A281.9
Ag8A
c.4

United States
Department of
Agriculture

Economic
Research
Service

Agricultural
Economic
Report
Number 686

Economic Implications of Cleaning Corn in the United States

Chin-Zen Lin
William Lin

USDA
NAT'L AGRIC LIBRARY
1997 FEB -3 P 5: 26
CURRENT SERIAL RECORDS
ACQ/SERIALS BRANCH

It's Easy To Order Another Copy!

Just dial 1-800-999-6779. Toll free in the United States and Canada. Other areas, please call 1-703-834-0125.

Ask for *Economic Implications of Cleaning Corn in the United States (AER-686).*

The cost is $9.00 per copy. For non-U.S. addresses (including Canada), add 25 percent. Charge your purchase to your Visa or MasterCard. Or send a check (made payable to ERS-NASS) to:

ERS-NASS
341 Victory Drive
Herndon, VA 22070

We'll fill your order by first-class mail.

The United States Department of Agriculture (USDA) prohibits discrimination in its programs on the basis of race, color, national origin, sex, religion, age, disability, political beliefs, and marital or familial status. (Not all prohibited bases apply to all programs.) Persons with disabilities who require alternative means for communication of program information (braille, large print, audiotape, etc.) should contact the USDA Office of Communications at (202) 720-5881 (voice) or (202) 720-7808 (TDD).

To file a complaint, write the Secretary of Agriculture, U.S. Department of Agriculture, Washington, DC 20250, or call (202) 720-7327 (voice) or (202) 720-1127 (TDD). USDA is an equal employment opportunity employer.

Economic Implications of Cleaning Corn in the United States. By Chin-Zen Lin and William Lin. Commodity Economics Division, Economic Research Service, U.S. Department of Agriculture. Agricultural Economic Report No. 686.

Abstract

Although foreign buyers prefer low-BCFM (broken corn and foreign material) corn, cleaning is not the solution to quality issues associated with U.S. corn cleanliness. The cost of cleaning corn above the current level at the least net-cost locations, both inland subterminals and river elevators, exceeds domestic benefits by $49 million. Because of the breakage susceptibility of corn kernels, the BCFM level in U.S. corn increases as corn moves toward ports. Thus, cleaning at the current level would still need to occur at every point in the marketing channel along with the additional cleaning to lower the BCFM level. The best approach to address the corn cleanliness issue is to reduce breakage susceptibility in corn through careful selection of drying systems and developing genotypes or hybrid varieties less prone to breakage.

Keywords: Broken corn and foreign material (BCFM), broken corn (BC), foreign material (FM), corn, breakage susceptibility, mechanical cleaning

Acknowledgments

The authors would like to thank the following reviewers: Mark Ash, Sam Evans, Lowell Hill, Linwood Hoffman, Mack Leath, Stephanie Mercier, Tom Tice, and members of the Economic Research Service-Federal Grain Inspection Service Steering Committee. Their thoughtful comments and technical assistance were invaluable.

1301 New York Avenue, NW.
Washington, DC 20005-4788

June 1994

Contents

Summary iii

Introduction 1
The Structure of the Study 2

The Role of Cleanliness in Corn Quality 2
Corn Quality 2
Corn Cleanliness 3
Role of Cleanliness in U.S. Grain Grades and Standards 3

Economics of Cleaning Corn 5
Farms 5
Country Elevators 5
Subterminal Elevators 6
Export Elevators 6
Dry Millers 6
Wet Millers 7
Feedlots and Feed Manufacturers 7

Options for Cleaning Corn Within the Production-Marketing System 8
On-Farm 8
Country Elevators 10
Subterminal Elevators 11
Export Elevators 11
Mills 11

Methodology 11

Determinants of Costs and Benefits of Cleaning 12
Determinants of the Costs of Cleaning 12
Determinants of the Benefits of Cleaning 14

Costs and Benefits of Cleaning Corn 15
Cleanliness in U.S. Corn 15
Costs and Benefits of Delivering Cleaner Corn 16
Regional Impacts 19

Conclusions 19

References 20

Glossary 21

Appendix A: Premiums and Discounts 23

Appendix B: Unit-Cost of Operating a Grain Cleaner 24

Appendix C: Aggregate Costs and Benefits 25

Summary

Although foreign buyers have shown a preference for lower levels of broken corn and foreign material (BCFM) in imported corn, additional cleaning of corn in the United States does not pay. Barring any benefits from international markets, the costs of cleaning all U.S. export corn above the current level exceed domestic benefits. Even at the most cost-effective point of cleaning (inland subterminals and river elevators), cleaning benefits of $27.5 million are not enough to compensate for the $77 million in cleaning costs on a yearly basis. Thus, benefits from international markets must exceed $49 million to justify additional cleaning of all U.S. export corn.

Cleaning at both inland subterminals and river elevators has the least net cost because these elevators have a smaller cleaning volume than farms or country elevators, and a lower value of weight loss than export elevators. Net costs of cleaning averaged 3.4 cents per bushel at both inland subterminals and river elevators. In contrast, per bushel net costs would reach 4 cents at the second lowest net cost location, the export elevator.

End-users of corn primarily rely on price discounts and contracts to convey the value of cleanliness in their operations. However, buyers seldom offer premiums for cleaner corn in the domestic market. Thus, any incentives for additional cleaning, in terms of premiums for cleaner corn, must come from foreign buyers.

Because artificially dried corn is very susceptible to breakage, it would be unrealistic to expect that additional cleaning at subterminal elevators would guarantee lower BCFM levels at final domestic destinations, unless current cleaning practices continue at all other market points. Export elevators would need to clean corn even though their allowable BCFM limits are higher than any other domestic location.

Contrary to the cleanliness pattern in U.S. wheat, where dockage declines as wheat moves through the marketing system, the BCFM level in U.S. corn increases as corn moves toward ports. Breakage of corn kernels occurs after corn is artificially dried and handled. Breakage of kernels generally exceeds the amount of BCFM removed at each point in the market, which makes the BCFM level higher upon delivery to the next stage of the marketing system. Lowering the breakage susceptibility of corn kernels would be a more effective means of reducing the BCFM content than cleaning, partly because of the need to clean corn at each point in the marketing system. Development and release of corn varieties less susceptible to breakage would be an effective means of lowering breakage susceptibility.

In addition, corn breakage can be controlled through the selection of certain drying systems, such as the low-temperature drying. Producers in the Midwest have begun to adopt low-temperature drying systems. This drying method would be adopted more rapidly if there were more price incentives for delivering corn with fewer stress cracks and less breakage. Thus, technologies addressing the breakage issue are actually in place, but additional incentives from buyers for cleaner corn in the marketplace are not.

Economic Implications of Cleaning Corn in the United States

Chin-Zen Lin and William Lin

Introduction

U.S. export corn is often lower in cleanliness than corn exported by competitors. Foreign buyers have complained about receiving U.S. corn with levels of broken corn and foreign material (BCFM) exceeding the 4-percent grade limit for U.S. No. 3, the grade most commonly traded. In many cases, the level of BCFM exceeded the limit for U.S. No. 4, even though U.S. No. 3 was specified in contracts. Although the BCFM level of U.S. export corn is generally within the grade limit at the time of loading, breakage occurs during handling before corn is shipped to foreign destinations.[1] In contrast, corn exported by competitors tends to be cleaner. The level of BCFM at loading averaged 1.3 percent for South African corn and 1.6 percent for Argentine corn in recent years (Bender, Hill, and Valdes).[2, 3]

Congress and the U.S. corn industry are concerned about U.S. competitiveness in the world market being hampered by the high level of BCFM in exported corn. However, the U.S. market share of world corn exports shows no discernible long-term declining trend as is evident in wheat and soybean exports (fig. 1). Also, the temporary decline in U.S. market share during 1983/84-1985/86 was not caused by the high level of BCFM. While U.S. share declined from 77 percent to 58 percent during this period, the level of BCFM in U.S. exported corn remained fairly constant, around 3.4-3.5 percent.

Congress recognized that information available during the 1990 Farm Bill debate was insufficient to reach a conclusion on the costs and benefits of cleaning corn. To better understand costs and benefits associated with grain cleaning and to address other quality issues, Congress included a Grain Quality Title (XX), "Grain Quality Incentives Act of 1990," in the Food, Agriculture, Conservation, and Trade Act of 1990 (P.L. 101-624).

Section 2005 of the Grain Quality title requires the Federal Grain Inspection Service (FGIS), U.S. Department of Agriculture (USDA), to establish or amend the grain grades and standards to include "economically and commercially practical levels of cleanliness" for grain meeting the requirements of grade U.S. No. 3 or better. Prior to implementing changes, USDA was required to conduct a comprehensive commodity-by-commodity study of technical constraints, and economic costs and benefits associated with such changes. Studies were mandated for wheat, corn, soybeans, sorghum, and barley.

USDA's Economic Research Service (ERS), in cooperation with researchers at land-grant universities and the U.S. grain industry, was charged by FGIS with conducting the commodity-by-commodity studies. This report, the second in a series that began with wheat, estimates costs and domestic benefits of cleaning corn beyond the current level in order to lower the BCFM content in corn exported from the United States.

This report has been prepared in response to the congressional mandate. It focuses on costs and domestic benefits of cleaning corn in the United States. It does not analyze the effects of selling cleaner U.S. corn in

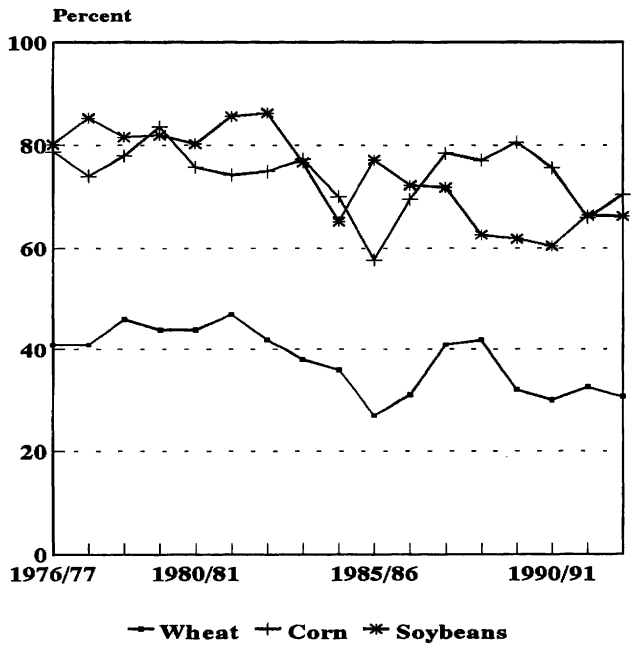
[1]During 1989-91, the BCFM level for corn reported on U.S. export certificates at loading averaged 3.3 percent. However, the BCFM level reached as high as 4.0 percent for U.S. No. 3 corn in each of the 3 years (USDA/FGIS, 1992).

[2]Corn exported by South Africa contains lower BC and FM in part because of natural drying of corn in the field and their Grade No. 1 contract being specified by foreign buyers. In addition, more direct marketing channels from producers or handlers to export ports and the unavailability of storage facilities have also contributed to the lower BC and FM levels in corn exported by Argentina and South Africa. Flint corn, the primary variety exported by Argentina, and dent variety are both susceptible to breakage when subject to high drying temperatures.

[3]Names in parentheses refer to sources listed in the references at the end of this report.

Figure 1

U.S. share in world markets



Excludes intra-EC trade.

the international market. The international benefits from selling cleaner corn will be covered in a companion report, *The Role of Quality in Corn Import Decisionmaking* (Mercier).

The Structure of the Study

In the debate over the need for tighter cleanliness standards, the terms "cleanliness" and "quality" are sometimes confused. In the second section, the definition of cleanliness and its role within a much broader context of corn quality are examined.

In section three, the economics of cleaning corn are discussed by examining the motivation of final buyers and suppliers of cleaner corn. The demand for cleaner corn depends on the price domestic and foreign buyers are willing to pay and the desire of foreign buyers to purchase more U.S. corn. The supply of cleaner corn depends upon the costs of delivering cleaner corn to the next stage in the marketing system.

The fourth section focuses on available options and current practices of delivering cleaner corn at each market location. These options include changes in production, harvesting, and drying practices on farms as well as mechanical cleaning and blending at farm, mill, and elevator points. The advantages and disadvantages of each option are discussed.

In section five, the procedures used to derive costs and benefits of cleaning corn are highlighted. Costs and benefits of cleaning corn are estimated under the scenario of lowering the maximum allowable percent of BCFM for all grades by 1.5 percent. This scenario was chosen because it would reduce BCFM levels in U.S. No. 2 corn by one-half, and by 1.5 percentage points for all other grades, making the BCFM level of U.S. corn exports comparable with those of competing countries.

The sixth section examines the determinants of the costs and benefits of cleaning corn, the rationale behind each determinant, and how each determinant affects the costs and benefits of cleaning.

Section seven presents the costs and benefits of cleaning corn for producers, country elevators, subterminal elevators, and export elevators. Appendices present more detailed information about the data, assumptions, and study results.

The Role of Cleanliness in Corn Quality

Although cleanliness is only one of many quality characteristics, the terms "cleanliness" and "quality" are sometimes interchanged and confused in the debate over the need for higher quality standards. To highlight the difference between "cleanliness" and "quality," these terms are differentiated by examining the role of cleanliness in corn quality.

