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The Cost of Corn Processing for Finishing Cattle[1]

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Abstract

Three corn processing methods were compared for use in 5,000- and 20,000-head capacity feedlots. Processing methods were dry-rolled (DRC), early harvest and ensiling high-moisture (HMC), and steam-flaked corn (SFC). Processing costs were determined to be $1.58, $4.71, and $9.57/t (metric ton; DM basis) for DRC, HMC, and SFC, respectively, for the 5,000-capacity feedlot. Processing costs were less for the 20,000-capacity feedlot at $0.81, $3.07, and $6.23/t (DM basis) for DRC, HMC, and SFC, respectively. Using these economic calculations in an 85% corn diet (DM basis), an improvement of dietary feed efficiency would need to be 2.4 and 6.1% for feeding HMC or SFC, respectively, compared with feeding DRC in a 5,000-capacity feedlot to be of economical value. For the 20,000-capacity feedlot, an improvement of dietary feed efficiency would need to be 1.7 and 4.2% for feeding HMC or SFC, respectively, compared with feeding DRC. Variables such as corn price, feed efficiency response, energy cost, and feedlot size determine economic returns for corn processing. Feeding SFC appears to generate economic return in both sizes of feedlots compared with feeding HMC or DRC. Calculated economic returns involving HMC were more variable than the economic returns generated from DRC data.

Key words: corn processing, economics, finishing cattle

Introduction

Corn is a major constituent of diets fed to finishing beef cattle in the United States. The major component of yellow dent corn is starch, which is approximately 72% of the DM (Huntington, 1997). Starch utilization is fundamental to improving efficiency of production of feedlot cattle (Theurer, 1986). Corn is processed to increase starch availability to improve cattle performance. Galyean (1996) surveyed consulting nutritionists and evaluated the 3 major corn processing methods, which were dry-rolling, early harvest and ensiling, and steam-flaking. Several studies (Huck et al., 1998; Cooper et al., 2002; Scott et al., 2003; Macken et al., 2006) and a review (Owens et al., 1997) determined finishing cattle responses to these different processing methods. However, limited work has been reported in the literature to define the cost associated with each processing method. Knowing the costs of processing corn is a critical part in determining economic advantages that can be gained by the different processing methods. A certain processing method may in fact cost more than the improvement in cattle performance justifies. Economic evaluation of corn processing is difficult to define as it can be specific to individual producers. Therefore, objectives of this evaluation were 1) to outline cost of processing corn, 2) to provide general numbers associated with processing of corn, and 3) to discuss potential economic gain from corn processing based on cattle performance.

Materials and Methods

Units of Measurement. Because of unfamiliarity of metric terms when discussing economic costs, listed are some common conversions: 1 ton = 909 kg; 1 t (metric ton) = 2,205 lb; 1 bushel = 35.2 L; 1,000 ft^3 (**mcf**) = 28.3 kL; and 1 ft = 0.305 m. The density used for whole corn at 15.5% moisture was 0.72 kg/L (56 lb/bushel).

Economics. Economics of corn processing are dependent on many factors such as corn price, individual producer resources, and cost of processing inputs. Economic inputs were obtained by communication with feedlot consultants, feedlot managers, and grain handling suppliers and by review of the literature. Based on proprietary information of some inputs, some sources of information cannot be revealed. Assumptions have been made on several

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costs and inputs because of a lack of information available, and these assumptions are noted.

Economic evaluation of dry-rolled (**DRC**), early harvest and ensiled (**HMC**), and steam-flaked (**SFC**) corn were done for 2 sizes of feedlots (5,000- and 20,000-cattle capacity). To calculate corn use, an average intake of 7.73 kg (DM basis) of corn was assumed per head per day. Capacity of the feedlot was assumed to be 90%. Assumptions made were as follows: the feedyards were capable of receiving and storing whole shelled corn, a front-end loader was used to supply ingredients to a mixer, and any additional cost to process the corn would be accounted for in the different processing methods.

The diet used to determine dietary cost for these comparisons was 85% corn, 7% alfalfa hay, 5% supplement, and 3% tallow (DM basis). The costs of these ingredients were \$95.51/t for corn (\$2.05/bushel; Christian et al., 2003), \$93.70/t of alfalfa hay, \$275.58/t for supplement, and \$286.60/t for tallow (DM basis).

TABLE 1. Initial cost of dry-rolling corn.

Item	Cost, \$
5,000-head capacity	
55-t[a] supply bin	15,000
Elevated building; 3.7 m × 3.7 m; all steel; skin-covered	19,750
Single-stack rollermill; 17.8 cm × 45.7 cm; 10-hp motor	7,000
Bucket elevator; 5-hp motor	10,000
Wiring package with alarm system	5,250
Miscellaneous spouting and installation	9,500
Total initial cost	66,500
20,000-head capacity	
165-t supply bin	45,000
Elevated building; 3.7 m × 3.7 m; all steel; skin-covered	19,750
Single-stack rollermill; 22.8 cm × 91.4 cm; 30-hp motor	12,000
Bucket elevator; 5-hp motor	10,000
Wiring package with alarm system	5,250
Miscellaneous spouting and installation	9,500
Total initial cost	101,500

[a]t = metric ton.

