

Influence of substituting steam-flaked corn for dry rolled corn on feedlot cattle growth performance when cattle are allowed either *ad libitum* or restricted access to the finishing diet

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Objective: The influence of substituting steam-flaked corn (SFC) for dry rolled corn (DRC) on feedlot cattle growth performance and dietary net energy when cattle are allowed either *ad libitum* or 2-h restricted access to the finishing diet was evaluated.

Methods: Treatment effects were tested using 96 crossbred steers (251±2 kg) during the initial 56 d of the finishing phase. Cattle were blocked by weight and randomly assigned within blocks to 16 pens (4 pens/treatment). Bunk space was sufficient (41 cm/head) to allow all steers access to the feed bunk at the same time. Treatments consisted of two finishing diets containing (dry matter basis) 77.1% corn grain processed by dry rolling (density = 0.50 kg/L) or steam flaking (density = 0.36 kg/L). Cattle were fed twice daily at 06:00 and 14:00 h, allowing for approximately 5% residual. In the case of restricted feeding, steers were allowed access to feeders for 1 h following each feeding, after which residual feed was withdrawn.

Results: There were no treatment interactions on dry matter intake (DMI), average daily gain (ADG), gain efficiency (G:F), or dietary net energy (NE). Restricting feed access time reduced ($p < 0.01$) feed intake, and hence, ADG. Substitution of SFC for DRC increased ($p < 0.01$) ADG, feed efficiency (G:F), and estimated dietary NE, without affecting DMI. Based on tabular net energy of maintenance (NE_m) value (2.18 Mcal/kg) for DRC, the estimated NE_m value for SFC using the replacement technique, averaged 2.44 Mcal/kg; an improvement of 10.7%. The ratio of observed-to-expected dietary NE was not affected by feed access time.

Conclusion: Substitution of SFC for DRC in finishing diets for feedlot cattle enhanced ADG, gain efficiency, and the NE value of the diet. Although restriction of feed access time depressed DMI and ADG, it did not affect the comparative benefit of steam flaking toward enhancement of ADG, G:F, and dietary NE.

Keywords: Corn Processing; Time of Feeding; Steers; Finishing; Performance

INTRODUCTION

The enhancement in corn digestion due to steam-flaking has been clearly demonstrated. Compared with dry rolled corn (DRC), steam flaked corn (SFC) increases ruminal and total tract starch digestion by an average of 25% and 10%, respectively [1,2], and the net energy (NE) value of corn for maintenance and gain by 13% and 16%, respectively [3]. The increase in NE is consistent with a 10% increase in total digestible nutrients, reflecting the fact that steam flaking increases the digestion of non-starch organic matter to the same extent that it increases starch digestion [2,4]. In a 12-trial summary, Zinn et al [3] observed that substitution of SFC for DRC in growing-finishing diets for feedlot cattle also increased (6.3%) average daily gain (ADG). The basis for this effect is uncertain. In as much as the substitution of SFC for DRC increases the energy density of the diet, it follows that to the extent that time allowed at the feed bunk is restricted, the substitution could result in greater energy intake and hence, growth-performance. Although

feedlot cattle frequent the feed bunk on multiple occasions throughout the day, the actual time spent consuming feed is less than 2 hours [5-7].

The objective of this experiment was to evaluate how feed access (either *ad libitum* or restricted) affects the feeding value of steam-flaked and dry rolled corn as assessed based on growth-performance measures in feedlot steers.

