Economics of Fiber Separation from Distillers Dried Grains with Solubles (DDGS) Using Sieving and Elutriation

Radhakrishnan Srinivasan,[1] Vijay Singh,[1,2] Ronald L. Belyea,[3] Kent D. Rausch,[1] Robert A. Moreau,[4] and M. E. Tumbleson[1]

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ABSTRACT

Separation of fiber from distillers dried grains with solubles (DDGS) provides two valuable coproducts: 1) enhanced DDGS with reduced fiber, increased fat and increased protein contents and 2) fiber. Recently, the elusieve process, a combination of sieving and elutriation was found to be effective in separating fiber from two commercial samples of DDGS (DDGS-1 and DDGS-2). Separation of fiber decreased the quantity of DDGS, but increased the value of DDGS by increasing protein content and produced a new coproduct with higher fiber content. Economic analysis was conducted to determine the payback period, net present value (NPV), and internal rate of return (IRR) of the elusieve process. The dependence of animal foodstuff prices on their protein content was determined. Equipment prices were obtained from industrial manufacturers. Relative to crude protein content of original DDGS, crude protein content of enhanced DDGS was higher by 8.0% for DDGS-1 and by 6.3% for DDGS-2. For a dry-grind plant processing corn at the rate of 2,030 metric tonnes/day (80,000 bushels/day), increase in revenue due to the elusieve process would be $0.4 to 0.7M/year. Total capital investment for the elusieve process would be $1.4M and operating cost would be $0.1M/year. Payback period was estimated to be 2.5–4.6 years, NPV was $1.2–3.4M, and IRR was 20.5–39.5%.

In a dry-grind corn plant, starch is converted to ethanol. Remaining components in the corn are protein, fiber, fat, unconverted starch, and ash that form a coproduct known as distillers dried grains with solubles (DDGS). Ethanol production in the United States is expected to increase in the future (RFA 2004). Dry-grind plants are preferred over wet-milling plants because they require less equipment and have lower capital investment (Belyea et al 2004). Currently, dry-grind plants contribute to 70% of the U.S. ethanol production and it is expected that future ethanol production will arise mainly from expansion of existing plant and construction of new dry-grind plants. Nearly 1 kg of DDGS is produced per kg of ethanol produced in a dry-grind plant (Schilling et al 2004). DDGS supply will increase proportionate to ethanol production. There is a need to find new uses for DDGS and make innovative products from DDGS.

Wu and Stringfellow (1986) had reported that sieving of DDGS produced DDGS fractions that were different in fiber and protein contents. Singh et al (2002) observed that elutriation or aspiration could be a method for obtaining fiber-enriched fractions from DDGS. Srinivasan et al (2005) developed the elusieve process, a combination of sieving and elutriation, which adds value to dry-grind processing by producing two products: 1) DDGS with reduced fiber, increased fat, and increased protein contents; and 2) elusieve fiber. Though sieving and elutriation were conceived and researched as individual methods for fiber separation from DDGS (Wu and Stringfellow 1986; Singh et al 2002), combination of the two methods was perhaps not attempted before Srinivasan et al (2005) due to a lack of conception as well as lack of motivation for fiber separation.

Currently, DDGS is limited in use as food for ruminant animals, dairy, and beef cattle. DDGS produced from the elusieve process has lower fiber which could potentially be used as nonruminant animal foodstuff. DDGS with increased protein and fat contents will enhance nutritional value and increase market value. From a nutrient content basis, DDGS with high fat (13%) and high protein (33%) is worth $5–20 per ton more than DDGS with lower fat (11%) and lower protein (28%) (Belyea et al 2004). Thus, DDGS produced from the elusieve process could sell at higher prices due to higher nutritional value as well as opening up new markets. Fiber produced from the elusieve process could be used to feed ruminant animals and to make valuable products such as corn fiber oil, corn fiber gum, ethanol, and xylitol (Grohmann and Bothast 1997; Moreau et al 1999; Anonymous 2002; Buchanan 2002; Dien et al 2004). Elusieve fiber also could be used for power generation by combustion and residual ash could be used in cement making. Steam gasification of elusieve fiber can be used to produce a hydrogen-rich gas (Boateng et al 1992).

The elusieve process uses a combination of sieving and elutriation to separate fiber from DDGS. When air is passed through DDGS, fiber is carried away. Some nonfiber also is carried with the air. Srinivasan et al (2005) found that sieving the DDGS into various size categories and then elutriating each category at appropriate velocities was effective in separating fiber. The material remaining after removing fiber from DDGS was called enhanced DDGS.