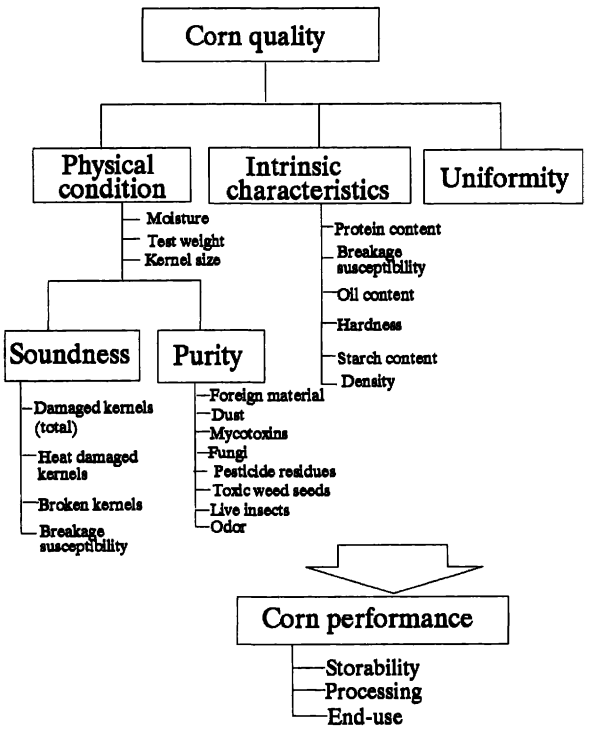
Corn Quality

The ultimate measurement of corn quality is its performance in producing the final product. Not all quality characteristics are included in the official U.S. grades and standards for corn. However, the final product is affected by all quality characteristics. Because of the wide range of quality characteristics and their varying effects on end-use performance, it is difficult to improve corn quality across the board. Various impacts must be considered when exploring changes in the corn grades and standards.

Corn quality has three dimensions: physical condition, intrinsic characteristics, and uniformity (fig. 2). Physical condition is further divided into two categories: soundness and purity. Soundness refers to physical defects and damage in corn kernels. This includes total damaged kernels, heat-damaged kernels, broken kernels, and breakage susceptibility related to stress cracks (see glossary). Purity measures the quantity of noncorn material. Its components include foreign material (FM), dust, mycotoxins (especially aflatoxin),

Figure 2

Corn quality dimensions that affect end-use performance



Source: Adapted from the ERS domestic wheat cleaning study.

fungi, toxic weed seeds, pesticide residues, live insects, and odor.[4]

Other physical characteristics include moisture, test weight, and kernel size. Although these characteristics are not included in purity or soundness, they are physical characteristics that are important to corn users. Moisture, although not a grade-determining factor, is a very important quality characteristic for corn. Corn with moisture above 15 percent is more susceptible to mold, bacteria, and sprout deterioration during storage (Watson). That is why combine-harvested corn must be artificially dried soon after harvest. Intrinsic characteristics are the structural and biological attributes inherent in corn. Important intrinsic characteristics include protein content, starch content, breakage susceptibility, oil content, hardness, and density. Buyers' requirements for intrinsic characteristics depend on end-use.

Uniformity is the degree of variation in the physical and intrinsic characteristics. To avoid frequent adjustments in operations, buyers prefer uniform corn quality. Because shipload lots of grain are frequently shared by several foreign buyers, uniformity is even more important in export markets. However, achieving uniformity has its practical difficulties. For example, fine materials naturally segregate during shipping, making the level of BCFM less uniform within a shipment and between shipments.

The importance of these quality characteristics depends on the end-use of corn. Livestock and poultry feeding, accounting for over 75 percent of domestic corn use, has the least restrictive quality considerations. Corn wet millers and dry millers, which account for most of the remaining domestic use, are more conscious of quality factors including the level of BCFM, stress cracks, and intrinsic characteristics.

Corn Cleanliness

Cleanliness is only one of many characteristics that determine overall corn quality. In this report, corn cleanliness refers to the level of broken corn and foreign material (BCFM). BCFM consists of all noncorn material such as weed seeds, other grains, cobs, leaves, stalks, and broken corn. Because of stress cracks from high-temperature drying, kernels of corn are more brittle and highly susceptible to breakage after drying and handling. Although mechanical cleaning can remove BCFM, breakage continues to occur throughout the marketing channel. Thus, the percentage of broken corn (BC) in BCFM tends to increase and foreign material (FM) tends to decrease as corn moves through the marketing system (Hill and others, July 1992). The selection of drying technique and the development of genotypes or hybrid varieties with lower breakage susceptibility are the most effective strategies to reduce corn breakage.

Role of Cleanliness in U.S. Grain Grades and Standards

The corn grades and standards help buyers determine quality and cleanliness and facilitate trade. The grades and standards deal mainly with physical characteristics including moisture, BCFM, heat-damaged kernels, total damaged kernels, and test weight. There are five numerical grades, U.S. No. 1 to U.S. No. 5, as well as a U.S. sample grade. While U.S. No. 2 grade dominates the domestic market, the most common grade traded in the international market is U.S. No. 3, accounting for nearly 70 percent of U.S. corn exports (Watson; USDA/FGIS, 1992).

[4]Dust is defined by FGIS as a component of FM. However, its physical and chemical properties differ from other FM components.

Cleanliness is reflected in the U.S. grain grades and standards for corn through the inclusion of a maximum limit for BCFM for each numeric grade (table 1). The maximum limit for BCFM in U.S. No. 2 is 3 percent and for U.S. No. 3 is 4 percent. In July 1987, FGIS began recording BC and FM as separate factors on inspection certificates for domestic sales and on FGIS's export logs, but the combined BCFM factor remained the single cleanliness characteristic recorded on inspection certificates for export corn. This change was made in response to the enactment of the Grain Quality Improvement Act of 1986, which prohibited addition or recombination of FM to grain, once removed. Along with the grades and standards, there are three classes of corn: yellow, white, and mixed corn.[5] No subclasses of corn exist. Yellow dent corn dominates U.S. production.

Not all buyers and producers rely solely on the corn grades and standards to specify quality needs. White corn and other specialty corns (such as seed corn and waxy corn) are usually grown under identity preservation contracts that specify strict quality characteristics. Under such contracts, buyers may have agents in the field telling producers when to harvest the corn to achieve the desired characteristics. They may also recommend certain hybrids and harvesting and drying techniques.

[5]Yellow corn must not contain more than 5-percent corn of other colors. White corn cannot contain more than 2-percent corn of other colors. Corn not meeting the color requirements for either yellow or white corn is considered mixed corn.

Table 1--Grade requirements for corn

	Minimum test weight per bushel	Maximum limits of-- Damaged kernels: Heat-damaged kernels	Damaged kernels: Total	Broken corn and foreign material
	Pounds	- - - - - - - - - - - - *Percent*	- - - - - - - - - - -	
U.S. No. 1	56.0	0.1	3.0	2.0
U.S. No. 2	54.0	0.2	5.0	3.0
U.S. No. 3	52.0	0.5	7.0	4.0
U.S. No. 4	49.0	1.0	10.0	5.0
U.S. No. 5	46.0	3.0	15.0	7.0

U.S. sample grade

U.S. sample grade is corn that:

(a) Does not meet the requirements for the grades U.S. Nos. 1, 2, 3, 4, or 5;

(b) Contains eight or more stones that have an aggregate weight in excess of 0.20 percent of the sample weight, two or more pieces of glass, three or more crotalaria seeds (Crotalaria spp.), two or more castor beans (Ricinus communis L.), four or more particles of an unknown foreign substance(s), eight or more cockleburs (Xanthium supp.) or similar seeds singly or combination, or animal filth in excess of 0.20 percent in 1,000 grams; or

(c) Has a musty, sour, or commercially objectionable foreign odor; or

(d) Is heating or otherwise of distinctly low quality.

Special grades and special grade requirements.

(a) Flint corn. Corn that consists of 95 percent or more of flint corn.

(b) Flint and dent corn. Corn that consists of a mixture of flint and dent corn containing more than 5 percent but less than 95 percent of flint corn.

(c) Waxy corn. Corn that consists of 95 percent or more waxy corn, according to procedures prescribed in FGIS instructions.

Economics of Cleaning Corn

The same corn quality characteristic may have different values, depending on its end-use. As with all quality characteristics, the amount of BCFM in a shipment affects producers, handlers, millers, and exporters differently. The demand for cleaner corn derives from the importance of cleanliness to buyers, which is communicated through the marketing channel from final end-users to intermediaries and back to producers. End-users of corn use various methods to convey the value of different characteristics to their sellers. These methods may include price discounts, weight deductions, contract specifications, and premiums.

Price discounts and contractual specifications are common tools used to communicate the effects of BCFM on a buyer's profit. The tool employed by the buyer has a direct bearing on options that are viable for the seller in meeting the buyer's demand for cleaner corn. If the purchase is made through contracts--a common practice between elevators and wet millers or dry millers--the seller has little choice but to meet the cleanliness requirement specified in the contract through acquisition of clean corn or additional cleaning. Alternatively, the seller may opt to let the buyer (for example, subterminal elevators) apply price discounts to corn shipments with levels of BCFM in excess of the U.S. No. 2 grade limit. Thus, each point in the marketing chain represents a distinct market for cleanliness.

In the United States, there are four major final destinations for corn: (1) wet mills, (2) dry mills, (3) feedlots and feed mills, and (4) export elevators. The country and subterminal elevators act as intermediaries for final domestic markets. However, these end-users can also buy directly from producers. This is the case with most specialty-use corn that is grown under contract.

In general, buyers seldom offer premiums for cleaner corn in the domestic markets. In 1991, only about 1 percent of the elevators paid premiums for corn containing less than 3-percent BCFM, according to the commercial elevator survey conducted by the National Grain and Feed Association (Ash and others). Premiums averaged 2.0-2.5 cents per bushel. Price discounts are used to discourage poor-quality corn (appendix A). The end-users producing higher value products tend to assess larger discounts for poor-quality corn. Firms with larger market share tend to apply the highest discounts (Hall and Rosenfeld).

Farms

The market offers little incentive for farmers or country elevators to produce or deliver cleaner corn.[6] Producers seldom receive price premiums for delivering corn with BCFM levels below the 3-percent grade limit. However, when BCFM content in corn exceeds the 3-percent limit, domestic buyers apply price discounts. The price a buyer pays for a specific grade of corn reflects the value he or she places on quality characteristics within the grade limit.

Avoiding price discounts is an important reason cited by producers for cleaning corn, according to a survey of producers conducted by the University of Illinois. Corn prices received by producers, on average, were discounted 1.3 cents per bushel for BCFM between 3 and 4 percent. However, because the BCFM level at harvest averaged 1.54 percent, many corn producers avoided price discounts.[7] In 1990, only 3.2 percent of corn sales by producers were discounted.

Improved storability of corn was regarded by producers as the most important reason for cleaning. Cleaning corn would reduce the accumulation of fines during storage and transportation, which can promote mold growth and hot spots. In addition, cleaning can reduce aeration costs and shrink during storage.

Cleaning corn is more common than the cleaning of other grains, such as wheat. Because cleaning corn has a lower unit-cost than cleaning wheat, producers have a greater incentive to market clean corn (see box).

Country Elevators

Country elevators receive most of their corn from producers and ship it to domestic millers (including feed manufacturers, dry millers, and wet millers), subterminal elevators, and export elevators. Premiums are not generally offered for cleaner corn except under special circumstances.[8] For this reason, country elevators are not able to offer premiums to producers. How-

[6]In general, domestic buyers purchase U.S. No. 2 corn, which has a maximum limit of 3-percent BCFM.

[7]Producers not meeting the requirement on average needed to remove 60.8 bushels of BCFM per farm in order to avoid discounts, according to the University of Illinois survey. This is equivalent to a farm growing about 470 acres of corn.

[8]Higher bid prices for cleaner corn are sometimes offered by exporters or processors when BCFM levels are unusually high.

Comparison of Unit-Cost of Cleaning: Corn versus Wheat

Reasons the unit-cost of cleaning corn is lower than wheat:

- Value of weight loss from cleaning corn is lower than for wheat because wheat prices are higher.
- Fixed costs of cleaning tend to be higher for wheat than corn. Screen cleaners owned by wheat producers are generally used only for wheat cleaning because wheat is the primary crop grown. In contrast, most corn producers also grow soybeans. Thus, cleaners can be used for both corn and soybean cleaning.
- Per-bushel fixed cost of mechanical cleaning tends to be lower for corn than wheat because of the larger volume of corn cleaned, which is a result of the higher yields per acre.
- BCFM is easier to remove from corn than dockage (and FM) is from wheat because there is a greater difference in particle size between BCFM and whole corn kernels than between dockage (and FM) and wheat.

ever, price discounts are often used to discourage high-BCFM corn.

Country elevators can supply cleaner corn through mechanical cleaning or blending, depending on market incentives, costs of cleaning, markets for screenings, and transportation costs. In addition, their cleaning decisions depend on how buyers or end-users communicate demands for cleaner corn. Dry millers and wet millers tend to achieve higher cleanliness standards through contracts with producers or elevators. In contrast, feed manufacturers tend to be less stringent regarding cleanliness than dry or wet millers because most feed millers do not remove the BC portion of BCFM prior to manufacturing formula feed.

According to the survey of elevators conducted by the National Grain and Feed Association, 64.2 percent of the country elevators handling corn owned cleaners. Country elevators owning cleaners seldom clean all corn delivered. Instead, a portion of high-BCFM corn is cleaned to a level well below the desired BCFM limit. This grain is then blended with the rest to achieve the targeted level of the contract or grade.

Subterminal Elevators

Subterminal elevators (including river and inland subterminals) serve as intermediaries for export market points and, to a smaller extent, for final domestic locations. The demands for cleaner corn by subterminal elevators are communicated to country elevators and producers primarily through price discounts. The market seldom offers premiums for corn cleaner than 3-percent BCFM, although bid prices to selected sellers are sometimes increased to obtain a supply of clean corn. Subterminal elevators generally apply higher BCFM discounts than other elevators (Ash and others). Subterminal elevators also have the capability to blend or do additional cleaning to meet buyers' cleanliness requirements.

