | 0.01 | .41                       | .03            | .55         |

Notes: SFC24: flake density = 0.31 kg/L (24 lb/bushel); SFC30: flake density = 0.39 kg/L (30 lb/bushel).

\(^{ab}\)SarTemp® (Sartec Corp., Auoka, MN).

\(^{c}\)Initial and final weights reduced 4% to account for fill.

\(^{d}\)Expected diet net energy values were calculated on the basis of diet formulation and tabular values for individual feed ingredients (NRC 2000; Table 1).

### Table 4. Influence of density of steam-flaked corn and tempering on carcass characteristics of feedlot steers.

| Item                      | SFC24 Flaked | SFC30 Flaked | SFC24 Tempered-flaked | SFC30 Tempered-flaked | SE | Flaked vs tempered-flaked | SFC24 vs SFC30 | Interaction |
|--------------------------|--------------|--------------|-----------------------|-----------------------|----|---------------------------|----------------|-------------|
| HCW, kg                  | 338.5        | 334.2        | 341.5                 | 330.4                 | 5.08 | .94                       | .15            | .52         |
| Dressing %               | 64.0         | 63.8         | 63.8                  | 63.7                  | 0.36 | .64                       | .64            | .76         |
| LM area, cm\(^2\)        | 86.2         | 83.8         | 85.2                  | 84.0                  | 1.94 | .84                       | .36            | .75         |
| Fat thickness, cm        | 1.50         | 1.50         | 1.40                  | 1.40                  | 0.08 | .40                       | .90            | .62         |
| KPH, %\(^{ab}\)          | 2.60         | 2.60         | 2.60                  | 2.70                  | 0.08 | .61                       | .45            | .21         |
| Retail yield, %\(^{ab}\) | 49.6         | 49.6         | 49.8                  | 49.7                  | 0.34 | .76                       | .77            | .99         |

Notes: SFC24: flake density = 0.31 kg/L (24 lb/bushel); SFC30: flake density = 0.39 kg/L (30 lb/bushel).

HCW = hot carcass weight; LM area = Longissimus muscle area; KPH = kidney, pelvic and heart fat.

\(^{ab}\)SarTemp® (Sartec Corp., Auoka, MN).

\(^{bc}\)Boneless closely trimmed retail cuts from carcass chuck, rib, loin and round as percentage of carcass weight.
This represents a decrease of 2.3% and 2.9% for maintenance and gain, respectively.

The influence of density of steam-flaked corn and tempering on carcass characteristics of feedlot steers is shown in Table 4. According with Zinn (1990a) and Hales et al. (2010), there were no treatment effects on carcass characteristics ($P > .10$).

4. Implications

Tempering corn grain before steam flaking increases the moisture content of corn as it exits the roles, but has minimal influence on the feeding value for corn. Increasing FD from 0.31 to 0.39 kg/L decreases starch reactivity and the NE value of corn, but does not affect daily weight gain or carcass characteristics.

Disclosure statement

No potential conflict of interest was reported by the authors.

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