Separation of fiber decreases DDGS quantity but increases the value of DDGS by increasing protein content. A second coproduct that is produced is elusieve fiber that currently has a lower price than DDGS. This study determined the payback period of the elusieve process. This economic study was conducted for four corn processing rates for dry-grind plants: 510, 1,020, 1,520, and 2,030 metric tonnes/day which correspond to 20,000, 40,000, 60,000, and 80,000 bushels/day, respectively. Processing rate of 2,030 metric tonnes/day (80,000 bushels/day) of corn was taken as the base case; this plant would produce ethanol at a rate of 848 m^3/day (224,000 gallons/day or 76 million gallons/year) and DDGS at a rate of 617 metric tonnes/day (680 tons/day or 56,670 lb/hr).

ECONOMIC ANALYSIS

Composition and Mass of Streams of Elusieve Processing

In an earlier study (Srinivasan et al 2005), commercial DDGS samples (DDGS-1 and DDGS-2) were obtained from two dry-grind corn plants in the United States. Sieving over screens, 24T (869 µm), 34T (582 µm), 35M (447 µm), 60M (234 µm), and pan produced five size categories. Size categories of material retained on these screens were referred to as 24T, 34T, 35M, 60M, and pan, based on their respective screen labels. Material passing through the sieve with a larger opening was collected and fed to the next smaller

[1] Department of Agricultural and Biological Engineering, University of Illinois at Urbana-Champaign, Urbana, IL.
[2] Corresponding author, Phone: 217-333-9510. Fax: 217-244-0323. E-mail: vsingh@uiuc.edu
[3] Department of Animal Science, University of Missouri, Columbia, MO.
[4] Crop Conversion Science and Engineering Research Unit, Eastern Regional Research Center, ARS, USDA, Wyndmoor, PA.

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sieve size. Neutral detergent fiber (NDF) of samples was determined by the procedure outlined by Van Soest et al (1991). Crude protein was reported as 6.25 × total nitrogen and was determined using Official Method 920.03 (AOAC 2003). Srinivasan et al (2005) reported composition values as the mean of two determinations taken from the same material lot. The two smallest size categories, 60M (234–447 μm) and pan (<234 μm), comprised 40% of the mass of the original DDGS for DDGS-1 (Table I) and 57% of the mass of the original DDGS for DDGS-2 (Table II). 60M and pan size categories contained lower fiber and higher protein contents with respect to the original DDGS samples (Tables I and II).

Elutriation of size categories that contained fiber, 24T, 34T, and 35M was conducted in an elutriation column. Material elutriated by the air was called the "lighter fraction". Material that settled to the bottom of the elutriation column was called the "heavier fraction". Elutriation of each size category was done at four different velocities. The velocity range was selected such that the yield of lighter fraction was a minimum of 15% and a maximum of 90%. Air velocities varied between 1.59 and 5.24 m/sec, depending on DDGS material characteristics and size category. Repeatability of the elutriation experiments was verified by conducting elutriation five times and determining the coefficient of variation for the lighter fraction yield. Coefficient of variation for the lighter fraction yield was <10%.

This economic study was based on low air velocities that produced ≈20% yield of lighter fraction (Tables I and II) from each of the three biggest size categories. Yield of elusieve fiber was <20% (11.7% for DDGS-1 and 8.7% for DDGS-2) because two size categories were not subjected to elutriation. Elutriation of DDGS-1, 24T size category at 2.47 m/sec reduced NDF from 30.2% in initial material to 28.3% in the heavier fraction and increased protein from 26.5% in initial material to 29.8% in the heavier fraction (Table I). Elutriation of DDGS-2, 34T size category at 2.09 m/sec reduced NDF from 36.7% in initial material to 31.4% in the heavier fraction and increased protein from 22.1% in initial material to 26.4% in the heavier fraction (Table II).

For every 100 kg of DDGS-1 processed, 11.7 kg of elusieve fiber was separated and 88.3 kg of enhanced DDGS was produced (Table I). For every 100 kg of DDGS-2 processed, 8.7 kg of elusieve fiber was separated and 91.3 kg of enhanced DDGS was produced (Table II). DDGS-1 contained 30.1% protein and 28.7% NDF, while enhanced DDGS produced by elusieve processing contained 32.5% protein and 25.2% NDF (Table I). DDGS-2 contained 29.2% protein and 30.0% NDF, while enhanced DDGS produced by elusieve processing contained 31.0% protein and 27.5% NDF (Table II). Difference in crude protein percentage of enhanced DDGS and original DDGS was 2.4% for DDGS-1 (Table I) and 1.8% for DDGS-2 (Table II).

Implementation of Elusieve Processing in Dry-Grind Plants

The elusieve process would be integrated into dry-grind plants at the end of the drying operation. DDGS would be sieved by sifters and fiber fraction would be separated from size categories by aspirators (Fig. 1). For industrial applications of this process, aspirators would be used instead of elutriation columns and it is expected that the fourth largest size category also would be subjected to aspiration (Fig. 1). In the aspirators, air carries the lighter fraction into the cyclone and the cyclone separates the lighter fraction from air. The lighter fractions, which contain higher concentrations of fiber, would be collected together as the elusieve fiber. The heavier fractions from aspirators and pan size category would be collected as the enhanced DDGS product.