Dry-Rolling Corn. Dry-rolling corn is accomplished by passing whole shelled corn through a rollermill. Single (one set of rolls) and double (2 sets of rolls) stack rollermills are available for use in feedlots. We assumed that a single stack rollermill would be used to crack the corn. A list of initial equipment and cost to roll corn is in Table 1. For the 5,000-head capacity feedlot, a rollermill (17.8-cm × 45.7-cm rolls with a 10-hp motor) that was capable of processing 15.4 t of corn (DM basis)/h was used. For the 20,000-head capacity feedlot, a rollermill (22.8-cm × 91.4-cm rolls with a 30-hp motor) that was capable of processing 48.1 t of corn (DM basis)/h was used. The rollermill is designed so that the mill is elevated, and the processed corn drops into a pile, allowing the front-end loader access to the corn without any other equipment needed to move corn away from the roller.

The rollermill is equipped with an alarm system to notify the operator that the supply bin is either full or empty. This provides employees the opportunity to conduct other tasks and not be present at the roller during the entire operation. Labor was based on the assumption of operating the mill 20 min/h. Total hours of operation of the rollermills was 2.25 and 2.89 h for the 5,000- and 20,000-head capacity feedlot, respectively, resulting in 0.75 (2.25 × 0.333) and 0.96 (2.89 × 0.333) h of labor/d. Maintenance and repairs costs, based on \$0.33/t of DM rolled, resulted from recorrugation of rolls, replacement of parts, and labor to complete these repairs.

Steam-Flaking Corn. In this processing method, corn is exposed to steam before passage through a set of rolls. A list of initial equipment and cost to flake corn is in Table 2. For this comparison, a flaker with the capability of processing 5.4 t of DM was used. The flaker's rolls are 45.7 × 91.4 cm and powered by a 75-hp motor. One flaker setup was used for the 5,000-head capacity feedlot, and 2 flakers were used for the 20,000-head feedlot. Steam for the flakers was generated by 125-hp double-pass boilers and a 9.1- × 0.97-m round stainless steel steam chest was used to cook the grain. Cost of natural gas was calculated by using 15.6 kL of natural gas/t of corn (DM basis). This mill was elevated so that the flakes fell into a pile after being processed. The pile was then accessed by a front-end loader that moved SFC into the mixer. Other equipment could be used to transverse flakes away from the flakers, which would increase the cost to flake corn.

The mill was equipped with a maximum and minimum grain concentration control. This design allows the system to keep the steam chest full automatically and opens the rolls when grain is no longer present to prevent damage to the rollers. This system allows for an employee to conduct other tasks; thus, constant observation while the flakers are operating is not required. Labor was based on 20 min/h of flaker operation. During this time, flake density can be checked. Total hours of operation of the rollermill were 6.37 and 12.75 h for the 5,000- and 20,000-head capacity feedlots, respectively. Start up and shut down is more labor-intensive than a dry-roll-

TABLE 2. Initial cost of steam-flaking corn.

Item	Cost, $
5,000-head capacity	
Elevated building; 4.0 m × 9.1 m; all steel; skin-covered	28,500
Double-pass boiler; 125-hp motor	52,000
Vent system	3,600
Scalper with magnet	3,250
Stainless-steel steamchest; 9.1 m × 1.0 m; round	14,200
Rolls; 45.7 cm × 91.4 cm; 75-hp motor	36,000
Rail system	3,000
Bucket elevator; 5-hp motor	10,000
Hydraulic pump system; 5-hp motor	10,000
Wiring package with alarm systems	16,750
Miscellaneous spouting and installation	12,500
Total initial cost	189,800
20,000-head capacity	
Elevated building; 4.0 m × 9.1 m; all steel; skin-covered	28,500
Double-pass boiler; 125-hp motor	52,000
Vent system	7,200
Scalper with magnet	3,250
2 stainless-steel steamchests; 9.1 m × 1.0 m; round	28,400
2 rolls; 45.7 cm × 91.4 cm; 75-hp motors	72,000
Rail system	3,000
Bucket elevator; 5-hp motor	10,000
Hydraulic pump system; 5-hp motor	17,000
Wiring package with alarm systems	16,750
Miscellaneous spouting and installation	12,500
Total initial cost	250,600

ing rollermill so 1 h was assigned for start up and 1 h for shut down. This resulted in 4.12 [(6.37 × 0.333) + 2] and 6.25 [(12.75 × 0.333) + 2] h of labor/d to flake the needed corn for the 5,000- and 20,000-head capacity feedlots, respectively. Maintenance and repairs, costing $0.83/t of DM rolled, included recorrugation of rolls, replacement of parts, and labor. Maintenance and repairs for flaking are more than dry-rolling because of more parts and the presence of steam, which causes corrosion.

Early Harvest and Ensiling High-Moisture Corn. Corn is harvested then ground or rolled and stored in oxygen-limiting structures at 25 to 32% moisture. The average moisture of corn was assumed to be 28.5% for economic analysis. Initial costs were estimated based on a trench silo with a cement floor and walls. Concrete walls were assumed to be 4.27 m tall and 10.2 cm thick. Area of the bunker was based on length:width of 3.54:1 and a peak height based on a ratio of 6:1 of half the width of bunker to peak height above wall height. A sample calculation is in Table 3. Area needed for corn storage for the 2 feedlots was based on total amount corn fed in a year and a density for 28.5% moisture to be 0.90 kg/L. Bunker floor was based on 20.3 cm thick concrete. Initial costs were calculated based on kiloliter of concrete needed to construct the bunker. A price of $91.56/kL was used for concrete costs plus construction costs. Construction costs were $65.40 and $58.86/kL of concrete for the 5,000- and 20,000-head feedlots, respectively (Table 4).