Export Elevators

Exporters respond to foreign demand for cleanliness by making certain that the level of BCFM is within the grade limit specified in the purchase contract. Pricing schemes of the export elevators reflect the demands for clean corn by foreign buyers.

Most lots of corn arriving at export elevators must be cleaned to meet the U.S. No. 3 standards for BCFM prior to loading. The high-speed, large-volume operations of export elevators often require more cleaning capacity to meet the grade limit than occurs at country and subterminal elevators.

Dry Millers

All corn is cleaned to remove BCFM to the extent possible prior to dry milling. With the exception of one large miller, no premiums were offered by U.S. dry millers for clean corn. According to the Office of Technology Assessment (OTA), over 70 percent of dry millers specified BCFM as a standard factor in their contract. Also, they rated BCFM as a "slightly important" quality factor (U.S. Congress, 1989a).

Dry millers tend to have more stringent quality specifications in contracts because sound, whole kernels are required to produce high yields of primary end-products (see "Dry Milling Process" box). Price discounts and rejection levels for BCFM and other quality factors are specified in contracts.[9] However, the rejection level for BCFM, in practice, is not a limiting factor because (1) the rejection level for BCFM can be set as high as 5 percent, and (2) even if BCFM exceeds the rejection level, millers often resolve this

[9]Typical price discounts by dry millers are about 2.5 cents per bushel for every 0.5 percentage point above the 3-percent BCFM limit (U.S. Feed Grains Council).

Dry Milling Process

Dry milling begins with cleaning the corn and tempering of the grain using steam heat or spraying warm water. The corn kernel is then broken apart into endosperm, germ, and pericarps through degermination. The endosperm is then cracked in degermination mills to remove the germ. The large pieces of endosperms are aspirated to remove loose pericarps. The corn bran is aspirated away and the endosperm fractions are sifted out. The materials are then sieved to determine the size of the particles and their subsequent use (U.S. Congress, 1989a).

Products of dry milling include flaking grits, meals, flour, oil, and hominy feed (including screenings). Corn for food use is primarily processed in dry-milling facilities. The low-fat flaking grits are the highest valued grit product and used primarily in breakfast foods. The majority of U.S. dry mills are located in the Midwest and Southeast.

Wet Milling Process

The wet milling process tempers and soaks corn in steep water to soften and swell the kernels, which aids in the separation of starch, solubles, gluten, and hulls. As in dry milling, all corn is cleaned with screen cleaners and aspirators prior to milling. The tempering and steeping process takes between 22 to 50 hours (U.S. Congress, 1989a).

Water is used to transport the corn from steeping tanks to holding bins where grinders break up the kernels. Materials are then transported to flotation tanks where water is added to help the germ float to the top. Germs are removed, washed, screened, dried, and processed to remove oil. The remaining material is screened to separate fiber from starch and gluten.

Primary products of wet milling include starch, high fructose corn syrup (HFCS), oil, and ethanol. Byproducts, mainly corn gluten feed (including screenings), gluten meal, and the water used in the tempering process, are sold for feed use.

problem through price discounts, which create an incentive for blending. Also, BCFM rarely is a problem if other quality requirements, such as test weight, are met.

Dry mills clean corn using a combination of cleaners, each designed to separate whole kernels from all other materials. Cleaning equipment includes magnetic separators to remove metals, and screeners and aspirators to remove pieces of cob, FM, and broken corn.

Wet Millers

About 75 percent of wet millers specified BCFM as a standard factor in their contracts. In addition, they ranked BCFM as a "most important" quality factor (U.S. Congress, 1989a).

Like dry millers, wet millers generally offer no premiums for cleaner corn. All corn is cleaned to the extent possible prior to milling (see "Wet Milling Process" box). Dust, chaff, cobs, stones, broken corn, and other foreign material are removed to minimal levels by cleaners at the mill. Although the market does not offer incentives for delivering corn cleaner than the maximum BCFM limit, corn with high-BCFM content is discouraged by all wet millers through contract specifications. A rejection level for BCFM is frequently specified in purchase contracts with elevators. As in dry milling, the rejection level for BCFM imposed by wet millers is not a limiting factor. When the BCFM level exceeds the rejection level, wet millers generally resolve the problem through price discounts.

Feedlots and Feed Manufacturers

The OTA study reported that about 70 percent of feed manufacturers specified BCFM as a standard factor in their contracts and rated it as a "slightly important" quality factor. About 5 percent of U.S. corn is sold by producers directly to feedlots and other farmers, but corn used by feed manufacturers typically accounts for one-fourth of all farm sales and about a third of corn is used on the farm where it was grown (Leath and Hill). Feed manufacturers acquire corn from country and subterminal elevators, in addition to direct purchases from producers.

As long as insects and mycotoxins are not present, broken corn is not of great concern to feeders and feed manufacturers; thus, they are less inclined to offer premiums for low-BCFM corn. However, clean, dust-free whole kernels are preferred. Further evidence of their preference for low-BCFM corn are price discounts applied by feeders and feed manufacturers to corn with high-BCFM contents. In general, other than cleaning to remove insects, mycotoxins, and metal, which could present safety hazards to the mill, U.S. feed manufacturers do not remove the BC portion of BCFM prior to grinding and mixing feed ingredients.

Options for Cleaning Corn Within the Production-Marketing System

There are several important aspects of production and marketing practices that are unique for corn cleaning. First, unlike wheat, which requires drying less frequently, artificial drying of corn is common because of its high moisture content (typically about 20-25 percent) at harvest.[10] Rapid drying and temperature changes during artificial drying, however, cause stress cracks and breakage of corn kernels during handling.[11] Second, the amount of broken kernels increases each time corn is handled throughout the marketing system. Finally, value of cleanliness for corn differs depending on its end-use. Cleanliness in corn may not be as critical for feeders and feed manufacturers as it is for dry millers and wet millers, especially when food products are involved.

On-Farm

Almost half of the corn producers answering the on-farm survey conducted by the National Corn Growers Association owned cleaners. The majority of corn producers and especially those involved in long-term storage, such as the farmer-owned reserve (FOR), clean corn to improve storability. By comparison, only one-fourth of the wheat producers owned cleaners, and fewer barley and sorghum producers owned cleaners (9.1 percent and 11.8 percent, respectively).

Farmers use a number of methods that enable them to deliver cleaner corn. Production, harvest, and drying practices can be altered to reduce BCFM directly. Also, mechanical cleaners can be used to remove BCFM. However, reducing or removing BCFM through these methods alone will not guarantee high corn cleanliness. Because of the continued breakage of corn throughout the marketing system, reducing BCFM by lowering the breakage susceptibility would be the best approach to improving corn cleanliness. Lowering breakage susceptibility could be achieved through careful selection of drying systems and developing genotypes or hybrid varieties that are less prone to breakage.

Production Practices

Producers can alter production practices to reduce FM directly (though a relatively minor problem) and to lower breakage susceptibility. Practices to reduce FM include additional tillage, crop rotations, and the use of herbicides and other chemicals. Corn breakage can be reduced by carefully selecting hybrids with lower breakage susceptibility. Cultural practices and maturity seem to influence breakage susceptibility (Paulsen, Darrah, and Stroshine).

More cultivation and tillage of soil can reduce weed problems and reduce herbicide input required for weed control. However, these changes involve additional expenses and contribute to other problems such as soil erosion.

Crop rotations can be used to interrupt the life cycle for some pests and reduce the incidence of weeds, insect pests, and diseases. Crop rotation effectively reduces chemical costs and raises annual yields. The most common practice is corn-soybean rotation because of its higher profitability, partly due to the nitrogen contribution of soybeans relative to other rotations, as well as to reductions in weeds, insect pests, and diseases (Sundquist, Menz, and Neumeyer). Only an additional 40 percent of corn producers can change production practices through crop rotations because most producers have already adopted this practice. Also, returns from the corn program and protection against losing base acreage (prior to the implementation of flexibility provisions in 1991) often made planting continuous-corn, year after year on the same land, the most profitable cropping pattern and increased the opportunity cost of rotating crops.

The BCFM level also can be reduced through increased chemical applications, including herbicides, insecticides, and fungicides. Chemicals are already applied to virtually 100 percent of all corn in the United States. Although increasing chemical applications may lower FM levels, it also raises production costs. The viability of increasing chemical applications to reduce FM in corn is and will continue to be controversial because of public concerns about water pollution and pesticide residues on food.

Altering production practices to reduce weeds and insect infestation can lower FM levels. Of the entire 1.54 percent BCFM at harvest, FM typically accounts for only 0.2-0.5 percent. Since most BCFM is broken kernels, little reduction in FM can be obtained by altering production practices. With current low levels of FM, it would be very expensive to achieve any

[10]In the Corn Belt region, harvesting usually begins in September and ends during October. Early harvesting, when the moisture content of corn kernels is high, reduces field losses. Increased field losses during harvesting generally occur when corn is left in the field longer and harvested at below 25-percent moisture contents (Sundquist, Menz, and Neumeyer).

[11]High temperature during drying could also affect starch extraction during milling. This is a special concern for the 1992 corn crop, which was late maturing and harvested under wet conditions.

significant reduction in BCFM. The low FM content in the corn crop and higher costs make changing production practices an ineffective way to lower the FM level.

Producers can also reduce breakage susceptibility by carefully selecting hybrid seed and by changing other production practices. Commercially available hybrids differ in breakage susceptibility during harvesting, handling, and drying. A producer's choice of variety or genotype can influence the amount of subsequent breakage that occurs as the corn moves through the marketing system. However, hybrids are often bred and selected based on yield potential, not breakage susceptibility.[12] The marketplace must offer more incentives for cleaner corn if breeding of varieties with lower breakage susceptibility is to occur. Thus, it is not surprising that only 32 percent of the on-farm survey respondents indicated that they could reduce the BCFM level by changing production practices.

In addition, according to the study by Paulsen, Darrah, and Stroshine, cultural practices and maturity also affect breakage susceptibility. Higher levels of nitrogen fertilization and decreased plant density tend to decrease breakage susceptibility. Genotypes from later maturing varieties may have lower breakage susceptibility and late-planted corn may increase it. Finally, irrigation of corn grown under dryland conditions may increase susceptibility to breakage.

Harvesting and Drying Practices

In addition to changing production practices, producers can alter harvesting and drying practices to reduce stress cracks and breakage.

Combine adjustment is the most common method of altering harvesting practices to lower the BCFM level. However, there are costs associated with such adjustment. Modifications to improve grain separation can result in higher damage or loss of grain.[13] Seventy-seven percent of the on-farm survey respondents indicated that they could alter harvesting and drying practices to reduce the BCFM level.

The moisture content at harvest affects the amount of kernel damage produced through combining. Harvesting corn at moisture contents between 20 and 22 percent generally results in less breakage than harvesting at higher moisture because the pericarp is not as easily damaged (Peterson and Siemens). However, with high yields being the primary focus of producers, corn tends to be harvested at 25-percent moisture content or higher. Increased field losses occur when corn is harvested at moisture levels below 25 percent (Sundquist, Menz, and Neumeyer). Drying is required to reduce the moisture content from these levels to the desired 14-15 percent for safe storage.[14]

On-farm drying methods include high-temperature/high-speed systems, low-temperature systems, and combination drying systems. Farmers may also allow corn to dry in the field. The most common on-farm drying system is the high-temperature dryer. Approximately 75 percent of the corn grown in the Midwest is artificially dried with a high-temperature dryer (Eckhoff). This type of dryer permits the greatest flexibility at harvest. However, it decreases starch yields, starch purity, and quality, and increases heat damage, stress cracks, and breakage susceptibility.

Research suggests that at temperatures above 65°C, starch yield decreases by 1.0-1.5 percent per 10°C increase in temperature. Stress cracks are caused by rapid temperature changes during drying. As corn is dried, a moisture gradient (the difference between the moisture in the outer kernel and inner kernel) is established because the outer part of kernels dries faster and tends to shrink. The wetter inner core causes stress cracks during high-temperature drying. The level of stress cracks is positively correlated to the moisture gradient; large moisture gradients due to faster drying rates result in higher numbers of stress cracks. These stress cracks weaken the mechanical integrity of the kernels and make them more susceptible to breakage during impact (Eckhoff).

Low-temperature dryers, in contrast, remove moisture with ambient air (or with less than a 7°C incremental rise in temperature) for a longer drying period. The slower, more gentle drying results in fewer internal stress cracks and significant reductions in breakage. This drying method best reduces breakage susceptibility. However, greater operator skill is required to operate this system to avoid losses due to molding and other storage problems.

[12]Scientists of USDA's Agricultural Research Service recently produced a corn hybrid that has kernels for livestock feed and is less likely to break before reaching export markets. The hybrid is a cross between Argentinean and U.S. varieties, with a greater proportion of the U.S. variety being added to improve yields. The hybrid contains less moisture at harvest, thereby reducing the need for artificial drying that can increase breakage.

[13]The latest generation of grain harvesters can automatically monitor and adjust concave opening to cylinder speed for maximum cleanliness and minimal damage (U.S. Congress, 1989a).

[14]In current practice, domestic buyers discount corn prices for moisture content above 15 percent.

Producers have begun to adopt low-temperature dryers under the existing market incentives. In 1986, over 15 percent of dryers in the Midwest were low-temperature systems (including solar dryers)--18.1 percent in Indiana, 22.2 percent in Iowa, and 25.4 percent in Illinois (Hill and others, Nov. 1991). These systems compare favorably with hot-air drying systems for smaller farms (Schwart and Hill).[15] For more widespread and faster adoption of low-temperature dryers, the marketplace must offer more incentives for cleaner corn or reduce farm drying costs.