TABLE I
Composition (wb) and Fractions (wt%) from Sieving and Elutriation of DDGS-1[a]

Material	Nominal Particle Size (μm)	Wt% of Original DDGS	Crude Protein (%)	NDF (%)	Air Velocity (m/sec)	Yield (L) (%)	Crude Protein (H) (%)	NDF (H) (%)
Original DDGS	All	100.0	29.4[b] (30.1)[c]	28.7	...	...	...	...
24T	>869	27.0	26.5	30.2	2.47	17.2	29.8	28.3
34T	582–869	19.4	24.5	34.5	2.22	23.1	28.4	30.6
35M	447–582	13.3	28.1	30.3	1.84	19.3	31.4	24.5
60M	234–447	20.1	33.6	26.2	...	...	...	...
Pan	<234	20.2	38.2	17.2	...	...	...	...
Enhanced DDGS	All	88.3[d]	32.5[d]	25.2[d]	...	...	...	...
Elusieve fiber	>447	11.7[d]	12.0[d]	54.6[d]	...	...	...	...

[a] Values reported on dry basis in Srinivasan et al (2005). Neutral detergent fiber (NDF); heavier fraction (H); lighter fraction (L).
[b] Measured value.
[c] Value obtained from material balance.
[d] Computed values.

TABLE II
Compositions (wb) and fractions (wt%) from Sieving and Elutriation of DDGS-2[a]

Material	Nominal Particle Size (μm)	Wt% of Original DDGS	Crude Protein (%)	NDF (%)	Air Velocity (m/sec)	Yield (L) (%)	Crude Protein (H) (%)	NDF (H) (%)
Original DDGS	All	100.0	28.8[b] (29.2)[c]	30.0	...	...	...	...
24T	>869	12.7	19.6	36.1	2.55	21.2	23.4	29.4
34T	582–869	16.9	22.1	36.7	2.09	21.2	26.4	31.4
35M	447–582	13.3	25.4	31.7	1.59	18.2	29.4	26.2
60M	234–447	30.1	31.0	27.4	...	...	...	...
Pan	<234	27.0	36.8	25.6	...	...	...	...
Enhanced DDGS	All	91.3[d]	31.0[d]	27.5[d]	...	...	...	...
Elusieve fiber	>447	8.7[d]	10.4[d]	59.0[d]	...	...	...	...

[a] Values reported on dry basis in Srinivasan et al (2005). Neutral detergent fiber (NDF); heavier fraction (H); lighter fraction (L).
[b] Measured value.
[c] Value obtained from material balance.
[d] Computed values.

Regression Model to Estimate Animal Foodstuff Prices Based on Protein Content

The dependence of animal foodstuff prices on their protein content was estimated based on market prices of wheat middlings (16.5% protein), corn gluten feed (21% protein), DDGS (28% protein), cottonseed meal (41% protein), soybean meal (50% protein), and corn gluten meal (60% protein) for 2003-2004 and 2002-2003 reported in ERS (2005) and the current prices (June 20, 2005) obtained from University of Missouri Extension (2005). Linear regression was used to determine the dependence of animal foodstuff prices on protein content. R^2 values varied between 0.87 and 0.95 (Fig. 2). Increase in animal foodstuff price per % increase in protein content was $4.44, 5.00 and 3.66/ton for June 20, 2005, 2003-2004 and 2002-2003 prices, respectively (Fig. 2). DDGS prices were $87, 116, and 75/ton for June 20, 2005, 2003-2004, and 2002-2003, respectively.

Equipment Capacities, Capital Investment and Operating Cost

For the base case with a corn processing rate of 2,030 metric tonnes/day (80,000 bushels/day), DDGS would be produced at 25,720 kg/hr (56,670 lb/hr). Three sifters with a capacity of 10,000 kg/hr (22,000 lb/hr) each would be needed. Purchased equipment cost for sifters was obtained from an industrial manufacturer. Each sifter would cost $100,000; therefore total purchase cost for sifters would be $0.3M (Table III).

It is expected that the fourth largest size category also would be aspirated by air to separate fiber (Fig. 1). Four aspirators would be needed to separate fiber from the four largest size categories and one aspirator would be needed for standby purposes. For the base case with a corn processing rate of 2,030 metric tonnes/day (80,000 bushels/day), each aspirator would have a capacity of 12,000 kg/hr (25,000 lb/hr) of material. Purchased equipment cost