MATERIAL AND METHODS

Diets, animals, and experimental design

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

Ninety-six crossbred steers (251 ± 2 kg) were utilized to evaluate the influence of substituting SFC for DRC on feedlot cattle growth performance when cattle are allowed either *ad libitum* or 2-h restricted access to the finishing diet during to the initial 56 d of the finishing phase. Upon arrival, steers were vaccinated against infectious bovine rhinotracheitis, bovine viral diarrhoea (type 1 and 2), parainfluenza 3 virus, and bovine respiratory syncytial virus (Cattle Master Gold FP 5 L5, Zoetis, New York, NY, USA), clostridia (Ultrabac 8, Zoetis, USA), treated against internal and external parasites (Dectomax, Zoetis, USA), injected with 1,500 IU vitamin E (as d-alpha-tocopherol) 500,000 IU vitamin A (as retinyl-palmitate) and 50,000 IU vitamin D₃ (Vital E-AD, Stuart Products, Bedford, TX, USA), and 300 mg tulathromycin (Draxxin, Zoetis, USA). Following a 45-d receiving period, steers were implanted with Synovex C (Zoetis, USA), blocked by weight into four groups and randomly assigned within weight groupings to 16 pens (six steers per pen). Pen areas were 62 m² with 25 m² overhead shade, automatic waterers, and 2.44 m fence-line feed bunks (41 cm/steer linear bunk space). Treatments consisted in two finishing diets (Table 1) containing 77.1% corn grain (dry matter [DM] basis) processed by either dry rolling or steam flaking. Dry rolled corn was prepared by passing corn through rollers that had been adjusted so that kernels were broken to a density of 0.50 kg/L. Steam-flaked corn was prepared as follows: A chest situated directly above the rolls (46×61 cm, corrugated) was filled to capacity (440 kg) with corn and brought to a constant temperature (102°C) at atmospheric pressure using steam (boiler pressure 6.89 kPa). The corn was steamed for 25 min before starting the rolls. Tension on the rolls was adjusted to provide a flake density of 0.36 kg/L. Retention time of grain in steam chamber was set at approximately 25 min. The SFC was allowed to air-dry before incorporation into the complete mixed diet. Feeding management treatments were: i) *ad libitum* (24 hours feed access), or ii) restricted (2 hours feed access). Steers were provided fresh feed twice daily at 06:00 and 14:00 h, allowing for approximately 5% residual. In the case of steers provided *ad libitum* access to feed, refusals were collected and weighed prior to the morning for determination of daily feed intake. In the case of restricted

Table 1. Composition of experimental diets (DM basis)¹⁾

Items	Corn processing	
	Dry rolled	Steam-flaked
Ingredient composition (% DM)		
Dry rolled corn	77.10	0.00
Steam-flaked corn	0.00	77.10
Rice straw	5.00	5.00
Alfalfa hay	5.00	5.00
Yellow grease	3.50	3.50
Cane molasses	5.00	5.00
Fishmeal	1.50	0.00
Urea	0.60	1.00
Laidlomycin (mg/kg)	12.20	12.20
Limestone	1.34	1.50
Dicalcium phosphate	0.36	0.50
Magnesium oxide	0.20	0.20
Tracemineralized salt ²⁾	0.40	0.40
Nutrient composition (%) ³⁾		
NE _m (Mcal/kg)	2.10	2.24
NE _g (Mcal/kg)	1.44	1.57
Crude protein (%)	11.5	11.5
NDF (%)	13.4	13.45
Calcium (%)	0.80	0.80
Phosphorus (%)	0.38	0.36

DM, dry matter; NE_m, net energy of maintenance; NE_g, net energy for gain; NDF, neutral detergent fiber.

¹⁾ Diets formulations were balanced for crude protein, estimated metabolizable protein, Ca and P per kg dry matter intake [21].

²⁾ Trace mineral salt contained: 0.052% KI; 0.68% CoSO₄; 1.04% CuSO₄; 1.07% MnSO₄; 1.24% ZnO₄; 3.57% FeSO₄; 92.96% NaCl.

³⁾ Calculated based on tabular NE values for individual feed ingredients [21].

steers, access to feed was limited 1 h following each feeding, after which residual feed was withdrawn. The DM content (method 930.15 [8]) of feed and feed refusal was determined daily. All steers were provided *ad libitum* access to water. The experiment lasted 56 days.

Calculations

Energy gain (EG, Mcal/d) was calculated by the equation: $EG = 0.0557SBW^{0.75} \times ADG^{1.097}$; where EG is the daily deposited energy and shrunk body weight (SBW) is the average body weight×0.96 [9]. Maintenance energy (ME), Mcal/d) was calculated by the equation: $ME = 0.077SBW^{0.75}$ [10]. From the derived estimates of net energy required for maintenance and gain, the NE_m and NE_g values of the diet were obtained using the quadratic formula:

$$x = (-b - \sqrt{b^2 - 4ac})/2c$$

Where x = diet NE_m, Mcal/kg, $a = -0.41ME$, $b = 0.877ME + 0.41DMI + EG$, and $c = -0.877DMI$, and $NE_g = 0.877NE_m - 0.41$ [11].