The combination drying system is an alternative to the popular high-temperature drying system. Combination drying, mainly used for on-farm corn drying, is a system in which high-temperature/high-speed drying is followed by low-temperature, slower in-bin drying and cooling (U.S. Congress, 1989a). The combination drying system captures the advantages of the higher drying capacity of a high-temperature drying system and the lower breakage susceptibility of a low-temperature system.

Slower drying rate is often cited as an undesirable trait of corn with lower breakage susceptibility. However, it is possible to reduce breakage susceptibility without reducing drying rates, such as by developing later maturity genotypes. Smaller kernels would also reduce breakage susceptibility and increase drying rates.

In addition, plant breeders have developed varieties that dry down faster, thereby lowering corn breakage. However, this may be achieved by lowering yields. Although drying on the ear is technically the best way to avoid breakage, the high risk of field losses is a major deterrent to using this method. Farmers seldom dry corn on the ear because there is not enough time for corn to dry down before winter weather arrives.

Farm Cleaning

Because of the risks or costs involved in altering production, harvesting, and drying practices, cleaning corn mechanically is a more cost-effective option for reducing the BCFM level on the farm (Hill, Bender, and Beachy). Instead of applying changes to the entire corn crop, mechanical cleaning permits producers to selectively clean corn only if the BCFM level exceeds the 3-percent limit.

Although corn cleaning is more common than cleaning of other grains, it is not a universal practice. Forty-five percent of the corn producers responding to the on-farm survey owned cleaners and cleaned an average of 72 percent of their corn crop.[16]

Methods of Reducing Breakage Susceptibility Without Lowering Drying Rates

- Reducing kernel volume reduces breakage susceptibility and increases drying rates.
- Reducing pericarp thickness does not influence breakage susceptibility; however, it increases drying rates.
- Later-maturity genotypes may have lower breakage susceptibility and do not seem to affect drying rates.

Source: Paulsen, Darrah, and Stroshine.

Country Elevators

Country elevators handle approximately 80 percent of the corn sold by producers. Most of these elevators measure the BCFM content of incoming corn. The corn is usually cleaned or blended to meet the BCFM limit for U.S. No. 2. Blending lots of high- and low-BCFM corn to meet the grade limit is common, but a lower BCFM limit would reduce the potential to make grade through blending.

Corn cleaning in country elevators is more common than wheat cleaning. According to the 1991 survey of elevators conducted by the National Grain and Feed Association (NGFA), 64.2 percent of the country elevators handling corn owned cleaners, and 50.4 percent of them cleaned corn as part of normal operations.

Overall, country elevators that owned cleaners reported removing, on average, 2.2 percentage points of BCFM during cleaning.

[15]In 1975, the total cost of drying 5,000 bushels of corn was 47 cents per bushel when using low-temperature dryers and 66 cents per bushel for high-temperature dryers (Schwart and Hill). More recently, the ambient air, low-temperature drying systems were found to be cost competitive up to 40,000-bushel drying capacity. In 1985, annual costs for ambient dryers were estimated at 56 cents per bushel at their drying capacity, compared with 66 cents for continuous flow, high-temperature systems. The per-unit costs for continuous flow drying declined at capacities greater than 70,000 bushels since lower per-unit storage costs were realized in taller storage bins (Holmes, Klemme, and Lindholm). These cost estimates for drying represent total average costs (fixed and variable) of reducing the moisture content by 10 percentage points.

[16]On average, these farmers produce about 37 percent more corn than those not owning cleaners.

Small country elevators may choose not to purchase cleaners because of concerns for recouping the cost of investment. Although some elevators own cleaners, they may not clean corn because of limited demand for cleaner corn. This is reflected in the fact that smaller discounts are received for BCFM than it would cost to clean at the elevators.

Subterminal Elevators

About 90 percent of inland subterminal elevators clean some corn. The cost of operating cleaners is lower at inland subterminal elevators because of economies of scale resulting from larger volumes and year-round receiving and shipping. However, the reduction in cleaning costs is offset by other factors. These offsetting factors include: a requirement for a high capacity system to match load-out capacity; smaller revenues from sales of screenings, which are priced lower than corn; an increase in transportation costs for screenings; and possible limits in storage capacity for screenings and cleaner capacity.

Many river elevators are not structured to accommodate cleaners because of their high throughput and limited facility space. Only 29 percent of the river elevators handling corn owned cleaners, according to the NGFA elevator survey. Also, only 13.5 percent of corn arriving at river subterminals was cleaned (Hill and others, May 1991). Grain is transferred directly from trucks to barges at many river elevators and cleaning is not a practical alternative at these locations. In the short run, most river subterminals would not be able to clean the corn they receive because of a lack of cleaners. Additional facilities would have to be built to house cleaners.

Export Elevators

All export elevators clean corn primarily to meet contract specifications, not to avoid discounts. Overall, export elevators remove an average of 1 percentage point of BCFM. Unlike producers and country elevators, export elevators do not benefit from the improved storability of cleaner corn, since port facilities do not have long-term grain storage facilities. Export elevators in the Great Lakes operate like inland subterminals when lake shipping is closed because of ice.

Mills

Corn cleaning is an integral part of the milling process because cleaners are incorporated in the mill's refining system. All dry millers and wet millers clean all corn to reduce BCFM to a minimal level before milling. Thus, cleaning would continue at the dry and wet mills regardless of the level of BCFM present in corn received. These mills are more concerned about how susceptible the corn is to breakage prior to milling; corn with fewer stress cracks has a higher economic value to millers.

Methodology

This analysis incorporates data from four broad sources: (1) surveys, (2) economic analyses, (3) economic-engineering studies, and (4) other corn-related studies, such as those conducted by cereal chemists and other analysts.

Economic-engineering studies by the University of Illinois and Iowa State University were used to quantify the costs and benefits of cleaning corn. An economic-engineering study is an approach for assessing the cost-output relationship for a production process by separating the production activities into stages and estimating the input-output relationships at individual stages of a production operation. The study uses a model in which physical relationships (such as airflow resistance of corn with fines) were incorporated into the estimation of costs associated with cleaning.

The costs and domestic benefits of cleaning were calculated for farms, country elevators, and export elevators using surveys, economic-engineering studies, and other economic analyses. The calculations apply to both the current grade limits for BCFM and the "cleaner corn" BCFM level. Cleaner corn, as defined in the section entitled "Costs and Benefits of Cleaning Corn," is corn that contains a BCFM level of no more than 2.5 percent (1.5 percentage points below the current U.S. No. 3 limit) for export elevators and 1.5 percent (one-half of the current U.S. No. 2 grade limit) for other locations in this study. The costs and benefits of cleaning corn are associated with additional cleaning beyond the current level. Costs and benefits were not calculated for wet and dry mills because more stringent BCFM requirements would not alter their practice of cleaning all corn to a minimal level prior to processing.

The survey of producers was conducted by the National Corn Growers Association in conjunction with the University of Illinois (see "On-Farm Survey" box). The surveys of elevators and dry millers were conducted by the National Grain and Feed Association (NGFA) and the American Corn Millers Federation, respectively (see "Commercial Elevator Survey" box). The response rate from surveyed millers was too small to be useful for the analysis. Thus,

On-Farm Survey

Two types of questionnaires were sent in 1991--a short postcard and a long-form survey. The postcard survey was sent to 25,000 members of the National Corn Growers Association. Similar surveys were sent to other grain producers who also grow corn through their trade organizations. Of the 286 postcards returned from members of the National Corn Growers Association, 45 percent of the respondents owned cleaners. Although the response rate of the postcard survey is small, it is not unusually low for this type of survey. The long form was sent to 305 corn producers owning cleaners, including growers who are members of other grain grower organizations, to obtain more indepth information about cleaning. Responses from 124 producers were received.

The short form covers information about (1) grains produced, (2) the level of BCFM for corn at harvest and cleanliness levels for other grains, (3) the viability of delivering cleaner grains (at no or little additional cost) by changing harvesting and handling practices, and (4) ownership of cleaners.

The long form asked questions dealing with: (1) the purpose of cleaning, (2) the extent of cleaning, (3) types of cleaners used, (4) alternative strategies to reduce BCFM, (5) premiums and discounts for BCFM, and (6) storage and sales of screenings.

Commercial Elevator Survey

Survey questionnaires were sent by NGFA in April 1991 to 6,237 elevators registered by the Agricultural Stabilization and Conservation Service, USDA. Respondents to the NGFA survey included 758 elevators that handled corn. All elevators were asked general questions about the type of operation, volume handled, and source of grain. The survey was also divided into commodity-specific sections. Questions were asked concerning winter wheat, spring wheat, corn, soybeans, sorghum, and barley. The corn section of the survey was used in this report.

The corn section includes questions about: (1) the source of corn, (2) BCFM levels received, removed, and costs associated with removal, (3) premiums and discounts for BCFM, (4) corn storage practices, (5) storage and sales of screenings, and (6) rationales for cleaning and not cleaning.

earlier studies and industry sources were used in the wet- and dry-miller analysis.

Determinants of Costs and Benefits of Cleaning

Decisions of producers, handlers, and millers to clean corn are based on the benefits of lowering the BCFM level versus its associated costs. Factors affecting costs of cleaning include cleaning capacity and efficiency of cleaners, weight loss, disposal costs of screenings, and the beginning and ending BCFM level. Under the current marketing system, benefits (excluding trade effects) include improved storability, reduction in discounts, and revenue generated from screenings. The existence of price discounts and the lack of premiums are important in determining the current amount of cleaning. To encourage additional cleaning, the market must provide more incentives.

Determinants of the Costs of Cleaning

Although the determinants of costs are separated into distinct categories, they are interrelated and these relationships affect the overall costs of cleaning. For example, beginning and ending BCFM levels affect weight loss. Total cleaning costs increase as the difference between beginning and ending BCFM increases.

Cost of Operating Cleaners

The costs of operating a grain cleaner include fixed and variable costs (appendix B). Fixed costs are the costs of ownership and remain the same regardless of use. These costs include depreciation, interest expense, taxes, and insurance, and usually account for two-thirds or more of the cost of operating a cleaner, depending on the market point and the volume being cleaned. Fixed costs per bushel can be reduced if the cleaner can also be used to clean other grains. The variable costs of operating a cleaner are incurred only when the cleaner is in operation. These costs include labor, power, and maintenance. Labor and maintenance are the major variable cost items of operating a cleaner.

Capacity and Efficiency of Cleaners

The capacity and efficiency of a grain cleaner are important determinants of cleaning costs. The closer a cleaner's actual capacity is to the manufacturer's rated capacity, the more efficient it is. Cleaning efficiency depends on the type of cleaner used and the volume cleaned.

There are many types of cleaners. Each removes BCFM from corn based on differences in size, weight, and other characteristics. The most common cleaners owned by corn producers and handlers were rotary and screen-in-auger cleaners, both of which clean based on size. The rotary cleaner has the following advantages over the screen cleaner: simple drive, dynamic balance, and easy cleaning of openings (Hill, 1991). Because of their low unit capacity, rotary cleaners are best suited for farms or elevators with low cleaning volume.

Based on the on-farm survey, operating capacities of all types of cleaners were estimated to average 1,616 bushels per hour.[17] Of the farmers owning cleaners, 71.2 percent owned rotary cleaners, 21.3 percent owned screen in auger, and 26.9 percent owned other cleaners. This indicates that some producers own more than one type of cleaner. Additional cleaning of corn would require an increase in cleaning capacity at country and export elevators, which, together with the variable expenses, would result in an increase in the cost of operating the cleaner. Country elevators generally cleaned more intensively than terminal elevators.

Weight Loss

Mechanical cleaning results in some weight loss for corn. Weight loss refers to the loss of revenues resulting from the removal of BCFM and damage or loss of whole-kernel corn during the cleaning process. For example, the percent of BCFM removed to meet the current grade limit averaged 1.2 percent for corn received at country elevators. The loss occurs because these screenings are sold at a lower price than corn. The value of weight loss, the largest cost component of additional cleaning, ranged from approximately 40 to 60 percent of cleaning costs (Hill, Bender, and Beachy).

Increased Transportation Cost of Screenings

As transportation distance and quantity of screenings increase, total and per unit transportation costs also increase. Because most feeders and feed manufacturers are located near production areas, additional transportation costs for shipping screenings to these facilities are the lowest at the farm level. Many farmers feed screenings to their own livestock. Export elevators tend to incur the highest cost per unit because of the greater transportation distances. Export elevators may sell some screenings as sample grade corn to foreign buyers, depending on demand.

Cost of Storing Screenings

With additional cleaning, the cost of storing screenings would increase. Producers would incur little additional cost because they may feed screenings to their own livestock soon after cleaning. Country and export elevators, however, would incur additional costs for storing screenings. Because these elevators receive grain continuously and handle larger volumes, it is not practical to transport screenings after each cleaning. Instead, these elevators must store the screenings. Cost for storing screenings was estimated to be 3.6 cents per bushel at country elevators.[18]

Terminal elevators have a larger storage capacity than country elevators; however, port elevators have less ability to store screenings than country elevators due to the large volume of corn handled at ports. While nearly all country elevators had storage capacity of less than 6 million bushels, 15.4 percent of subterminals had a storage capacity of greater than 6 million bushels, and 58 percent of export elevators had a storage capacity of more than 5 million bushels (Hill, Bender, and Beachy). However, volume handled by export elevators averaged over 50 times that handled by country elevators.