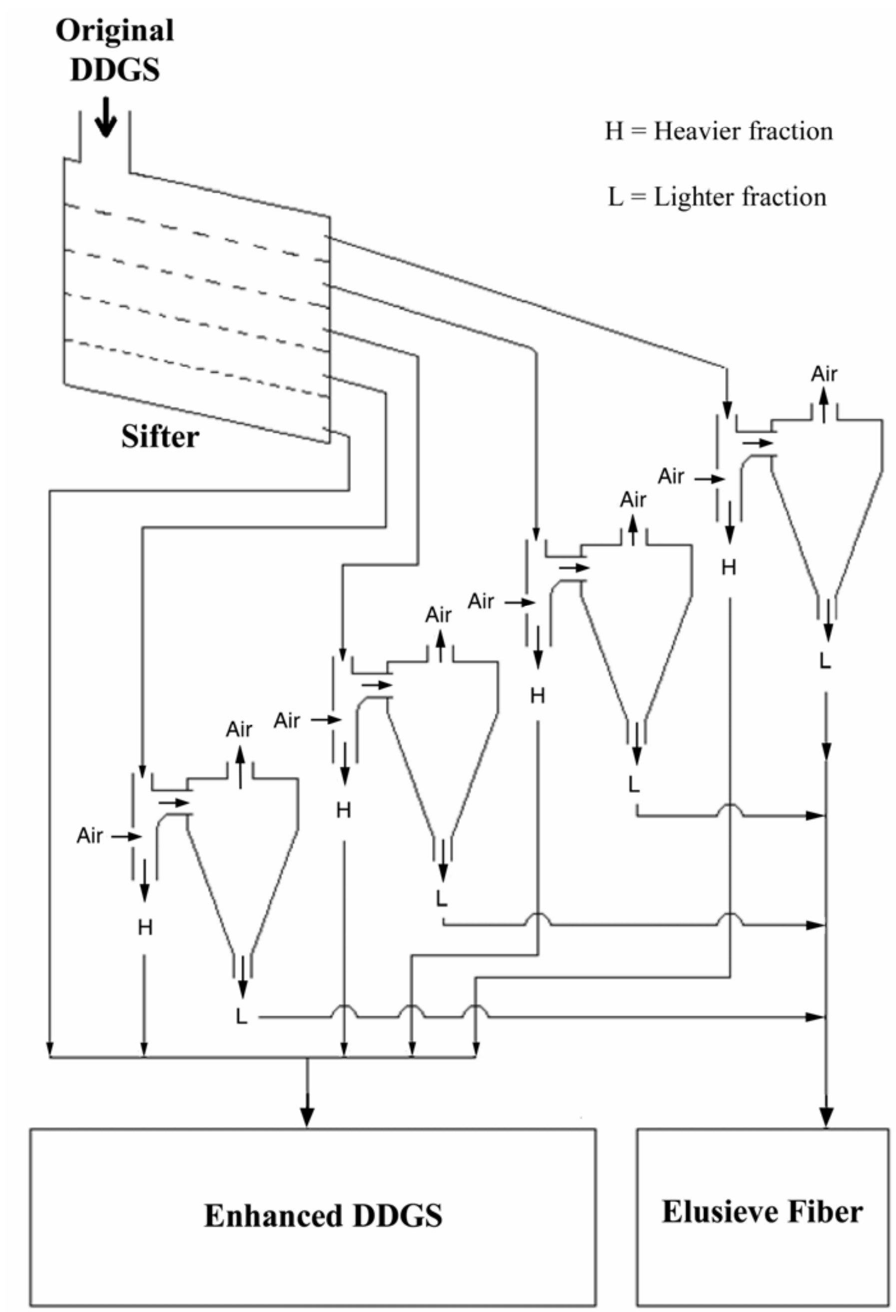

Fig. 1. Schematic of elusieve processing.

for aspirators was obtained from an industrial manufacturer; these would cost $26,000 each. Total purchase cost for aspirators would be $0.13M (Table III). Total capital investment was estimated as 3.25 times the cost of purchased equipment (Peters and Timmerhaus 1980). Working capital, building expenses, and service facilities were considered to be negligible because these are available in dry-grind plants (Singh and Eckhoff 1997). The elusieve process has a small footprint and could be implemented in the DDGS warehouse. Total capital investment for the elusieve process would be $1.4M.

For the base case with a corn processing rate of 2,030 metric tonnes/day (80,000 bushels/day), each sifter would be operated by a 3.7 kW (5 hp) motor and each aspirator would be operated by an 11.2 kW (15 hp) motor. Energy costs @ $0.05/kWh would be $0.02M/year (Table III). Labor needed would be 2 manhours/day costing $30/manhour, amounting to $0.02M/year. Maintenance costs were estimated at $0.06M/year. Total operating costs would be $0.1M/year. Using straight-line complete depreciation over 15 years, processing cost would be 8.4¢ per ton of DDGS.

For processing rates other than base case, purchased equipment cost was estimated as equipment cost for the base case times the ratio of processing rate to processing rate for base case raised to the power 0.6 (Peters and Timmerhaus 1980). Operating costs were estimated to be proportional to the processing rate. For 1,020 metric tonnes/day (40,000 bushels/day) plant, total capital investment would be $0.9M, operating costs would be $0.05M/year, and processing cost would be 9.7¢ per ton of DDGS (Table IV).