Custom operations are available to feedlots to unload trucks, process (roll or grind), pile, and pack HMC into the bunker. Custom crews can be hired for $0.0051 to $0.0055/kg of as-is weight if 11,000 t of DM is stored and $0.0046/kg of as-is weight if 44,000 t of DM is stored. Processing and storage costs were $0.0055 and $0.0046/kg of as-is weight for the 5,000- and 20,000-head feedlots, respectively (Tables 5 and 6). In these comparisons, feeding DRC or SFC requires an employee of the feedlot to unload the corn vs. the custom crew; therefore, a grain-handling discount was applied to feeding HMC. This discount was based on the number of truck loads (25 t of 15.5% moisture corn) needed to feed the cattle. Each load was assigned 20 min of labor. After HMC is stored, a polyurethane cover is placed on the bunker and held in place with tires. The cost to cover the bunker was based on area of the bunker and charged at $1.08/m^2$. Corn was purchased at a discount if corn moisture is >15.5%. High-moisture corn can be discounted in several ways, such as per point of moisture over 15.5%. A certain price per bushel can be discounted from the contract price, or a certain percentage discount can be applied to reduce the weight of the sale. We assumed a 1.5% discount per point of moisture above 15.5%; thus, a discount of 19.5% was used to reduce sale weight [(28.5% moisture – 15.5% moisture) × 0.015].

Fixed Cost. Depreciation and interest on initial cost were determined using the method of capital recovery [(amount to be depreciated/amortization factor) + (salvage value × interest rate)]. The initial cost of the equipment was depreciated over 10 yr using an interest rate of 10% and no salvage value. Amortization factor was calculated by the equation: $\{1 - [1/(1 + r)^n]\}/r$, where r = interest rate and n = years to be depreciated. Insurance was applied at $0.00462/yr per dollar of initial investment (McEllhiney, 1986). Taxes were applied based on 1% of the assessed value (40% of initial investment)/yr.

Variable Cost. Corn price used was $0.081/kg ($2.05/bushel at 15.5% moisture) based on a 5-yr av-

TABLE 3. Sample calculation for bunker size for high-moisture corn storage. t = metric ton.

Feedlot needs: 10,000 t of corn DM

Conversion to as-is kg:
$10{,}000 \text{ t} \times 1{,}000 \text{ kg} \div (1 - 0.285) = 13{,}986{,}014$ kg of 28.5% moisture corn

Conversion to area needed for storage:
$13{,}986{,}014 \text{ kg} \div 0.90 \text{ kg/L} = 15{,}540{,}015$ L needed to store 28.5% moisture corn

Determination of bunker size:
$(x \times 3.54x \times 4.27) + (x \times 0.1667x \times 3.54x/4) = 15{,}540{,}015$ L, where x = bunker width

Bunker size:
Width = 28.4 m
Length = 100.5 m (28.4 × 3.54)
Side height = 4.3 m
Center peak height = 6.6 m [(0.1667 × 28.4/2) + 4.3]

erage of corn in western Nebraska (Christian et al., 2003). Natural gas price used was $0.178/kL ($5.04/mcf) based on a 5-yr average (1998 to 2002) of the commercial sector in Nebraska. Electricity price used was $0.056/kwh, which was based on a 5-yr average (1998 to 2002) of the commercial sector in Nebraska. Electricity use was based on totaling horsepower of motors needed for the certain processing method and converting the horsepower to kilowatts by 1 hp = 0.7455 kw. Operating labor was based on wage and benefits of $15.00/h.

Results and Discussion

Initial cost of equipment is a major cost in corn processing. An efficiency ($ per head of capacity) of size exists for the larger compared with the smaller size feedlot. The initial cost for dry-rolling corn was $66,500 and $101,500 for the 5,000- and the 20,000-head feedlot, respectively (Table 1). However, the initial cost per head capacity was less for the 20,000-head feedlot ($5.08 per head) vs. the 5,000-capacity feedlot ($13.33 per head). The larger feedlot does need a larger supply bin, roller, or motor than the smaller feedlot. However, cost reduction is gained by increasing the amount of corn processed for the larger feedlot (4 times) and spreading it over the fixed costs. Depreciation and interest were $0.85 and $0.33/t of corn DM for the 5,000- and the 20,000-head capacity feedlot, respectively (Tables 5 and 6).

Efficiency of size was observed for initial cost of steam-flaking. The initial cost for SFC was $189,800 and $250,600 for the 5,000- and the 20,000-head capacity feedlot, respectively (Table 2), which equates to an initial cost per head capacity of $37.96 and $12.53, respectively. Cost reduction is gained because one boiler is used to operate one flaker in the smaller feedlot as well as 2 flakers in the larger feedlot. Depreciation and interest were $2.44 and $0.81/t of corn DM for the 5,000- and the 20,000-head feedlots, respectively (Tables 5 and 6).