Disposal Cost of Screenings

Although most corn screenings are sold as byproduct feeds to offset the value of the weight loss, some producers and elevators without such outlets are faced with disposal costs for screenings. Nearly all commercial elevators can sell their screenings as byproduct feeds.[19] About 14 percent of the farmers who clean corn reported an average cost of $9.33 per ton for the disposal of screenings. Because the percentage of total producers facing disposal costs is so small, the disposal costs of screenings were not included in the analysis.

Beginning and Ending BCFM Levels

Beginning and ending BCFM levels are pivotal factors in determining costs of cleaning. In general, larger differences between beginning and ending BCFM levels mean the cleaning time increases, and

[17]Rotary grain cleaners often used on farms were reported to have a rated capacity of 5,000-10,000 bushels per hour (Hurburgh and Meinders).

[18]This cost estimate assumed that screenings were stored for 1 month. The 3.6-cents-per-bushel cost was derived by adapting the study results by Hurburgh and Meinders to this assumption.

[19]Respondents in the NGFA survey indicated that only 0.2 percent of the screenings were not sold as byproduct feeds and had to be disposed at an average disposal cost of nearly $20 per ton.

so do costs per bushel. However, cleaning also takes more time when beginning and ending BCFM levels are both at very low levels. It is more difficult to achieve a 1-percentage-point reduction in corn with an initially low BCFM level than in corn with an initially high BCFM level.

The level of BCFM in corn at harvest depends on weather and region. Levels of BCFM in the 1990 corn crop at harvest averaged 1.54 percent nationwide, according to the 1990 on-farm survey conducted by the University of Illinois.[20]

Country elevators owning cleaners received corn with an average BCFM level of 2.52 percent, according to the NGFA elevator survey, which is considerably higher than that reported by producers at harvest because of breakage occurring between harvest and delivery at country elevators. Country elevators that owned cleaners removed an average of 2.2 percentage points of BCFM in corn handled prior to its shipment to ensure that the BCFM level will not exceed the limit for U.S. No. 2. Although the average BCFM of incoming corn was less than the 3-percent limit, it was necessary to clean corn because drying and handling at country elevators create more breakage. Subterminal and export elevators also clean corn for similar reasons.

The costs of cleaning corn vary by crop year in part because weather during the growing and harvesting seasons influences the amount of BCFM in each crop. Rain during harvest means longer drying time and more breakage.

Determinants of the Benefits of Cleaning

Commercial elevators and producers often cited avoiding price discounts and improved storability as two main reasons for cleaning corn. In addition, revenue from screening sales partially offsets the value of weight loss that occurs during the cleaning process.

Improved Storability

Cleaning reduces the loss of corn during storage by reducing the potential for developing storage molds. The storability of corn depends on management practices, grain moisture, temperature, energy requirements, and length of storage. The removal of foreign material and fines extends the safe storage life of corn by improving airflow and reducing power requirements, shrinkage, mold growth, and insect damage. Cleaning also allows corn to be stored at a higher moisture level, which reduces shrinkage and drying costs. Enhanced storability was cited by producers as the most important reason for cleaning corn, and it is an important benefit from corn cleaning at country elevators.[21] The longer the expected storage, the greater the benefit. Most producers clean corn for long-term storage under the Farmer-Owned Reserve (FOR). When farmers are faced with low prices and enter into the FOR, cleaning becomes more practical.

Country elevators could benefit from the improved storability of clean corn because they assemble and store a large volume of corn from producers. Benefits were estimated at nearly 1 cent per bushel of corn handled by elevators and stored for 6 months if additional cleaning of corn is done to lower the BCFM level to 1.5 percent (Hill, Bender, and Beachy). Export elevators and mills benefit little from enhanced storability because corn is only temporarily stored at these facilities.

Reduction in Discounts

An important incentive for cleaning corn on the farm or at country elevators is to avoid price discounts applied to BCFM above 3 percent. Producers responding to the on-farm survey indicated that avoiding price discounts was the second most important reason for cleaning. Only an average of 3.2 percent of producers' sales were penalized with price discounts because of excess BCFM. Discounts for corn containing 3-4 percent BCFM averaged about 1.3 cents per bushel.

The NGFA elevator survey indicated that commercial elevators also cited avoiding price discounts as the most important reason for cleaning corn. Corn prices received by commercial elevators were discounted by millers or export elevators on average 1.9 cents per bushel for corn containing a level of BCFM between 3 and 4 percent. Discounts received by commercial elevators were higher than those for producers because of the competitive market structure at the country elevator level. In the interest of generating customer loyalty, local elevators sometimes reduce or forgive price discounts to producers.

[20]The 1.54-percent BCFM level based on this data source is slightly lower than the 1.94-percent BCFM level obtained from the 1990 FGIS new crop quality report (USDA/FGIS, 1990). However, FGIS data from the new crop quality report are inspected during the first 4 weeks of harvest, and may reflect corn crop quality at any market point during that period, not necessarily the BCFM of new corn crop at the farm.

[21]Producers regarded improved storability to be even more important than avoiding price discounts as a reason for cleaning corn.

Screening Sales

Revenue from screening sales to feeders and feed manufacturers partially offsets the value of weight loss that occurs during the cleaning process. However, screenings are typically priced between 70 to 80 percent of the price of corn. This is the case because the price of screenings is determined not only by price of corn but also by the supply and demand of screenings itself. Variation in the price ratio between screenings and corn suggests that screenings and corn are not perfectly substitutable. According to the NGFA commercial elevator survey in 1991, the price of screenings differs by market, ranging from $64 per ton at country elevators to $83 at export elevators. Screening prices at the farm averaged $65 per ton, according to the 1991 on-farm survey.[22]

If additional cleaning is applied to all exported corn, the supply of screenings would increase by 0.7 million ton, a 35-percent increase over current levels, which were just over 2 million tons in 1989. Econometric analysis of monthly screening prices and quantities obtained from a survey of elevators demonstrated that a 1,000-ton increase in the screening supply reduced the price by $0.14 per ton. The price elasticity at the mean was -0.285 (Hill and others, July 1992). Thus, an increase of 700,000 tons of screenings would decrease the price by $98 per ton, resulting in a negative price for screenings. However, based on nutritional value and transport costs, it was estimated that the price of screenings would not fall below 60 percent of the price of corn under the additional cleaning scenario. Under this assumption, screening prices at country elevators might decline from $64/ton to $51/ton as a result of a 35-percent increase in screening supply (appendix table 6).

Screening Prices

Reasons screening prices are lower than corn prices:

- Higher fiber
- Lower energy values
- More storage difficulties
- Higher moisture
- Lower palatability
- Need to pelletize fines
- Lower test weight

Revenues from sales of screenings, which averaged 1.7 cents per bushel of corn cleaned at country elevators, accounted for 60 percent of all benefits (increases in revenues and reduction in costs) from cleaning. Screening sales offset some of the costs of cleaning corn at export elevators. The major benefit of cleaning corn at this location is to meet contract specifications.

Premiums

Currently, the U.S. corn market generally does not offer premiums for clean corn. However, at least one large dry mill offers premiums for cleaner corn.

Costs and Benefits of Cleaning Corn

This section focuses on the estimated costs and domestic benefits of delivering cleaner corn at each point in the U.S. production-marketing system. Prior to presenting these estimates, however, cleanliness in U.S. corn throughout the system is discussed. Cleaner corn can only be delivered through changes in production or harvesting practices at the farm or through additional cleaning. Cleanliness in U.S. corn reflects the current corn cleaning practices in the marketplace, which provides the context of analyzing costs and benefits of additional corn cleaning above and beyond the current level.

Overall, it does not pay to universally deliver cleaner corn at any location in the production-marketing system. The inland subterminals and river elevators are the most cost-effective points for cleaning export corn beyond the current level. Potential benefits from delivering cleaner corn in the international market are not discussed here, but are reported in a companion report (Mercier).

Cleanliness in U.S. Corn

The BCFM level in U.S. corn increases as corn moves toward export ports. The level of BCFM at harvest averages 1.54 percent, which is well within the 3-percent BCFM limit for U.S. No. 2 corn. As corn moves beyond the farm gate, however, the BCFM level increases to 2.52 percent when delivered

[22]Most screenings sold by elevators are marketed within a 50-mile radius.

to country elevators. For a typical marketing channel for export, corn would move from country elevators to subterminals and export elevators. The BCFM level averages 2.95 percent when it arrives at subterminal elevators, and 2.55 percent by the time corn arrives at export elevators (fig. 3).

Breakage of kernels, in general, exceeds the amount of BCFM removed at each market point. For example, while about 1.16 percentage points of BCFM were removed at country elevators, breakage of 1.59 percentage points occurred due to drying and handling corn at country elevators. This explains why country elevators still clean corn, even though the beginning BCFM level, on average, is within the 3-percent BCFM grade limit for domestic sales.

Breakage exceeds the amount of BCFM removed even more at export elevators. At this market point, while 0.98 percentage points of BCFM were removed, breakage of 1.73 percentage points occurred during handling and 1.50 percentage points occurred during loading due to the elevators' high-speed operations.[23] This helps explain why export elevators also clean corn despite a greater BCFM limit of 4 percent and why the level of BCFM in U.S. export corn often exceeds the grade limit at foreign destinations. The level of BCFM in U.S. export corn is even higher due to impact at unloading at the import destination. The unloading process can typically add another 2 percentage points of breakage (Hill, Paulsen, and Weinzierl).

Costs and Benefits of Delivering Cleaner Corn

The costs of delivering cleaner corn at each market location exceed the domestic benefits. Thus, an overall reduction in the BCFM level could benefit the corn industry only if cleaner U.S. corn induces benefits in the international market, in terms of additional trade or premiums that are greater than the domestic net costs. This section summarizes the costs of cleaning and the domestic benefits of selling cleaner corn at each of the market locations. These results are derived from surveys and engineering studies.

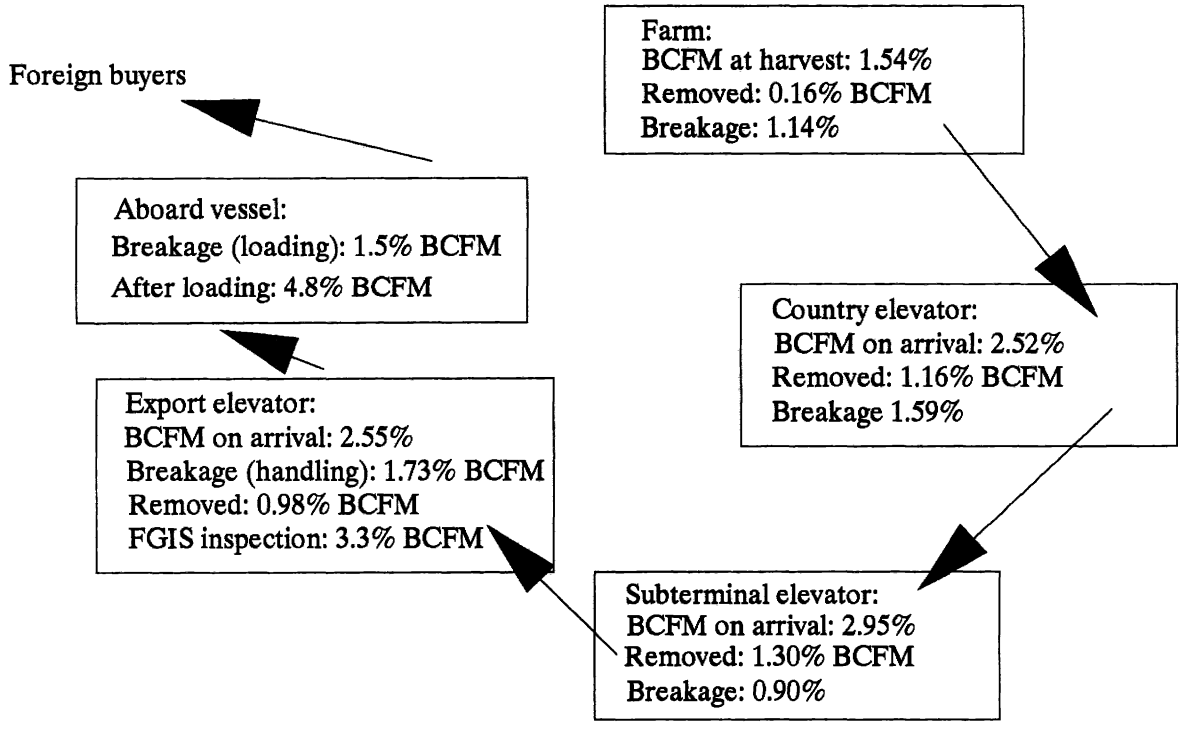
On-Farm

Mechanical cleaning of all corn marketed and altering production and harvesting practices do not yield any net benefits for all producers (Hill, Bender, and Beachy). Cleaning, however, is more cost-effective than altering production and harvesting practices because cleaning applies only to a portion of the corn crop. In contrast, changes in production and harvesting practices must apply to the entire crop. Changing production practices to reduce BCFM tends to incur

[23]The 1.5-percentage points additional breakage occurs after sampling inspection by FGIS. The 3.3-percent average BCFM is recorded on inspection certificates for U.S. export corn prior to loading.

Figure 3

BCFM: At arrival, removed, and breakage



higher costs because the level of weed seeds and other grains in the overall BCFM content is very small--typically around 0.2-0.5 percent. It is not practical to improve the cleanliness of corn by reducing foreign material from such a small level. Producers also perceived delivering cleaner corn through changes in harvesting practices incurs higher costs than mechanical cleaning.