Payback Period, NPV, and IRR Calculations

Payback period is defined as the minimum length of time theoretically necessary to recover the original capital investment based on total income minus all costs except depreciation (Peters and Timmerhaus 1980). In calculating payback period, interest and depreciation effects were not accounted for. Payback period (in years) was calculated as total capital investment divided by profit per year. Net present value (NPV) was calculated by adding the present values obtained from discounting the projected cash flows at an interest rate of 8% during the lifetime of the plant, 15 years. Internal rate of return (IRR) is the interest rate at which the NPV of the projected cash flows becomes zero.

TABLE III
Equipment and Associated Costs for Implementing Elusieve Process ing in a Dry-Grind Plant Processing Corn[a]

Type of Equipment	Sifter	Aspirator
Capacity	10,000 kg/hr (22,000 lb/hr)	12,000 kg/hr (25,000 lb/hr)
Units required for normal operation	3	4
Units required for standby purpose	0	1
Total units required	3	5
Purchase cost per unit	$100,000	$26,000
Purchase cost for plant	$0.3M	$0.13M
Motor rating per unit	3.7 kW (5 hp)	11.2 kW (15 hp)
Energy consumption	11.2 kW (15 hp)	44.7 kW (60 hp)
Energy cost @ $0.05/kWh	$4,600/year	$18,300/year

[a] At a rate of 2,030 metric tones/day (80,000 bushels/day).

RESULTS AND DISCUSSION

Price of Enhanced DDGS Based on Protein Content

The prices of DDGS for June 20, 2005, 2003-2004, and 2002-2003 were $87, 116, and 75/ton, respectively. Using the regression model to estimate animal foodstuff price based on protein content, price of enhanced DDGS-1 due to increase in protein content of 2.4% would be $98, 128, and 84/ton for June 20, 2005, 2003-2004, and 2002-2003 prices, respectively. Price of enhanced DDGS-2 due to increase in protein content of 1.8% would be $95, 125, and 82/ton for June 20, 2005, 2003-2004, and 2002-2003 prices, respectively. These prices of enhanced DDGS are conservative estimates and actual prices would be higher than estimated values as the following factors were not included: 1) increase in demand due to increased potential use in nonruminant foodstuff markets and 2) higher fat content of enhanced DDGS than original DDGS.

Price of Fiber from Elusieve Processing Based on Price of Corn Gluten Feed

Elusieve fiber produced from DDGS-1 contained 12.0% protein and 5.5% fat. Elusieve fiber produced from DDGS-2 contained 10.4% protein and 4.9% fat. These values for protein of elusieve fiber are nearly half of those for corn gluten feed (21% protein content). Price of elusieve fiber was estimated as half the price of corn gluten feed based only on protein content. Actual price will be higher as elusieve fiber has higher fat content than corn gluten feed, which would result in higher prices. Elusieve fiber prices that were estimated as half the prices for corn gluten feed were $30, 42, and 33/ton for June 20, 2005, 2003-2004, and 2002-2003, respectively.

Prices for elusieve fiber based on prices of wheat middlings (16.5% protein) and regression model for dependence of price on protein content were higher than the prices of elusieve fiber calculated as half the price of corn gluten feed (except for price of elusieve fiber from DDGS-2 for June 20, 2005 prices). Price of elusieve fiber was estimated as half the price of corn gluten feed due to a conservative estimated price.

It is expected that elusieve fiber would be used in production of valuable products such as corn fiber oil, corn fiber gum, xylitol, and ethanol. Pricing models based on use of elusieve fiber as animal foodstuff alone will not be valid when elusieve fiber is used to produce these products.

Revenue from Products of Elusieve Processing Compared with Revenue from DDGS

Based on the above prices for DDGS, enhanced DDGS, and elusieve fiber, increased revenue for 2,030 metric tonnes/day (80,000 bushels/day) dry-grind corn plant by elusieve processing

TABLE IV
Cost, Profit, and Payback Periods for Dry-Grind Plants Processing Corn at Rates of 510, 1,020, 1,520, and 2,030 metric tonnes/day (20,000, 40,000, 60,000, and 80,000 bushels/day)[a]

Processing Rate (bushels/day)	Total Capital Investment ($M)	Operating Cost ($)	Processing Cost per ton of DDGS (¢)	Revenue[b]	Revenue[c]	Profits ($M/year)	Payback Period (years)	IRR (%)	NPV ($M)
20,000	0.6	25,000	11.3	95.1–97.1	2.9–4.9	0.2–0.3	1.9–3.0	9.2–21.6	0.04–0.6
40,000	0.9	50,000	9.7			0.4–0.6	1.4–2.2	14.3–29.5	0.4–1.5
60,000	1.2	75,000	8.9			0.6–1.0	1.2–1.9	17.8–35.0	0.8–2.4
80,000	1.4	100,000	8.4			0.8–1.3	1.1–1.7	20.5–39.5	1.2–3.4