For HMC, the efficiency of size is not as large compared with DRC and SFC. Initial costs for HMC storage were $120,451 and $375,168 for the 5,000- and the 20,000-head feedlots, respectively (Table 4), which equates to an initial cost per head capacity of $24.09 and $18.76, respectively. Bunker size is greater for the larger feedlot; however, the differences in concrete and construction costs for area of storage between the 2 sizes of bunkers are not as great as the differences in efficiencies observed with DRC and SFC. Bunker cost per 1 kL of storage was $6.11 and $4.73 for the 5,000- and 20,000-head feedlots, respectively. Depreciation and interest were $1.55 and $1.21/t of corn DM for the 5,000- and 20,000-head feedlot, respectively (Tables 5 and 6). Total fixed costs per metric ton of corn DM for the 5,000-head feedlot were $0.89, $1.63, and $2.57 for DRC, HMC, and SFC, respectively (Table 5). Total fixed costs per metric ton of corn

TABLE 4. Initial cost of ensiling early harvest high-moisture corn.

Item	Cost, $
5,000-head capacity	
4.3-m × 31.7-m × 111.9-m concrete bunker (767.4 kL of concrete)	70,263
Construction	50,188
Total initial cost	120,451
20,000-head capacity	
4.3-m × 57.9-m × 204.8-m concrete bunker (2,494 kL of concrete)	228,363
Construction	146,805
Total initial cost	375,168

TABLE 5. Fixed and variable manufacturing costs [$/t (metric ton) of corn DM] for a 5,000-head capacity feedlot at 12,665 t of corn DM/yr.

Item	DRC[a]	HMC[a]	SFC[a]
Fixed cost			
Depreciation and interest[b]	0.85	1.55	2.44
Insurance[c]	0.02	0.04	0.07
Taxes[d]	0.02	0.04	0.06
Total fixed costs	0.89	1.63	2.57
Variable cost			
Labor[e]	0.32	—	1.78
Maintenance and repair	0.33	—	0.83
Natural gas[f]		—	2.78
Electricity[g]	0.04	—	1.61
Custom hire[h]		7.71	—
Cover bunker[i]		0.30	—
Moisture discount[j]		(4.65)	—
Corn handling discount[k]		(0.28)	—
Total variable costs	0.69	3.08	7.00
Total cost	1.58	4.71	9.57

[a]DRC = dry-rolled corn; HMC = early harvested and ensiled high-moisture corn; SFC = steam-flaked corn.
[b]Calculated using the capital recovery method of depreciation and interest.
[c]Based on $0.00462/yr per dollar of initial investment (McEllhiney, 1986).
[d]Tax at 1% of the accessed value (40% of initial investment).
[e]Labor includes wage and benefits at $15.00/h.
[f]Natural gas price was $0.178/L.
[g]Electricity price was $0.056/kwh.
[h]Custom crew is hired to unload, process, and pack high-moisture corn for $0.0055/kg of corn (as-is basis).
[i]Cost to cover bunker with polyurethane and tires at $1.08/m^2.
[j]Discount applied at 1.5% per point of moisture above 15.5%.
[k]Discount applied to HMC as cost is covered in custom crew charge.

DM for the 20,000-head feedlot were $0.35, $1.27, and $0.85 for DRC, HMC, and SFC, respectively (Table 6).

A similar cost savings of size is recognized when comparing variable costs between the 2 sizes of feedlots. Total variable costs per metric ton of corn DM for the 5,000-head feedlot were $0.69, $3.08, and $7.00 for DRC, HMC, and SFC, respectively (Table 5). Total variable costs per metric ton of corn DM for the 20,000-head feedlot were $0.46, $1.80, and $5.38 for DRC, HMC, and SFC, respectively (Table 6). Much of the cost reduction for the larger feedlot is gained through labor cost. With HMC, the cost of the custom crew was less per bushel for the larger feedlot than for the smaller feedlot. Another cost reduction for feeding HMC at the larger feedlot is in the cost of covering the corn in the bunker. Cost reduction for SFC is gained by reducing electricity cost, because of the electricity needs of the 125-hp boiler when steam is being used for 2 flakers.

Total costs of processing corn per t of corn DM for the 5,000-head feedlot were $1.58, $4.71, and $9.57 for DRC, HMC, and SFC, respectively (Table 5). Total costs of processing corn per t of corn DM for the 20,000-head feedlot were $0.81, $3.07, and $6.23 for DRC, HMC, and SFC, respectively (Table 6). For all processing methods, the cost per t of corn processed is less in the larger feedlot compared with the smaller feedlot. Reductions of 49, 35, and 35% for DRC, HMC, and SFC, respectively, were observed for the cost to process in a larger feedlot compared with a smaller feedlot.

Other researchers have reported estimates for the costs of processing corn (Table 7). Processing DRC was estimated to cost $2.83/t (Schake and Bull, 1981), $1.97/t (McEllhiney, 1986), and $1.76/t of DM (Cooper et al., 2001) for 5,000-head capacity feedlots. Schake and Bull (1981) and Cooper et al. (2001) did not list all of the assumptions they used for equipment; thus, comparison with our calculations is difficult. McEllhiney (1986) did not specify if the processing cost was on a DM or as-is basis. However, assuming that the value is on an as-is basis and DRC is 15.5% moisture, the cost would be $2.34/t of corn DM processed. This number is slightly greater than our value, although McEllhiney (1986) used a bigger rollermill that was double stacked (22.9- × 91.4-cm rolls) and a larger motor (60 hp), which increases the cost to roll corn. Schake and Bull (1981) and Cooper et al. (2001) also did economic calculations for a 20,000-head capacity feedlot and reported a cost of $1.92 and $1.59/t of DM, respectively. Schake and Bull (1981) and Cooper et al. (2001) observed similar improvements in cost reductions for feedlot size that we observed for the larger feedlot.