Benefits from mechanical cleaning tend to be higher than those from changing production or harvesting practices. Improved storability of cleaner corn is the predominant benefit at the farm. In addition, mechanical cleaning also creates some benefits from sales of screenings. Benefits per bushel from additional cleaning are estimated to be 1 cent, compared with 2.5 cents per bushel costs (table 2).

Additional cleaning of all corn marketed by producers would incur a net cost of $74 million. The farm point would remove the smallest amount of BCFM. The amount of BCFM removed would reach a higher level at country and export elevators. The higher volume of BCFM removed at these points is due to higher BCFM levels on arrival and additional drying and handling. Additional cleaning to remove 1.5 percentage points of BCFM at inland subterminal elevators would reduce the BCFM level recorded on inspection certificates at export elevators from the current 3.3 percent to 1.8 percent (fig. 4). Cleaning at the current level at other locations would have to continue in order to accomplish this level of cleanliness. The aggregate weight losses of removing BCFM in the cleaning process are shown in appendix C.

To induce producers to undertake additional cleaning, the market would have to offer incentives, such as premiums, more severe discounts, or an increase in U.S. corn sales to compensate for the net domestic cost. The costs of segregating cleaner corn could reduce operational efficiency and further increase net cost. In addition, cleaning corn beyond the farm gate would have to continue at current or higher levels to maintain the BCFM level at export elevators within a lower limit for cleaner corn.

Country Elevators

Additional cleaning of corn at country elevators is analyzed under two scenarios: (1) cleaning the entire volume handled, and (2) cleaning only the volume exported. Cleaning a volume of corn equivalent to all exports at the country elevator would result in a net cost of $56 million. However, this is an optimal scenario in which country elevators are assumed to have perfect knowledge about the destination of corn shipments (table 2). In reality, most country elevators do not know the destination of their corn shipments. Under this circumstance, additional cleaning of all export corn might require additional cleaning of the entire volume handled by country elevators. Net costs of cleaning would then reach $96 million. Thus, net costs of cleaning at country elevators would range from $56 million to $96 million depending on the extent to which the destination of corn shipments is known. Costs of additional cleaning would include the value of weight loss, increased storage cost of screenings, and costs of operating cleaners. Cleaning to the 1.5-percent BCFM level is estimated to cost 5.3 cents per bushel. Unless cleaning can apply to outbound corn shipments for export, the segregation costs of cleaner corn must be added to arrive at total costs of cleaning.

Major benefits of cleaning include the value of screenings and improved storability. Aggregate benefits at country elevators are estimated to be $149 million if all volume handled is cleaned; benefits are $28 million if additional cleaning is limited to the volume exported, which is not enough to compensate for costs (table 2).

Subterminal Elevators

Additional cleaning applies to all volume received at inland subterminals and river elevators, most of which is destined for export markets. The volume received at both inland subterminals and river elevators totaled 1,477 million bushels in 1991, which is close to the 1,591 bushels exported.

Inland subterminals and river elevators are the least net-cost point of cleaning U.S. export corn. Net costs of additional cleaning of the volume received at these market points are estimated to total $49 million, which is smaller than the net costs of additional cleaning at any other market point. Some additional cleaning at the second least net-cost point, such as export elevators, would be necessary because about one-third of corn received by inland subterminals is sold to domestic corn millers or feed manufacturers.

Export Elevators

Additional cleaning at export elevators would incur a total net cost of $63 million. The cost per bushel of cleaning at this point is the highest because of the greater value of weight loss and higher costs of transporting screenings back to feeders and livestock feeding areas. In addition, the increased cleaning capacity required would result in a 50-percent increase in the cost of operating the cleaner. The higher price

Table 2--Costs and domestic benefits of additional cleaning to remove 1.5 percentage points of BCFM, 1991

Point of cleaning	Volume cleaned	Costs	Benefits	Net costs
	Million bushels		*Aggregate (million dollars)*	
Farms[1]	4,645	116.4	42.0	74.4
Country elevators:				
Volume handled[2]	4,645	245.2	149.2	96.0
Volume exported[3]	1,591	83.8	27.6	56.2
Inland subterminals	608.5	31.6	9.2	22.4
River elevators	868.6	44.9	18.3	26.6
Export elevators	1,591	90.3	26.9	63.4
			Cents per bushel	
Farms		2.5	0.9	1.6
Country elevators:				
Volume handled[2]		5.3	3.2	2.1
Volume exported[3]		5.3	1.7	3.6
Inland subterminals		5.2	1.5	3.7
River elevators		5.2	2.1	3.1
Export elevators		5.6	1.7	3.9

[1]Additional corn cleaning applies to all corn marketed by producers because they cannot differentiate corn sold for domestic markets from that destined for export markets.

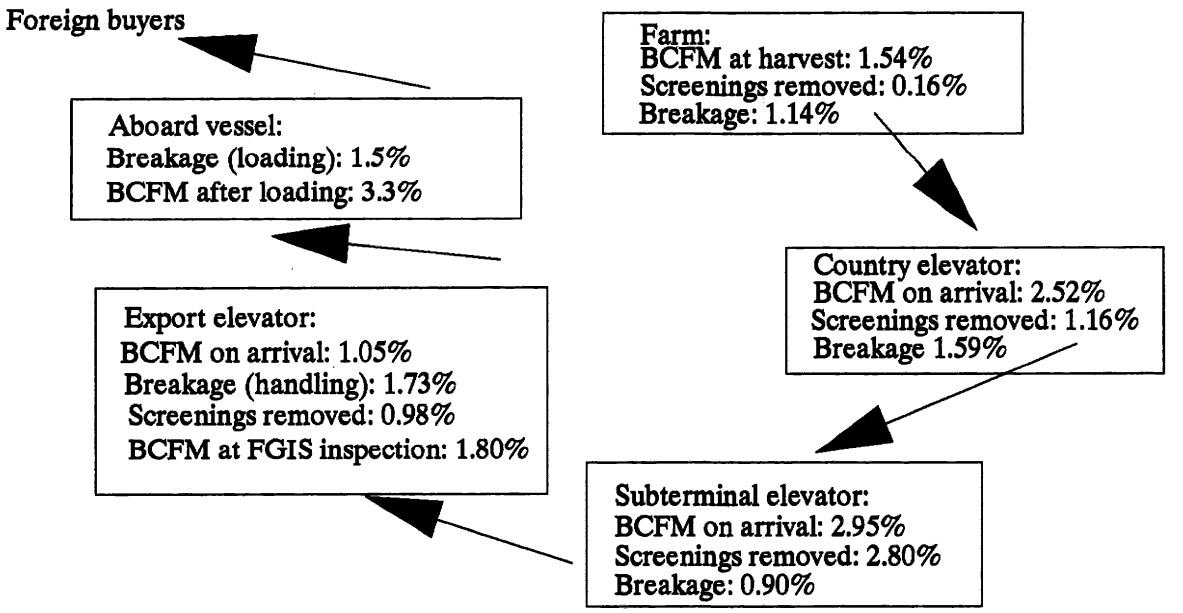
[2]This is the worst possible scenario where additional cleaning applies to the total volume sold by producers. Farm sales to subterminals are included because some subterminal elevators classified themselves as country elevators. This scenario reflects the fact that most country elevators do not have perfect knowledge about the destination of corn shipments from this market point. Thus, additional cleaning of all export corn may require additional cleaning of the total volume handled by country elevators.

[3]This is an optimal scenario where additional cleaning applies only to the volume of corn received by export elevators (1,591 million bushels in 1991). This scenario, not likely to occur, assumes that country elevators have perfect knowledge about the destination of corn shipments from this market point so that additional cleaning can apply only to outbound corn shipments for export, not the entire volume handled.

Source: Hill, Bender, and Beachy.

Figure 4

An illustration of changes in BCFM through additional cleaning at subterminal elevators



of corn at port terminals is the primary factor for the greater value of weight loss ($66.1 million as shown in appendix C). Costs of additional cleaning were estimated to total $90 million.

Revenue from sales of screenings is the only domestic benefit from additional cleaning at export elevators (Hill, Bender, and Beachy). This benefit partially offsets the weight loss by $26.9 million because screenings were valued only at 60 percent of corn prices at ports.[24] No benefit from improved storability of cleaner corn is expected because corn is stored only temporarily at port facilities.

Regional Impacts

Each market agent uses a different method or combination of methods to lower the BCFM content and costs. If the standards mandated corn with lower BCFM levels, producers, millers, and handlers would be affected differently. Producers and elevators would have to supply cleaner corn to meet the lower BCFM limits. Cleaner corn, because of its higher value, would tend to be priced higher than before.

It is not known with certainty how the additional costs associated with cleaning would be distributed among market participants. With a lower BCFM level, domestic wet and dry millers might pay higher prices for cleaner corn because of improved milling yields of primary products relative to byproducts. However, it is uncertain how much of the higher price the millers would eventually absorb or transfer back to elevators or producers.

Marketing cleaner corn would affect relative prices received by different producers. Currently, producers selling corn with less than 3-percent BCFM are not being compensated for lower BCFM content. However, if the BCFM limit for each grade was lowered, producers could be compensated partially with higher prices than they currently receive. Since price discounts for BCFM would probably start below 3 percent, corn with the current BCFM level would be discounted more than cleaner corn. The higher price for cleaner corn, however, would offset price discounts received by producers, and leave the value of the corn crop intact regardless of the change in the grade limit. Thus, the benefits of marketing cleaner corn might include more outlets, some resultant price benefits, and a greater price differential to farmers for low-BCFM corn.

Buyers and producers would also be affected differently. Because the beginning and ending BCFM levels affect cleaning costs, these costs would differ by region. According to the on-farm survey, producers in the Northern Plains region have the lowest average level of BCFM at harvest (1.5 percent) and thus would be less affected by lower BCFM limits. Producers in the Corn Belt would be more adversely affected because their average BCFM level is 1.8 percent. The Northeast, although not a major corn producing area, would be adversely affected even more because the region's BCFM level is the highest, at 2.15 percent.

The impacts of cleaner corn on port areas would depend on the responses of foreign buyers. Export elevators supplying countries with contract specifications for cleaner corn would incur higher cleaning costs than elevators exporting to countries with less demand for cleaner corn. If additional cleaning occurred at country elevators, cleaning to or above the current level would still have to take place at other market points, including ports.

Conclusions

There is no basis for mandatory additional cleaning of corn in the United States unless benefits from selling cleaner corn in the international market exceed the $49 million net cost of cleaning at the least net-cost locations, inland subterminals and river elevators on a yearly basis. This cost estimate assumes that corn received at the subterminals is destined for export markets. To the extent that a small proportion of the volume received at these market points is sold to domestic markets, additional cleaning of some export corn would have to occur at the second lowest net-cost point of cleaning, export elevators.

Per bushel costs of additional cleaning increase as corn moves through the marketing system. While additional corn cleaning is estimated to cost 2.5 cents per bushel at the farm, the cost rises to 5.3 cents at country elevators, 5.2 cents at subterminals, and 5.6 cents at export elevators. Costs of cleaning U.S. export corn above the current level at both inland subterminals and river elevators are estimated to total $77 million per year.

Benefits from cleaning a given volume of corn would be the greatest at country elevators because of the higher value of screenings and improved storability of the corn. Per bushel benefits reach 3.2 cents for cleaning all volume received at country elevators,

[24]Additional cleaning would increase the supply of screenings and lower its price. However, price of screenings is not likely to fall below 60 percent of the price of corn based on nutritional value and transport costs.

compared with 0.9 cent at the farm and 1.7 cents at export elevators. The higher value of weight loss makes cleaning at export elevators less attractive.

The costs and benefits of additional corn cleaning may be quite different for individual commercial elevators because of differences in elevators' size, location, and the cleanliness of corn handled. Depending on the practices of the elevator, the costs and benefits for a specific elevator may be greater or less than the ones studied in this report.

Producers and elevators clean corn to remove BCFM to meet the U.S. corn standard. Despite cleaning, BCFM increases as corn moves through the marketing system because of breakage susceptibility in corn. Lowering breakage susceptibility of corn kernels through the development and release of corn varieties is a more effective means to reduce the BCFM content in corn than cleaning, in part because of the need to clean corn at each point in the marketing system. In addition, corn breakage can be controlled through the selection of certain drying systems, such as the low-temperature dryers. Thus, the development and release of corn varieties with lower breakage susceptibility and the selection of certain drying systems are the most effective strategies to reduce corn breakage.

References

Ash, M.S. *Animal Feeds Compendium.* AER-656. U.S. Dept. Agr., Econ. Res. Serv., May 1992.

Ash, M.S., W.B. Just, B.T. Hyberg, and K. McComas. "Corn Cleaning Practices of U.S. Commercial Elevators," *Feed Situation and Outlook Report*, FdS-320, U.S. Dept. Agr., Econ. Res. Serv., Nov. 1991.

Bender, K., L. Hill, C. Valdes. *A Comparison of Grain Grades Among Countries.* AE-4685, Univ. of Ill. Urbana-Champaign, Dept. Agr. Econ., July 1992.

Eckhoff, S. "Effects of High-Temperature Drying on Wet Milling Performance," *Wet Milling Notes*, Note No. 8, Univ. of Ill. Urbana-Champaign, Dept. Agr. Engineering, Oct. 1993.

Fruin, J., D. Halbach, and L. Hill. "Corn Movement in the United States, Interregional Flow Patterns and Transportation Requirements in 1985," North Central Regional Research Bulletin 326, Agricultural Experiment Station, University of Illinois at Urbana-Champaign, 1990.

Hall, L.L., and A. Rosenfeld. *Price-Quality Relationship for Grains: An Evaluation of Buyer's Discount Behavior*, Research Bulletin 82-37, Dept. of Agricultural Economics, New York Agricultural Experiment Station, Cornell University, Ithaca, NY, 1982.