[a] Profits, payback period, internal rate of return (IRR), and net present value (NPV) have a range of values because they are based on animal foodstuff prices for different years (June 20, 2005, 2003-2004, and 2002-2003).
[b] Revenue from enhanced DDGS as % of total revenue.
[c] Revenue from elusieve fiber as % of total revenue.

of DDGS-1 would be \$0.6, 0.5, and 0.7M/year for June 20, 2005, 2003-2004, and 2002-2003 prices, respectively. Increase in revenue for 2,030 metric tonnes/day (80,000 bushels/day) dry-grind corn plant by elusieve processing of DDGS-2 would be \$0.5, 0.4, and 0.5M/year for June 20, 2005, 2003-2004, and 2002-2003 prices, respectively. Revenue from enhanced DDGS was 95.1–97.1% and revenue from elusieve fiber was 2.9–4.9% of total revenue from the elusieve process (Table IV).

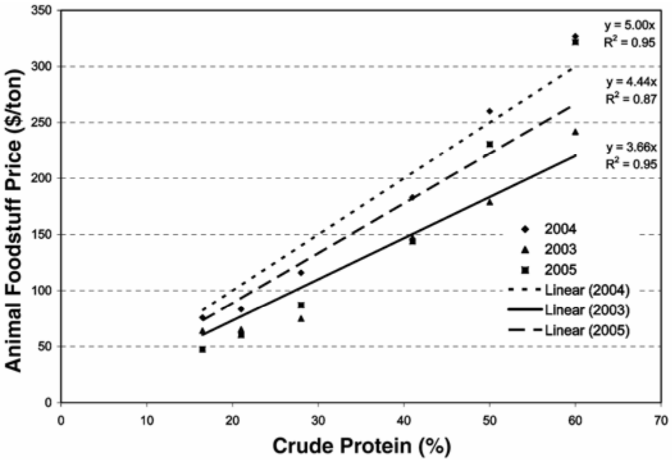

Fig. 2. Dependence of animal foodstuff prices on protein content based on June 20, 2005, 2003-2004, and 2002-2003 prices.

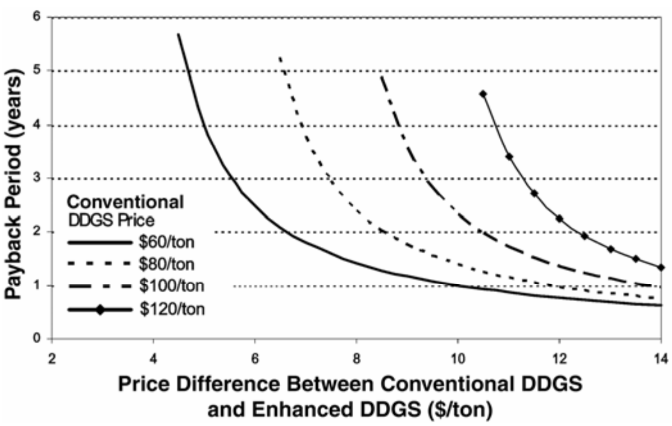

Fig. 3. Payback period vs. price difference between conventional DDGS and enhanced DDGS for a 2,030 metric tonnes/day (80,000 bushels/day) dry-grind corn plant for 8.7% yield of elusieve fiber.

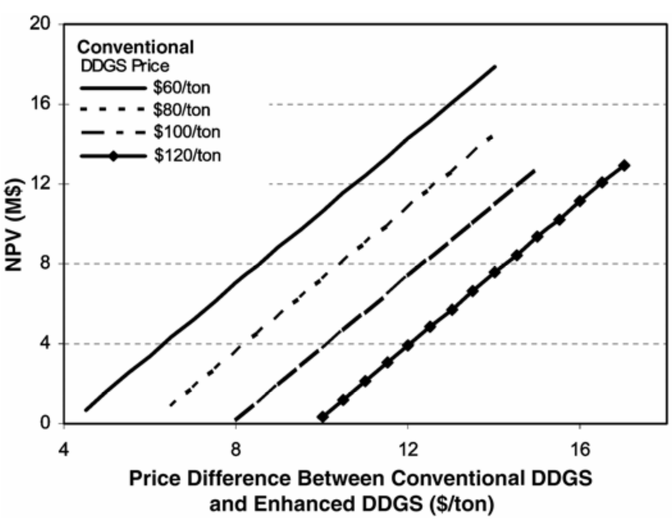

Fig. 4. IRR vs. price difference between conventional DDGS and enhanced DDGS for a 2,030 metric tonnes/day (80,000 bushels/day) dry-grind corn plant for 8.7% yield of elusieve fiber.

Payback Period, NPV, and IRR

For the base case with a corn processing rate of 2,030 metric tonnes/day (80,000 bushels/day), profits from the elusieve process would be \$0.3 to 0.6M/year depending on animal foodstuff prices. Hence, payback period based on total capital investment of \$1.4M needed would be 2.5–4.6 years, IRR would be 20.5–39.5%, and NPV would be \$1.2–3.4M (Table IV).