Statistical analysis

The trial was analyzed as a randomized complete block design

with a 2×2 factorial arrangement of treatments, using pens as experimental units according to the following statistical model: $Y_{ij} = \mu + B_i + T_j + \epsilon_{ij}$, where μ is the common experimental effect, B_i represents initial weight block effect, T_j represent dietary treatment effect, and ϵ_{ij} represents the residual error. Performance data were determined considering initial and final shrunk (live weight reduced 4% to account for digestive tract fill) weight. Treatments effects were separated by means of the following orthogonal polynomials: i) Corn processing (steam flaked vs dry rolled), ii) feeding system (*ad libitum* vs restricted), and iii) the corn processing×feeding system interaction. Significant difference was considered when the p-value was ≤ 0.05 and tendencies when $p > 0.05 \leq 0.10$. Data were analyzed using the MIXED procedure of SAS [12].

RESULTS AND DISCUSSION

Treatment effects on growth performance and estimated dietary NE of steers are shown in Table 2. There were no treatment interactions on dry matter intake (DMI), ADG, feed efficiency (G:F), or dietary NE. There was a feeding management by corn processing interaction ($p = 0.05$) on the within-pen standard deviation (SD) in steers ADG. Under condition of *ad libitum* feed access, the SD for within-pen ADG was greater in steers fed DRC- vs SFC-based diets. In contrast, under conditions of restricted feed access the SD for within-pen ADG was greater for SFC- vs DRC-based diets. The basis for these differences in within-pen ADG is not certain. Daily weight gain is closely associated with energy intake [13]. Accordingly, variation in ADG can be interpreted as a reflection of variation in DMI. Limit feeding programs where

the daily amount of feed provided was restricted by 5% to 10% has in some instances [14,15] decreased within-pen variation in ADG. Whereas, in other cases [16,17] limiting the amount of feed provided did not affect within-pen variation in ADG. As dietary treatments allow for growth rates that more closely approximate genetic potential, it is expected that variation in ADG will diminish. This effect is apparent for steers with *ad libitum* access to feed. Conversely, when feeding management restricts the animal's ability to achieve its genetic potential greater variation in individual ADG is expected due to differences in individual feeding activity (aggression at the feed bunk). Management restrictions resulting in marked reductions in both ADG and within pen SD for ADG (as was the case with restricted access time to the DRC-based diet), may reflect generalized subclinical acidosis [5].

In the present study, the amount of feed provided was not restricted. Instead, we evaluated how the amount of time allotted to consume feed affects growth-performance responses to DRC- vs SFC-based diets. The amount of time feedlot cattle spend actually consuming feed has been a recurring research topic, with estimates of average consumption rates ranging from 0.075 to 0.400 kg/min [5,6,18-20]. Differences in feeding rates seem to be largely a function of how the assessment is done (for example, time spent at, or in close proximity to the feed bunk vs time spent with the head in the feed bunk). Based on radio telemetry (measuring time spent when the cattle head comes within 50 cm of the outside edge of the feed bunk), cattle spent a total of 32 ± 5 min/d consuming 12.2 kg of a barley-based finishing diet [5]. Rate of feed consumption averaged 0.38 kg/min, with an average feeding

Table 2. Influence of corn processing and time period of feed access on growth performance and dietary energy of feedlot steers

Items	Treatments ¹⁾				SEM	p value		
	SFC-24h	DRC-24h	SFC-2h	DRC-2h		SFC vs DRC	24 h vs 2 h	Processing× feed access
Days on fed	56	56	56	56	-	-	-	-
Pens	4	4	4	4	-	-	-	-
Weight (kg) ²⁾								
Initial	251.9	252.1	249.0	252.8	0.91	-	-	-
Final	327.1	319.0	308.1	296.7	3.10	0.02	<0.01	0.61
Weight gain (kg/d)	1.34	1.19	1.06	0.78	0.06	<0.01	<0.01	0.33
DM intake (kg/d)	6.10	5.99	5.01	4.85	0.19	0.50	<0.01	0.89
Gain to feed	0.221	0.200	0.212	0.160	0.008	<0.01	0.02	0.08
Observed NE (Mcal/kg)								
Maintenance	2.18	2.05	2.22	1.96	0.04	<0.01	0.55	0.12
Gain	1.50	1.39	1.54	1.31	0.04	<0.01	0.55	0.12
NE, observed-to-expected ³⁾								
Maintenance	0.97	0.98	0.99	0.93	0.02	0.20	0.50	0.11
Gain	0.96	0.97	0.99	0.91	0.02	0.20	0.49	0.11
Means for SD for ADG	0.238	0.366	0.301	0.224	0.044	0.59	0.40	0.05

SFC, steam-flaked corn; DRC, dry rolled corn; SEM, standard error of the mean; DM, dry matter; NE, net energy; SD, standard deviation; ADG, average daily gain.