Hill, L.D. *Uniformity by 2000: Highlights of an International Workshop on Maize and Soybean Quality.* Department of Agricultural Economics, University of Illinois at Urbana-Champaign, 1991.

Hill, L.D. *Grain Grades and Standards: Historical Issues Shaping the Future.* Urbana, IL: University of Illinois Press, 1990.

Hill, L.D. "Grain Grades and Standards" in *Grain Marketing Economics* by G.L. Cramer and W.G. Heid, John Wiley & Sons, New York, 1983, pp. 120-144.

Hill, L.D., K.D. Bender, and K.D. Beachy. *Costs and Benefits of Cleaning Grain.* Department of Agricultural Economics, Agricultural Experiment Station, College of Agriculture, University of Illinois at Urbana-Champaign, July 1993.

Hill, L.D. , M.R. Paulsen, R.S. Weinzierl. *Changes in Corn Quality During Exports from New Orleans to Japan.* Bulletin 788A, Illinois Agr. Exp. Station, Dec. 1990.

Hill, L.D., J.P. Brophy, S. Zhang, and W.J. Florkowski. *Farmer Attitudes Toward Technological Changes Affecting Grain Handling and Quality.* Bulletin 805, Univ. of Ill., Urbana-Champaign, Nov. 1991.

Hill, L.D., C.R. Hurburgh, K. Bender, and B. Meinders. *Costs and Benefits of Redefining the Grade Factor: Broken Corn and Foreign Material, Executive Summary.* AE-4692, Univ. of Ill. at Urbana-Champaign, Dept. Agr. Econ., Aug. 1992.

_____. *Costs and Benefits of Redefining the Grade Factor: Broken Corn and Foreign Material.* Research contribution to NC-151, July 1992.

Hill, L.D., K.D. Bender, S. Eckhoff, M. Paulsen, and K. Snyder. *Economic Evaluation of Air Dried Corn.* AE-4698, Univ. of Ill., Urbana-Champaign, Dept. Agr. Econ., Jan. 1988.

Hill, L., M. Leath, O. Shotwell, D. White, M. Raulsen, and P. Garcia. *Alternative Definitions for Grade Factor of Broken Corn and Foreign Material*, Bulletin 776, Univ. of Ill. at Urbana-Champaign, Oct. 1982.

Hill, L.D., M. Paulsen, K. Bender, D. Marriott, D. Timmerman, and T. Kile. *Impact of Separating the Factor of BCFM in Corn Grades: Market for Corn Screenings*. AE-4670-3, Univ. of Ill. at Urbana-Champaign, Dept. Agr. Econ., May 1991.

Holmes, B.J., R.M. Klemme, J. Lindholm. "Economic Evaluation of Corn Drying System in the Upper Midwest," *Transactions of the ASEA*, 28(3): 907-914, May-June 1985.

Hurburgh, Charles R., and Bruce L. Meinders. "Costs and Benefits of Redefining the Grade Factor Broken Corn-Foreign Material in Corn: Final Report of the Iowa Component," Agricultural and Biosystems Engineering Department, Iowa State University, 1992.

Leath, M., and L. Hill. "Economics of Production, Marketing, and Utilization," Chapter 7 in *Corn: Chemistry and Technology* by S. Watson and P.E. Ramstad, 1987.

Mercier, S. *The Role of Quality in Corn Import Decisionmaking*. AER-684. U.S. Dept. Agr., Econ. Res. Serv., June 1994.

National Grain and Feed Association. Unpublished commercial elevator survey data. 1991.

Paulsen, M.R., L.L. Darrah, and R.L. Stroshine. "Genotypic Difference in Breakage Susceptibility of Corn and Soybeans," in *Fine Material in Grain*, OARDC Special Circular 141, Sept, 1992.

Peterson, W. and J. Siemens. "Meeting the Competition...Understanding the Issues in Grain Quality," Cooperative Extension Service, University of Illinois at Urbana-Champaign, No date.

Schwart, R.B. and L.D. Hill. *Costs of Drying and Storing Shelled Corn on Illinois Farms*. Circular 1141, Cooperative Extension Service, College of Agriculture, University of Illinois, Urbana-Champaign, Aug. 1977.

Sundquist, W. Burt, Kenneth M. Menz, and Catherine F. Neumeyer. *A Technology Assessment of Commercial Corn Production in the United States*, Station Bulletin 549-1982, Agricultural Experiment Station, University of Minnesota, 1982.

U.S. Congress, Office of Technology Assessment, *Enhancing the Quality of U.S. Grain for International Trade*, OTA-F-399, February 1989 (a).

_____. *Enhancing the Quality of U.S. Grain for International Trade Summary*, OTA-F-400, Feb. 1989 (b).

_____. *Enhancing the Quality of U.S. Grain in International Trade: A Comparison of Major U.S. Competitors*, OTA-F-402, Feb. 1989 (c).

U.S. Department of Agriculture, Economic Research Service, *Feed Situation and Outlook Report*. Fds-320, Nov. 1991.

_____, Federal Grain Inspection Service, *1991 U.S. Grain Exports: Quality Report*, April 1992.

_____. *1990 U.S. Corn Quality: 1990 Preliminary New Crop Corn Inspection Data*, Dec. 1990.

U.S. Feed Grains Council. Personal communication. May 1993.

University of Illinois. Unpublished on-farm survey data. 1991.

Watson, Stanley A. "Measurement and Maintenance of Quality," in *Corn: Chemistry and Technology* by S. Watson and P. E. Ramstad, 1987.

Glossary

Aeration--The passage of air through the grain mass to control the adverse effects of excessive moisture, temperature, and humidity. This is usually done by forcing air through the grain mass with fans.

Aspirator--A device that draws a column of high velocity air across a flowing grain stream to separate low density materials from the grain kernels. The air pressure is based on the weight of the corn. An aspirator can operate at a higher throughput capacity than screen cleaners but may result in a higher corn loss. Aspirators are generally used to remove low density materials such as FM, chaff, and dead insects.

Blending--The systematic combining of two or more lots of grains with different characteristics to obtain a uniform mixture of a desired specification.

Breakage susceptibility--The probability that a given corn kernel will crack during handling. It has been scientifically established that breakage susceptibility differs by corn.

Broken corn (BC)--All matter that passes readily through a 12/64-inch, round-hole sieve and all matter that remains on top of a 6/64-inch, round-hole sieve according to procedures described in FGIS instructions.

Broken corn and foreign material (BCFM)--Kernels and pieces of kernels of corn and all matter other than corn which will pass readily through a 12/64-inch sieve, and all matter other than corn which remains in the sieved sample.

Cleanliness--The level of broken corn and foreign material in corn.

Dent corn--Corn with kernels of starchy nature (more than 50 percent of endosperm) and with a dent or crease in the crown.

Discount--Reductions from the base price offered for grain. Generally calculated for factors that lower the value of the grain. May be expressed as a percentage of the price or as a fixed amount per bushel. Discounts serve as a disincentive for selling grain below the quality of the base market grade.

Dry milling--Process in which corn is tempered to uniform moisture and physically separated into products based on particle size. The major products in dry milling are grits, meal, flour, oil and feed.

Endosperm--A nutritive tissue in corn contained in the inner bulk of the kernel that consists primarily of complex carbohydrates. It also contains protein, riboflavin, and B vitamins. The quality of vitreous or hard endosperm relative to floury endosperm in kernel determines the hardness of the grain.

Fines--The materials obtained from passing corn over a sieve of a size smaller than the kernels; the small particles passing through the sieve, either in an inspection procedure or in a commercial cleaning operation.

Flint corn--Corn with kernels that are hard in nature and predominantly vitreous (more than 50 percent of the endosperm).

Foreign material (FM)--All matter that passes readily through a 6/64-inch, round-hole sieve and all matter other than corn that remains on top of a 12/64-inch, round hole sieve according to procedures described in FGIS instructions.

Grade--A number designation assigned to grain based on a pre-established set of criteria.

Grain grades and standards--Specific standards established for each grain that describe the physical characteristics of different lots. The grades and standards facilitate trade by permitting the purchase of grain without the need for visual inspection and testing by the buyer.

Hominy feed--A byproduct of corn dry-milling process. It is a preferred ingredient for dairy cattle rations. It is the equivalent of corn grain in feed value, although with higher protein and fiber content.

Hybrid corn--Hybrid corn is the product of a controlled, systematic crossing of specially selected parental strains called 'inbred lines.' Accompanying inbreeding is a rigid selection for the elimination of those inbreds carrying poor heredity, and which fail to meet established standards. A hybrid from two corn parents that have been bred to produce particular traits, such as yield and protein, may be bred to produce a high-protein, high-yield corn.

Intrinsic value--Characteristics critical to the end-use of grain. These are nonvisual and can only be determined by analytical tests. For example, the intrinsic quality of corn is determined by characteristics such as protein, oil, and starch content.

Marketing channels--The agencies and institutions through which products are moved from their original producers to the final consumers in the marketing of grain. The market channel includes all of the stages from the point of first delivery from the farm to the final consumer of raw or processed products.

Moisture content--The amount of water in corn; measured by the weight of water as a percent of total weight of the grain including water.

Nongrade-determining factors--Factors that influence the quality of grain, and must be reported as information whenever an official inspection is made. However, they are not used in determining the numerical grade. Moisture is an example.

Pericarp--The covering of a seed that is derived from the ovary wall.

Premium--Increases from the base price offered for grain of higher quality characteristics than specified for the base grade. Generally calculated for factors that increase the value of the grain.

Screen cleaner--A series of angled perforated plates or wire screens that separates the grain from particles

that are larger or smaller than the grain kernel. The screens may be stationary, shaken, or rotated. The screen cleaner removes BCFM on the basis of particle size. The screens may differ, but screen cleaners are generally used to remove large particles.

Screenings--The material removed from grain by means of mechanical cleaning devices. Generally include broken grain as well as nongrain material removed on the basis of density or particle size.

Shrink--The loss of volume or weight that occurs during drying or as a result of fermentation and bacterial action.

Stress cracks--Cracks in the horny endosperm of corn caused by the rapid drying of kernels with heated air. Stress-cracking causes increased breakage during handling and reduces flaking grit yields.

Steeping--The act of soaking corn in warm water to remove soluble content or begin germination.

Test weight--A measure of grain density determined by weighing a prescribed quantity of grain using methods prescribed in the U.S. grades and standards. Test weight has always been a corn grading factor, and it is related to density of the grain mass. It is influenced by many factors, such as maturity of the grain.

Total damaged kernels--Kernels and pieces of corn kernels that are heat damaged, sprouted, frosted, badly ground damaged, badly weather damaged, moldy, diseased, or otherwise materially damaged.

Weight loss--The percentage of small, saleable corn kernels that are removed by the cleaner and/or broken by the motion of the cleaner itself.

Wet milling--Process in which corn is tempered, steeped, and converted into starches. Corn oil is also extracted during starch removal.

Appendix A: Premiums and Discounts

Premiums and discounts are used by grain buyers to convey their demands for quality. Buyers of corn use price discounts to discourage delivery of corn with high BCFM levels. Premiums are seldom used in the marketplace. The National Grain and Feed Association (NGFA) commercial elevator survey found that only a very small portion of elevators (0.4 percent) set maximum allowable levels of BCFM. Corn lots exceeding these limits were rejected.

The NGFA commercial elevator survey asked respondents to provide information on discounts and premiums received. Information about discounts for corn with BCFM levels ranging from 3 percent to over 7 percent as well as premiums for low-BCFM corn were obtained. The average discount for BCFM tended to increase as the BCFM content increased. The percentage of elevators charged with price discounts also increased as the BCFM level increased. Elevators cleaning corn were assessed discounts for BCFM that were 30 percent higher than those for elevators that did not clean corn.

The average discount assessed to U.S. elevators for corn with BCFM between 3 and 4 percent was 1.9 cents per bushel (appendix table 1). At this level, about 38 percent of the respondents were assessed price discounts for higher BCFM. The discount increased to 2.7 cents per bushel if the BCFM level of corn was between 4 and 5 percent, and the proportion of the respondents assessed by buyers increased to 85 percent.

Only about 2 percent of elevators reported being offered premiums by millers or other elevators for low-BCFM corn. Premiums averaged about 2.2 cents per bushel, and ranged from 0.3 to 9 cents per bushel. While elevators were seldom offered premiums, many of them were assessed with price discounts for high-BCFM corn. Elevators in the Corn Belt generally were assessed the smallest discounts for high-BCFM

Appendix table 1--Average discounts and premiums received by elevators

BCFM level	Discount	Premium	Elevators affected
	--- Cents/bushel ---		*Percent*
Less than 3 percent		2.2	2
3-4	1.9		38
4-5	2.7		85
5-6	4.2		NA
6-7	5.4		NA
Over 7	7.4		NA

NA=Not available.
Source: NGFA 1991 Commercial Elevator Survey.

Appendix table 2--Average discounts received by corn producers

BCFM level	Discount
Percent	*Cents/bushel*
3.1-3.5	1.2
3.6-4.0	1.3
4.1-4.5	1.5
4.6-5.0	1.4
Above 5.0	1.8

Source: University of Illinois 1991 Corn Producer Survey.

by buyers while elevators in the Northern Plains generally received larger discounts.

Producers received lower price discounts from their buyers than did commercial elevators (appendix table 2). Country elevators, which purchase about 80 percent of the corn sold by producers, sometimes charge lower discounts to producers for high-BCFM corn and, in some cases, even forgive producers for selling high-BCFM corn to maintain their business volume. This is the case because of the competitive market structure at the country elevator level. Blending corn with different BCFM contents at this market point makes this discounting practice possible. In contrast, feed manufacturers and dry and wet millers tend to charge discounts on a universal basis to sellers of high-BCFM corn, because they do not blend grain.