Schake and Bull (1981) and Cooper et al. (2001) also made economic calculations for HMC and SFC for both the 5,000- and 20,000-head feedlots. The cost to feed HMC was $13.83 (Schake and Bull, 1981) and $2.58/t of DM (Cooper et al., 2001) for the 5,000-head feedlot and $12.62 (Schake and Bull, 1981) and $2.18/t of DM (Cooper et al., 2001) for the 20,000-head feedlot. Costs reported by Schake and Bull (1981) are

TABLE 6. Fixed and variable manufacturing costs [$/t (metric ton) of corn DM] for a 20,000-head capacity feedlot at 50,662 t of corn DM/yr.

Item	DRC[a]	HMC[a]	SFC[a]
Fixed cost			
Depreciation and interest[b]	0.33	1.21	0.81
Insurance[c]	0.01	0.03	0.02
Taxes[d]	0.01	0.03	0.02
Total fixed costs	0.35	1.27	0.85
Variable cost			
Labor[e]	0.10	—	0.68
Maintenance and repair	0.33	—	0.83
Natural gas[f]		—	2.78
Electricity[g]	0.03	—	1.09
Custom hire[h]		6.48	—
Cover bunker[i]		0.25	—
Moisture discountj		(4.65)	—
Corn handling discount[k]		(0.28)	—
Total variable costs	0.46	1.80	5.38
Total cost	0.81	3.07	6.23

[a]DRC = dry-rolled corn; HMC = early harvested and ensiled high-moisture corn; SFC = steam-flaked corn.

[b]Calculated using the capital recovery method of depreciation and interest.

[c]Based on $0.00462/yr per dollar of initial investment (McEllhiney, 1986).

[d]Tax at 1% of the accessed value (40% of initial investment).

[e]Labor includes wage and benefits at $15.00/h.

[f]Natural gas price was $0.178/kL.

[g]Electricity price was $0.056/kwh.

[h]Custom crew is hired to unload, process, and pack HMC for $0.0046/kg of corn (as-is basis).

[i]Cost to cover bunker with polyurethane and tires at $1.08 m^2.

[j]Discount applied at 1.5% per point of moisture above 15.5%.

[k]Discount applied to HMC as cost is covered in custom crew charge.

significantly greater compared with those reported by Cooper et al. (2001), but Schake and Bull (1981) did not account for any moisture discount when purchasing the HMC, which markedly increased costs. The cost to process SFC was $10.70 (Schake and Bull, 1981) and $7.89/t of DM (Cooper et al., 2001) for the 5,000-head feedlot and $6.96 (Schake and Bull, 1981) and $7.48/t of DM (Cooper et al., 2001) for the 20,000-head feedlot. McEllhiney (1986) also calculated cost to process SFC for a 5,000-head feedlot to be $5.72/t. McEllhiney (1986) did not specify if the cost was on a DM or as-is basis. Assuming an as-is basis and flakes are 18% moisture, the cost would be $6.98/t of DM. McEllhiney's (1986) estimated cost was less than our cost because we used a larger boiler size and greater natural gas price.

Based on our economic analysis of corn processing, percentage improvement in total dietary feed efficiency required to cover the cost of feeding HMC or SFC would need to be 2.4 and 6.1% (sample calculation in Table 8), respectively, in an 85% corn diet (DM basis) compared with DRC in a 5,000-head feedlot. In feeding SFC, a feed efficiency improvement of 3.6% is required to cover the additional costs compared with feeding HMC in a 5,000-head feedlot. These improvements assume equal ADG among the processing methods. For a 20,000-head feedlot, the percentage improvement in total diet efficiency would need to be 1.7 and 4.2% for feeding HMC or SFC compared with DRC in an 85% corn diet

TABLE 7. Summary of costs to process dry-rolled, high-moisture, and steam-flaked corn [$/t (metric ton) on a DM basis].

	5,000-head feedlot			20,000-head feedlot		
Item	DRC[a]	HMC[a]	SFC[a]	DRC[a]	HMC[a]	SFC[a]
Schake and Bull (1981)	2.83	13.83	10.70	1.92	12.62	6.96
McEllhiney (1986)[b]	2.34	—	6.98	—	—	—
Cooper et al. (2001)	1.76	2.58	7.89	1.59	2.18	7.48
Current results	1.58	4.71	9.57	0.81	3.07	6.23

[a]DRC = dry-rolled corn; HMC = early harvested and ensiled high-moisture corn; SFC = steam-flaked corn.

[b]Author did not specify a DM or as-is basis, and the assumption was made that values were presented on an as-is basis and were adjusted to a DM basis using 15.5% moisture for DRC and 18% moisture for SFC.

TABLE 8. Sample calculation for determining required improvement in feed efficiency to cover processing cost (DM basis).

Item[a]	Cost,[b] $/t	Processing cost, $/t	Percentage inclusion (DM basis)	Diet cost, $/t
DRC diet				
Corn	95.51	1.58	85.0	82.54
Alfalfa hay	93.70	—	7.0	6.56
Supplement	275.58	—	5.0	13.78
Tallow	286.60	—	3.0	8.60
Total diet cost				111.48
SFC diet				
Corn	95.51	9.57	85.0	89.31
Alfalfa hay	93.70	—	7.0	6.56
Supplement	275.58	—	5.0	13.78
Tallow	286.60	—	3.0	8.60
Total diet cost				118.25

[a]DRC = dry-rolled corn; SFC = steam-flaked corn.