For a corn processing rate of 1,020 metric tonnes/day (40,000 bushels/day), profits from the elusieve process would be \$0.2–0.3M/ year, total capital investment would be \$0.9M, payback period would be 3.3–6.0 years, IRR would be 14.3–29.5%, and NPV would be \$0.4–1.5M. As processing rate decreased, the estimated payback period increased, IRR decreased, and NPV decreased (Table IV).

Sensitivity Analysis

Economic analysis of the elusieve process would be affected by variation in price difference between conventional DDGS and enhanced DDGS due to variation in crude protein increase. Economic analysis of the elusieve process also would be affected by variations in market price of DDGS, dependence of animal foodstuff prices on crude protein content, and yield of elusieve fiber obtained from the process. These variations have been partially taken into account by conducting economic analysis for two different DDGS samples and using market prices for animal foodstuff for three different years. The individual effect of variation in these parameters on payback period, IRR, and NPV also was determined.

The effect of variation in DDGS price and variation in price difference between conventional DDGS and enhanced DDGS on payback period, IRR, and NPV was determined for a dry-grind plant processing corn at 2,030 metric tonnes/day (80,000 bushels/ day), 8.7% elusieve fiber yield (DDGS-2 yield), and \$30/ton fiber price. Payback period decreased as price difference between conventional DDGS and enhanced DDGS increased (Fig. 3). The decrease in payback period was smaller for larger price differences between conventional DDGS and enhanced DDGS. For the same price difference between conventional DDGS and enhanced DDGS, payback period increased as DDGS price increased (Fig. 3). IRR and NPV increased as price differences between conventional DDGS and enhanced DDGS increased due to increased revenue. For the same price difference between conventional DDGS and enhanced DDGS, IRR and NPV decreased as DDGS price increased (Figs. 4 and 5).

The effect of variation in elusieve fiber yield on payback period, IRR, and NPV for a dry-grind plant with a corn processing rate of 2,030 metric tonnes/day (80,000 bushels/day) at fiber, DDGS, and enhanced DDGS prices of \$30, 100, and 110/ton, respectively, was determined. Payback period increased as elusieve fiber yield increased due to decrease in profits from decreased yield of enhanced DDGS, which is higher priced than fiber (Fig. 6). The increase in payback period was higher as elusieve fiber yield increased (Fig. 6). IRR and NPV decreased as elusieve fiber yield increased due to decrease in profits (Figs. 7 and 8).

Potential Variations in Implementation of Elusieve Processing

This study was based on low air velocities that produced nearly 20% yield of fiber fraction (Tables I and II). In an earlier study (Srinivasan et al 2005), higher air velocity increased the mass of lighter fraction and reduced the mass of heavier fraction. Correspondingly, protein and fat contents were higher in the heavier fraction and neutral detergent fiber (NDF) was lower in the lighter fraction because higher air velocities carried nonfiber components into the lighter fraction. At higher air velocities, increased removal of fiber reduces the quantity of DDGS (higher priced than elu-

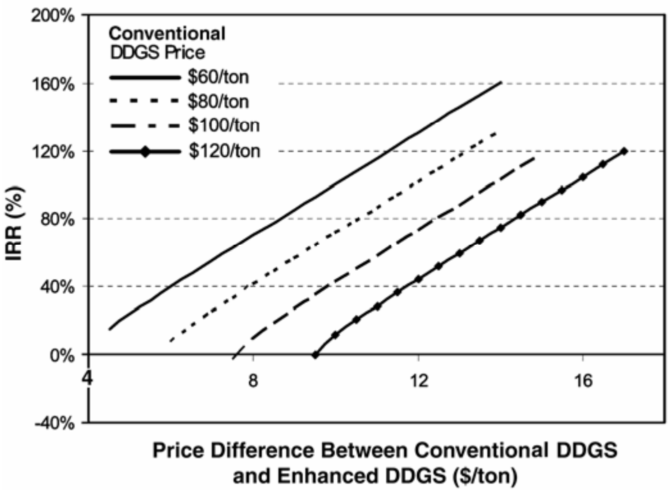

Fig. 5. NPV vs. price difference between conventional DDGS and enhanced DDGS for a 2,030 metric tonnes/day (80,000 bushels/day) dry-grind corn plant for 8.7% yield of elusieve fiber with an interest rate of 8%.