¹⁾ SFC-24h, diet with steam flaked corn accessed all day; DRC-24h, diet with dry-rolled corn allowed during all day; SFC-2h, diet with steam flaked corn accessed 2 hours only per day; DRC-2h, diet with dry-rolled corn allowed during 2 hours day.

²⁾ Initial and final weights were reduced by 4% to account for digestive tract fill.

³⁾ Expected diet NE based on tabular values for individual dietary ingredients [21].

frequency of 7.1 ± 0.6 visits/d to the feed bunk. Applying a similar approach, Schwartzkopf-Genswein et al [6] observed that over a 153-day finishing period, steers spent a total of 106 ± 5 min/d consuming 8.2 kg of a steam-rolled barley-based diet. The rate of feed consumption averaged 0.077 kg/min, with an average feeding frequency of 9 ± 0.2 visits/d to the feed bunk. In contrast, Golden et al [7], using the same technique, observed that steers spent an average of 51 min/d consuming 7.1 kg of a whole corn-based finishing cattle diet. The rate of feed consumption averaged 0.14 ± 0.03 kg/min, with an average feeding frequency of 16 ± 3 visits/d to the feed bunk. From the above, it is apparent that for feedlot cattle fed high-grain finishing diets, frequency of visits to the feed bunk can be quite variable. Nevertheless, in these studies the total time spent consuming feed will be less than two hours, with rate of feed consumption being partly dependent on differences in total feed consumed. In the present experiment, bunk space was sufficient (41 cm/head) to allow all steers access to the feed bunk at the same time. Notwithstanding, restricting access to feed to two periods of one hour each resulted in a marked reduction ($p < 0.01$) in DMI, and hence, ADG.

Consistent with previous work [3], the substitution of SFC for DRC increased ($p < 0.01$) ADG, G:F, and estimated dietary NE, without affecting ($p = 0.50$) DMI. Given that the NE_m value for DRC is 2.18 Mcal/kg [21], the estimated NE_m value for SFC using the replacement technique, averaged 2.44 Mcal/kg; an improvement of 10.7%. This result is in agreement with the 11.3% average increase in the NE_m value of SFC vs DRC reported in a 12-trial summary [3].

Compared with *ad libitum* feed access, restricting feed access to 2 h/d markedly decreased (18%, $p < 0.01$) DMI, and hence, ADG (27%, $p < 0.01$), and G:F (12%, $p = 0.02$). However, the ratio of observed-to-expected dietary NE was not affected ($p = 0.50$). Hence, daily gain and feed efficiency were predictable functions of differences in dietary NE and observed DMI. As indicated previously, provided all steers simultaneously feed at the bunk (as was the case in this study), the restriction of feed access time, per se, to 2 h/d should not have limited steer's ability to consume sufficient feed to achieve its growth potential. Hence, changes in growth-performance between *ad libitum* vs restricted feed access time may reflect the importance of meal size and frequency of feeding (not measured in this study).

Why the substitution of SFC for DRC results in greater energy intake is not certain. Using diet formulations comparable to those fed in the present study, Plascencia et al [20] observed that rate of consumption of DRC-based diets was actually slightly greater (14%, $p = 0.02$) than that of SFC-based diets, averaging 0.107 and 0.097 kg/min. It follows then that independently of corn processing, 6 kg of DM (average of DM intake observed with *ad libitum* feeding; Table 2) could have been consumed in a total of 60 min ($6 \text{ kg} \times 0.10 \text{ kg/min}$). Hence, the lack of increased intake of the DRC-based diet sufficient to compensate for its lower energy density was not a simple function of feed access time.

Furthermore, there was no interaction ($p = 0.89$) between grain processing and feed access time on comparative intake of the DRC- and SFC-based diets.

CONCLUSION

In conclusion, the substitution of steam-flaked corn for dry rolled corn in finishing diets for feedlot cattle will enhance ADG, G:F, and the NE value of the diet. Although restriction of feed access time depressed DMI and ADG, it did not influence the comparative benefit of steam flaking toward enhancement of dietary NE and ADG.

CONFLICT OF INTEREST

We certify that there is no conflict of interest with any financial organization regarding the material discussed in the manuscript.

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