[b]Diet cost = (ingredient cost + processing cost) – percentage inclusion.

[c]Required improvement in feed efficiency for SFC compared with DRC: 118.25/111.48 = 1.061.

(DM basis). A feed efficiency improvement of 2.4% is required for feeding SFC compared with feeding HMC in a 20,000-head feedlot.

Comparing these breakeven improvements in dietary efficiency to feeding studies reported in the literature is essential in determining the potential economical gain from the different processing methods. Huck et al. (1998) fed diets that contained 74% corn, which was DRC, HMC, or SFC. Corn inclusion (Huck et al., 1998) was less than the 85% corn diet in our economic breakeven analysis; therefore, evaluating dietary feed efficiency improvements are not equitable. We adjusted the feed efficiency improvement observed to that expected for a dietary feed efficiency of an 85% corn diet. We accomplished this by dividing 85 by 74 and multiplying by the observed dietary feed efficiency improvement to calculate an adjusted feed efficiency for an 85% corn diet. Observed dietary feed efficiency improved 3.4 and 8.6% for HMC and SFC compared with cattle fed DRC. Making the adjustment to an 85% corn diet, the improvement was 3.9 and 9.8% for HMC and SFC compared with cattle fed DRC. Feeding SFC improved adjusted feed efficiency 5.6% compared with feeding HMC. Using these adjusted feed efficiency improvements, economical gain would be accomplished feeding SFC or HMC compared with DRC in an 85% corn diet. However, feeding HMC would not provide positive economic returns compared to feeding SFC.

In a review of feeding studies by Owens et al. (1997), improvements in observed dietary feed efficiency were 2.2 and 11.9% for HMC and SFC, respectively, compared with feeding DRC to finishing cattle in diets that averaged 82% grain. When adjusted to an 85% corn diet, results were observed similar to Huck et al. (1998), who reported that feeding SFC would be advantageous compared with feeding DRC or HMC. However, feeding HMC would generate positive returns for the 20,000-head feedlot and not cover the cost to store and process corn compared with DRC in a 5,000-head feedlot.

Recently, Scott et al. (2003) and Macken et al. (2006) fed diets that contained DRC, HMC, or SFC with wet corn gluten feed (**WCGF**). Wet corn gluten feed reduced the risk of acidosis (Krehbiel et al., 1995b). Feeding WCGF with more intensively processed corn can be beneficial in improving cattle performance. Scott et al. (2003) reported an improvement of 4.9 and 2.0% for observed dietary feed efficiency for feeding HMC compared with DRC for trials 1 and 2, respectively. In their diets, corn was fed at 52.5 and 62.5% of dietary DM for trials 1 and 2, respectively, which was considerably less than the 85% corn diet we used for economic breakeven analysis. Therefore, feeding WCGF in the diet (25% of dietary DM) equal to the price of corn and replacing corn, a dietary feed efficiency improvement of 1.7 and 1.2% is needed to cover cost of feeding HMC compared with DRC for the 5,000- and 20,000-head feedlots, respectively. In both trials, the feed efficiency gained by feeding HMC would be advantageous for the 5,000- and 20,000-head feedlots compared with feeding DRC. Macken et al. (2006) reported a dietary feed efficiency improvement of 8.0% for feeding HMC compared with DRC in 60% corn diets. In this trial, improvement in cattle performance more than covered the cost of processing and storing HMC.

Scott et al. (2003) observed dietary feed efficiency improvement of 6.6 and 9.9% for feeding SFC compared with feeding DRC for trials 1 and 2, respectively. Adjusting feed efficiency to a 60% corn diet, an improvement of 7.4 and 9.5% for feeding SFC compared with feeding dry-rolled corn for trials 1 and 2, respectively, was obtained. Macken et al. (2006) observed a slightly greater feed efficiency improvement of 12.1% for feeding SFC compared with DRC. No adjustment is needed for Macken et al. (2006), as corn was fed at 60% of the dietary DM. When feeding WCGF (25% dietary DM) in a 60% corn diet, dietary feed efficiency improvement of 4.3 and 2.9% is needed to cover cost of feeding SFC compared with DRC for the 5,000- and 20,000-head feedlots, respectively. In the 3 cases with WCGF (Scott et al., 2003, trial 1 and 2; Macken et al., 2006), SFC would be advantageous to feeding DRC.

Comparing SFC with HMC in a 60% corn diet, dietary feed efficiency improvement of 2.6 and 1.7% is needed to cover the additional cost of feeding SFC for the 5,000- and 20,000-head feedlots, respectively. Scott et al. (2003) observed dietary feed efficiency improvements of 1.5 and 7.8% for feeding SFC compared with feeding HMC in trials 1 and 2, respectively. Adjusting feed efficiency to a 60% corn diet, an improvement of 1.7 and 7.5%, was calculated for feeding SFC compared with feeding HMC in trials 1 and 2, respectively. In trial 1, feeding SFC was not advantageous to feeding HMC; however, in trial 2, feeding SFC was advantageous to feeding HMC. Macken et al. (2006) reported an improvement of 3.8% for feed efficiency for SFC compared with HMC, and this improvement would cover the additional cost of SFC.