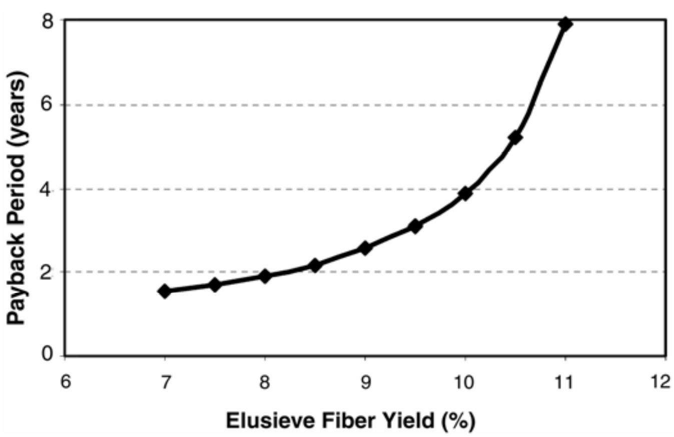

Fig. 6. Payback period vs. elusieve fiber yield for a 2,030 metric tonnes/day (80,000 bushels/day) dry-grind corn plant for DDGS price of $100/ton and enhanced DDGS price of $110/ton.

sieve fiber); this reduction in quantity is not compensated by the increase in the price of DDGS due to higher protein content. It would become economical to operate at higher air velocities if the rate of increase in price of DDGS with protein content is high and price difference between enhanced DDGS and elusieve fiber is low.

Difference in crude protein content of original DDGS and enhanced DDGS was 2.4% for DDGS-1 (Table I) and 1.8% for DDGS-2 (Table II). For scenarios where enhanced DDGS would sell at a higher price only if the difference in crude protein content between original DDGS and enhanced DDGS is more than a threshold value, it may be beneficial to make two types of DDGS: type 1 with two times the difference in crude protein content compared with that of enhanced DDGS, and type 2 with the same crude protein content as the original DDGS. This can be accomplished by mixing heavier fractions from each size category in the appropriate proportions.

CONCLUSIONS

The total capital investment needed for implementing the elusieve process in a 2,030 metric tonnes/day (80,000 bushels/day) dry-grind plant was estimated to be $1.4M. Based on studies conducted on two DDGS commercial samples, increase in revenue due to products from the elusieve process compared with original DDGS would be $0.4–0.7M/year. Payback period would be 2.5–4.6 years, IRR would be 20.5–39.5%, and NPV would be $1.2–3.4M. These values were based on conservative estimates for prices of products from the elusieve process.

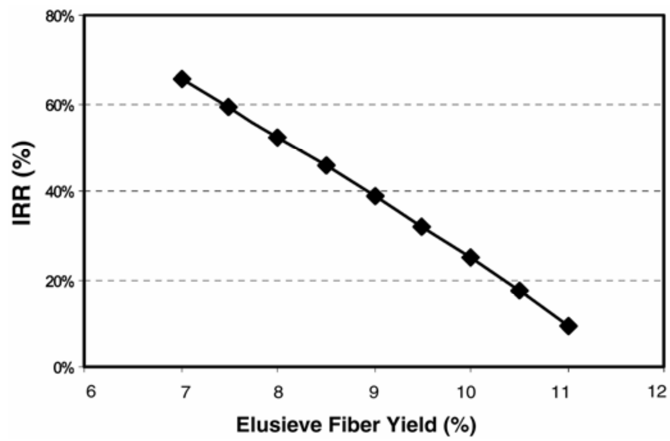

Fig. 7. IRR vs. elusieve fiber yield for DDGS price of $100/ton and enhanced DDGS price of $110/ton.

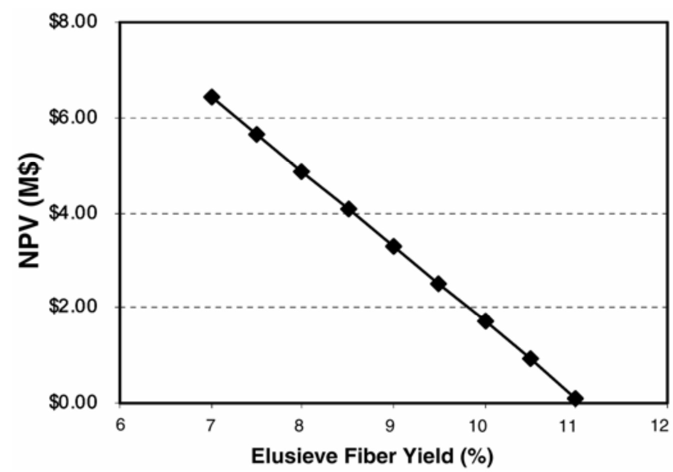

Fig. 8. NPV vs. elusieve fiber yield for a 2,030 metric tonnes/day (80,000 bushels/day) dry-grind corn plant for DDGS price of $100/ton and enhanced DDGS price of $110/ton with interest rate of 8%.

The elusieve process is a relatively simple process and requires low capital investment, important factors in dry-grind ethanol plants that are preferred over wet-milling plants due to low initial investment. Thus, the elusieve process and its products would benefit dry-grind corn processors. This process does not require changes in the existing dry-grind corn process and hence facilitates easy implementation in existing plants. The elusieve process addresses the need for increasing the value of dry-grind coproducts.

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