Feeding SFC appears to be advantageous to feeding DRC. With the costs used in this economic analysis and with the summarized cattle performance, economic return would be generated. A large cost of flaking corn is the cost of natural gas. Natural gas cost was 29 and 45% of the cost to flake corn for the 5,000- and 20,000-head feedlots, respectively. Natural gas prices can fluctuate, and flaking corn may not always be advantageous compared with dry-rolling. The average improvement in feed efficiency for feeding SFC compared to DRC from the 2 studies without WCGF (Owens et al., 1997; Huck et al., 1998; Table 9) and the 3 studies with WCGF (Scott et al., 2003; Macken et al., 2006; Table 9) was 10.3 and 9.5%, respectively. Using the average adjusted feed efficiency improvement (11.1%; Table 9) in an 85% of dietary DM inclusion of corn, the cost of natural gas can range as high as $0.600 and $0.758/kL for the 5,000- and 20,000-head feedlots, respectively, before the price becomes too great (breakeven). These prices are almost 3 and 4 times the 5-yr average of $0.178/kL. One of the difficulties with economics is that a specific point in time must be selected, and inputs must be kept constant. If natural gas prices increase, corn price may also increase as well, which would increase the natural gas breakeven. The relationship between corn prices and the breakeven cost of natural gas for a 20,000-head feedlot is presented in Figure 1. The price of corn is another important variable to consider in determining the economics of a processing system. Feedlots can feed SFC and gain economic advantage compared with DRC until the price of corn drops below $0.031 and $0.012/kg ($0.79 and $0.30/bushel at 15.5% moisture) for the 5,000- and 20,000-head feedlots, respectively, in an 85% corn diet.

Feeding HMC compared with DRC did generate economic returns, except for 2 cases (Owens et al., 1997; Scott et al., 2003). Feeding HMC compared with SFC was more variable in generating economic returns compared with feeding DRC. In other reported comparisons of feeding DRC to HMC (Stock et al., 1987a, 1991; Krehbiel et al., 1995a), feed efficiency was similar between the processing methods. However, Stock et al. (1987b) and Ladely et al. (1995) reported feed efficiency improvements >9% for cattle fed HMC compared with those fed DRC, which would have economic benefits. Stock et al. (1987a) used combinations of DRC and HMC and found that a ratio of HMC to DRC of 50:50 to 75:25 produced a positive associate effect. In this situation, HMC increased dietary feed efficiency 9% compared with dry corn. Feeding HMC appears to be variable; control of acidosis may explain this variability, as shown by the combination of HMC and dry corn (Stock et al., 1987a). Similar control may be evident with WCGF, as average feed efficiency response of 2.8% improvement (Owens et al., 1997; Huck et al., 1998; Table 9) in diets without WCGF is slightly less than the average improvement of 5.0% (Scott et al., 2003; Macken et al., 2006; Table 9) for feed efficiency for HMC compared with DRC.

Determining the corn price breakeven for feeding HMC compared to DRC, corn must be priced at $0.071/kg ($1.80/bushel at 15.5% moisture) and $0.062/kg ($1.57/bushel at 15.5% moisture) before feeding DRC is advantageous to HMC in a 5,000- and 20,000-head feedlot, respectively, using a 3.1% (Table 9) improvement for an adjusted feed efficiency in an 85% corn diet without WCGF. In diets with WCGF (25% of dietary DM and 5.2% adjusted feed efficiency improvement; Table 9), corn must be priced at $0.036/kg ($0.91/bushel at 15.5% moisture) and $0.030/kg ($0.77/bushel at 15.5% moisture) before DRC is advantageous to HMC. Another consideration is how much the moisture of the corn is discounted. Some feedlots use a 1.75% discount per point of moisture above 15.5%. Using a 1.75% discount, cost to feed HMC is $1.04 and –$0.60/t of corn (DM basis) for the 5,000- and 20,000-head feedlots, respectively. At these costs, feeding HMC would be advantageous to feeding either DRC or SFC. Thus, the price of corn and its moisture discount are important considerations in deciding when to feed HMC compared with when to feed DRC or SFC.

Another unique opportunity when feeding HMC compared with feeding dry corn is the time when corn is purchased. These economic comparisons assume corn was purchased as needed, and an average yearly price was used. However, when feeding HMC, corn is delivered to the feedlot in a short period in the fall and not throughout the whole year. Various pricing structures are available to price corn. Common methods to price corn are at the time of

TABLE 9. Summary of feed efficiency response for corn processing.

Item	CONT[a]	TRT[a]	Percentage of corn diet DM	Efficiency ratio[b]	Adjusted to 85%[c]	Adjusted to 60%[d]
Owens et al. (1997)	DRC	HMC	82	1.022	1.023	1.016
		SFC		1.119	1.124	1.087
Huck et al. (1998)	DRC	HMC	74	1.034	1.039	1.028
		SFC		1.086	1.098	1.069
Scott et al. (2003), trial 1[e]	DRC	HMC	53	1.049	1.079	1.056
		SFC		1.066	1.105	1.074
Scott et al. (2003), trial 2[e]	DRC	HMC	63	1.020	1.027	1.019
		SFC		1.099	1.134	1.095
Macken et al. (2006)[e]	DRC	HMC	60	1.080	1.113	1.080
		SFC		1.121	1.171	1.121
Total average	DRC	HMC	66	1.041	1.056	1.040
		SFC		1.098	1.126	1.089
Average without WCGF	DRC	HMC	78	1.028	1.031	1.022
		SFC		1.103	1.111	1.078
Average with WCGF	DRC	HMC	59	1.050	1.073	1.052
		SFC		1.095	1.137	1.097

[a]CONT = control corn processing method; TRT = treatment corn processing method (DRC = dry-rolled corn; HMC = high-moisture corn; SFC = steam-flaked corn).

[b]Treatment divided by control processing method for the whole diet.

[c]Expected feed efficiency response for corn inclusion at 85% of dietary DM {1 + [(85/% corn in diet) × (efficiency ratio – 1)]}.

[d]Expected feed efficiency response for corn inclusion at 60% of dietary DM {1 + [(60/% corn in diet) × (efficiency ratio – 1)]}.

[e]Diets contained wet corn gluten feed (WCGF).

delivery (**DEL**); one-third at delivery, one-third 3 mo later, and one-third 6 mo later (**1/3P**); one-twelfth each mo of the yr (**1/12P**); or some other combination; each method has advantages and disadvantages. For a feedlot, the earlier the corn is priced, the more total interest is required. However, earlier purchase of corn typically lessens the amount paid for corn. Corn prices are generally least at harvest time and increase throughout the year until the following harvest (Figure 2). Using the 3 pricing methods discussed, corn would be purchased at $0.078, $0.081, and $0.081/kg ($1.99, $2.05, and $2.05/bushel at 15.5% moisture) for DEL, 1/3P, and 1/12P, respectively, using the 5-yr average (1997–2002). Additional interest expense for DEL and 1/3P would be $0.004 and $0.003/kg, respectively, based on 0.5-mo periods for usage of the corn. Total cost of purchasing corn would be $0.082, $0.084, and $0.081/kg ($2.08, $2.12, and $2.05/bushel at 15.5% moisture) for DEL, 1/3P, and 1/12P, respectively. Early purchase of the corn did not have economic benefit for a feedlot over this 5-yr period (1997–2002). However, evaluating the situations over a 10-yr period (1992–2002) when corn prices increased more throughout the year (Figure 2), advantages for purchasing corn are evident. Using the 10-yr average, total cost of purchasing corn would be $0.090 ($0.004 of interest expense/kg), $0.094 ($0.003 of interest expense/kg), and $0.092 of interest expense/kg ($2.28, $2.40, and $2.36/bu at 15.5% moisture) for DEL, 1/3P, and 1/12P, respectively.

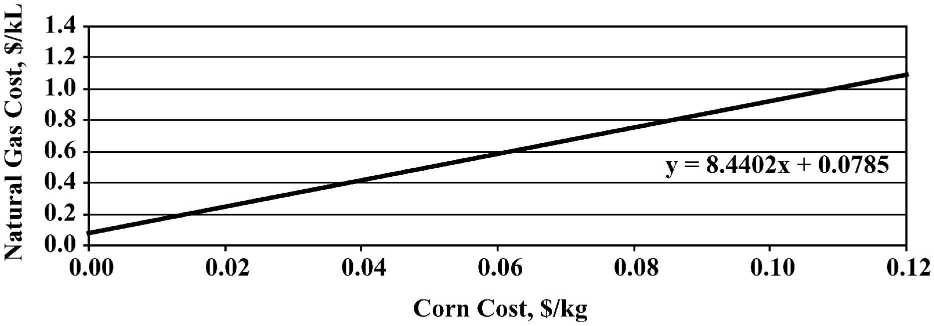

Figure 1. Relationship of corn cost to breakeven natural gas cost for a 20,000-cattle capacity feedlot.

Implications

Economic return attributable to processing corn is dependent on variables such as corn price, feed effi-

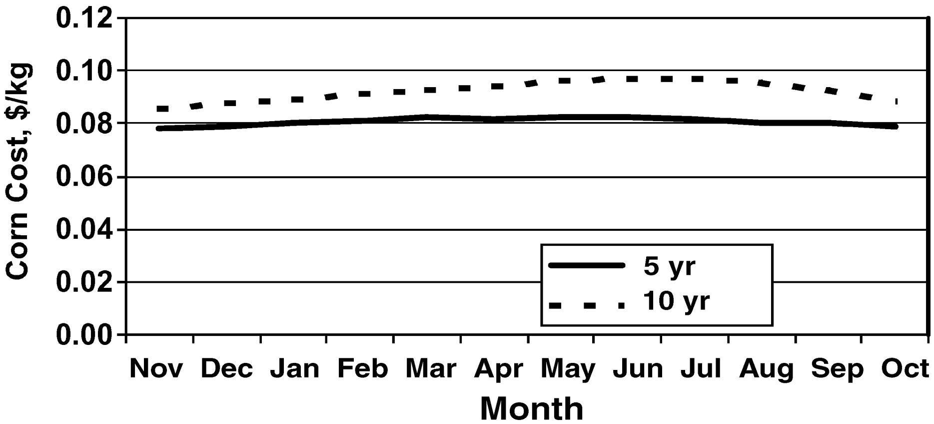

Figure 2. Seasonal 10- and 5-yr averages of corn price for Western Nebraska (Christian et al., 2003).

ciency response, energy cost, and size of feedyard. These costs and variables can vary for individual feedyards. However, using these economic variables, SFC generated economic return compared with feeding DRC in both a 5,000- and 20,000-head feedlots. Feeding HMC compared with DRC appeared to be variable in generating economic return compared with feeding DRC. There are situations when feeding HMC is beneficial to feeding SFC that are dependent on when corn is purchased, corn price, and control of acidosis.

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