Appendix B: Unit-Cost of Operating a Grain Cleaner

Operating a grain cleaner incurs fixed and variable costs. Fixed costs are the costs of ownership and remain the same regardless of use. These costs include depreciation, interest expense, taxes, and insurance. The variable costs are the costs that are incurred only when the cleaner is in operation. These costs include labor, power, and maintenance.

At all locations the per bushel average fixed cost, variable cost, and total cost increase as the volume cleaned decreases. Fixed costs account for the bulk of the cost of operating a grain elevator. Depreciation is the largest component cost.

Appendix table 3--Cost per bushel of operating a farm grain cleaner[1]

Cost	Bushels cleaned 10,000	25,000	50,000
	Cents per bushel		
Fixed costs:			
Depreciation	3.00	1.20	0.60
Interest	1.35	0.54	0.27
Insurance and misc.	0.60	0.24	0.12
Average fixed costs	4.95	1.98	0.99
Variable costs:			
Labor	0.34	0.34	0.34
Power	0.03	0.03	0.03
Maintenance	0.30	0.24	0.18
Average variable costs	0.67	0.61	0.55
Average operating costs	5.62	2.59	1.54

[1]Costs are indicated for cleaning to the 1.5-percent BCFM level.
Source: Hill, Bender, and Beachy.

On-Farm

The cost of operating a grain cleaner was estimated based on a cleaner with a rated capacity of 2,500 bushels per hour, which costs $3,000 to install (appendix table 3). The depreciation estimates were based on a 10-percent rate. Interest on investment was 9 percent times the average remaining balance over the projected 10-year life of the cleaner. Insurance and miscellaneous expenses were assumed to be 2 percent of the capital investment or $60.

Variable costs include labor, power, and maintenance. It is estimated that an operator's supervision is required for 50 percent of the time the cleaner is in operation. The labor rate was assumed to be $7.50 per hour. Power costs were based on a rate of 10 cents per kilowatt-hour. The maintenance requirements of a cleaner depend on the volume cleaned. Estimates of maintenance costs ranged from 1 percent of purchase price for 10,000 bushels to 3 percent for 50,000 bushels of grain cleaned per year.

The main factor affecting the unit-cost of operating a cleaner is the volume cleaned. Variable costs are relatively constant, ranging from 0.55 to 0.67 cent per bushel. Fixed costs, however, ranged from 0.99-4.95 cents per bushel. Depreciation is the largest item in both fixed and total costs and accounts for 61 percent

of fixed cost. Interest accounts for 28 percent and insurance and other miscellaneous expenses account for only 12 percent.

The largest component of variable costs was labor, which was 0.34 cent per bushel for all volumes studied. The power requirement remained constant at all three volumes analyzed and was the smallest cost component of variable costs at 0.03 cent per bushel. At 10,000 bushels, the maintenance cost was 0.30 cent per bushel; while at 50,000, it cost 0.18 cent to maintain the cleaner.

Country Elevator

Cleaning at the country elevator incurs both fixed and variable costs to operate the cleaner (appendix table 4). The fixed costs at the country elevator accounted for approximately 75 percent of the total costs. The unit fixed costs, variable costs, and total costs increased as volume cleaned decreased. As on the farm, the largest cost component of the fixed costs was depreciation expense (65 percent of average fixed costs), which range from 0.60 to 2.40 cents per bushel. Interest expenses, insurance, and other minor expenses ranged from 0.27-1.08 cents and 0.06-0.24 cent per bushel, respectively.

Variable costs at the country elevator include power and maintenance. Unlike the farm, no operator's supervision is required to run the cleaner. Labor, however, is required to maintain and fix the cleaner. This labor is included in the maintenance cost estimates of 0.30-1.20 cents per bushel. Power cost is constant for all volumes cleaned and relatively small, accounting for about 0.01 cent per bushel.

Appendix table 4--Cost per bushel of operating a cleaner at the country elevator[1]

Cost	Bushels cleaned 250,000	500,000	1,000,000
	Cents per bushel		
Fixed costs:			
Depreciation	2.40	1.20	0.60
Interest	1.08	0.54	0.27
Insurance and misc.	0.24	0.12	0.06
Average fixed costs	3.72	1.86	0.93
Variable costs:			
Power	0.01	0.01	0.01
Maintenance	1.20	0.60	0.30
Average variable costs	1.21	0.61	0.31
Average operating costs	4.93	2.47	1.24

[1]Costs are indicated for cleaning to the 1.5-percent BCFM level.

Subterminals and Export Elevators

Cleaning at subterminals and export elevators may require installation of cleaners and initial capital costs. The cost of operating the cleaners would be similar to the 1-million-bushel case for the country elevator. With even greater volumes cleaned, the unit-cost of cleaning may decrease, but this decline will discontinue once the cost curve flattens out.

Appendix C: Aggregate Costs and Benefits

The costs and benefits of delivering cleaner corn were calculated at five points in the marketing channel: farms, country elevators, inland subterminal elevators, river elevators, and export elevators. We assumed that additional corn cleaning would require farms and country and subterminal elevators to reduce BCFM levels from 3 percent to 1.5 percent. For export elevators, additional corn cleaning would require a reduction in BCFM for U.S. No. 3 corn from the current 4-percent limit to a 2.5-percent limit. It was also assumed that additional cleaning would apply to all corn marketed by producers at the farm because domestic and export sales cannot be differentiated. Additional cleaning at country elevators includes two scenarios: (1) cleaning the volume of corn received (4.6 billion bushels), and (2) cleaning a volume equivalent to U.S. exports (1.6 billion bushels). The first scenario is more realistic for country elevators where the destination of the corn shipments after handling is not known with certainty. The second scenario assumes country elevators have perfect knowledge of the destination of the corn shipments. Additional cleaning at subterminal elevators would apply to the volume received, most of which would be destined for export markets. Currently, only a volume of corn equivalent to U.S. exports (1.6 billion bushels) receives additional cleaning at export elevators.[25]

[25]"Corn for export" refers to the aggregate volume of corn received at export ports. Export volume of 1,576 million bushels (USDA/ERS, 1991) is combined with the bushels of screenings removed at these ports, 15.4 million bushels, to derive the aggregate volume of corn received at export ports, 1,591 million bushels.

The costs and benefits of cleaning corn were based on estimates made by Hill, Bender, and Beachy. Costs and benefits of cleaning in their study were estimated under the assumption that all corn marketed or handled at each market point would be further cleaned to achieve the targeted BCFM levels.

Cleaning U.S. corn beyond the current level would incur costs that exceed potential domestic benefits. The total net cost of additional cleaning of export corn was the lowest at inland subterminals and river elevators.

Costs

The largest cost component for all locations except the farm was the value of weight loss, which ranged from $22 million at inland subterminals to $168.3 million at country elevators if all volume received were cleaned (appendix table 5). For a given volume of corn to be cleaned, export elevators had the highest value of weight loss because prices received for corn at export elevators generally are higher than at any other location. At the farm, value of weight loss is the lowest because of lower quantities of screenings removed and lower corn prices.

The value of weight losses was estimated by multiplying the price of corn by the volume of screenings removed. The price of corn varies by market point (appendix table 6). Corn prices at the farm and country elevator were based on the 1991 prices paid to producers and the discount rate of 1 cent per bushel per percentage point of BCFM above 3 percent at the farm level, and 1.3 cents per bushel per percentage

Appendix table 5--Aggregate costs and benefits of additional corn cleaning, 1991[1]

Cost or benefit	Farm[2]	Elevator: Country (volume handled)	Country (volume exported)	Inland subterminal	River	Export[3]
		Million dollars				
Additional costs:						
Value of weight loss	51.4	168.3	57.5	22.1	31.4	66.1
Cost of operating the cleaner	65.0	74.4	25.5	9.2	13.0	23.3
Storage of screenings	NA	2.5	0.8	.3	.5	.9
Total additional costs	116.4	245.2	83.8	31.6	44.9	90.3
Additional benefits:						
Value of screenings	27.8	81.0	27.6	9.2	18.3	26.9
Improved storability	14.2	68.2	NA	NA	NA	NA
Total additional benefits	42.0	149.2	27.6	9.2	18.3	26.9
Additional net costs:	74.4	96.0	56.2	22.4	26.6	63.4

NA=Not applicable.

[1]Assuming volume of corn marketed by producers or volume of corn handled by inland subterminal, river, and export elevators. Costs and benefits of cleaning all corn handled and only export corn are presented for country elevators. No segregation cost was calculated.

[2]Cleaning from 3-percent BCFM to 1.5-percent BCFM; farmers were assumed to clean all corn marketed because domestic and export sales cannot be differentiated.

[3]Cleaning from 4-percent BCFM to 2.5-percent BCFM.

Source: Derived from Hill, Bender, and Beachy.

Appendix table 6--Parameters used in calculating net benefits of additional corn cleaning under current and lower BCFM limits

Parameters	Location	Unit	Current limit	Lower limit
Price of corn	Farm	$/bu.	2.33	2.35
	Country elevator	Do.	2.38	2.40
	Subterminal elevator	Do.	2.40	2.42
	River elevator	Do.	2.40	2.42
	Export elevator	Do.	2.70	2.70
Price of screenings	Farm	$/ton	64.6	50.4
	Country elevator	Do.	64.3	51.4
	Subterminal elevator	Do.	69.6	51.8
	River elevator	Do.	66.1	51.8
	Export elevator	Do.	87.5	57.9
Cost of operating the cleaner	Farm	Cents/bu.	2.7	4.1
	Country elevator	Do.	3.2	4.8
	Subterminal elevator	Do.	2.9	4.4
	River elevator	Do.	2.9	4.4
	Export elevator	Do.	2.7	4.1
Cost of storing screenings	All locations	Cents/bu.	3.6	3.6
Length of corn storage	All locations	Months	6	6
Length of screenings storage	All locations	Month	1	1
Level of BCFM	Farm	Percent	3.0	1.5
	Country elevator	Do.	3.0	1.5
	Subterminal elevator	Do.	3.0	1.5
	River elevator	Do.	3.0	1.5
	Export elevator	Do.	4.0	2.5
Value of improved storability	Farm	Cents/bu.	0.24	0.93
	Country elevator	Do.	3.30	7.60
Volume of corn received	Farm	Billion bu.	4.65	4.65
	Country elevator	Do.	4.65 and 1.59	4.65 and 1.59
	Subterminal elevator	Do.	.61	.61
	River elevator	Do.	.87	.87
	Export elevator	Do.	1.59	1.59

Source: Hill, Bender, and Beachy.

point above the limit at country elevators. Export port prices were FOB (free on board) New Orleans (Hill, Bender, and Beachy). Screenings removed were calculated from survey responses.

Costs of storing screenings are incurred at country, inland subterminal, river, and export elevators. At the farm level, little storage of screenings occurs because they often are fed to livestock on the farm soon after cleaning. Screenings were assumed to be stored for 1 month at country elevators. The costs of storing screenings were estimated to be 3.6 cents per bushel using the procedure developed by Hurburgh and Meinders. Storage costs for screenings at the port were also estimated to be 3.6 cents per bushel. Storage space is more valuable at the port than at country elevators, but storage is usually for a shorter period of time (Hill, Bender, and Beachy).

The cost of operating cleaners was the highest at country elevators assuming all corn received was cleaned ($74.4 million) and at the farm ($65.0 million). The average costs of operating cleaners to reduce the BCFM level to the 3-percent limit for producers and country elevators and to the 4-percent limit for export elevators were taken from the surveys. The cost of increased cleaning capacity required to remove an additional 1.5 percentage points of BCFM and variable expenses were added to the survey results. Costs shown in appendix table 5 reflect those of additional cleaning from the current limit to the targeted, lower BCFM level.

Benefits

Revenues received from screening sales were the largest benefit for country and export elevators: $27 million at export elevators and $27.6-$81.0 million at country elevators, depending on whether additional cleaning was applied to the volume received or volume exported. These revenues offset 50 percent of the weight loss.

Revenues from sales of screenings were estimated by multiplying screenings removed by screening prices at each location. Screening prices varied by location but were estimated to fall to 60 percent of corn prices at all locations.

Improved storability is an important reason for cleaning corn at the farm and country elevators. This benefit totaled $14.2 million at the farm, and $68.2 million at country elevators if cleaning applies to the total volume handled. These benefits included savings on shrink, aeration, and spoilage, and were derived under the assumption that corn would be stored for 6 months after harvest. No appreciable benefit from improved storability would occur if additional cleaning at country elevators was applied to the volume exported because it was assumed that cleaning would apply only to outbound shipments. Benefits from improved storability were not calculated for export elevators because the corn cleaned is only stored temporarily at these locations.

The benefits from improved storability were adapted from a study by Hurburgh and Meinders. These benefits were calculated to be 1.5 cents per bushel stored when the BCFM content was reduced by 1 percentage point and when corn was stored for 6 months following harvest. Improved storability was only applied to the 2.4 billion bushels of corn on farms, the midpoint of on-farm corn stocks between March 1 and June 1, 1991, and the 1.6 billion bushels of off-farm corn stocks at that time. At the country elevator, it was estimated that reducing the BCFM level by an additional 1.5 percentage points would result in benefits from improved storability at $0.043 per bushel. This value was equivalent to $0.0287 per bushel per percentage point reduction in the BCFM content. Benefits from improved storability were computed by multiplying benefit per bushel by on-farm and off-farm stocks and by the percentage points of BCFM removed.

☆ U.S. GOVERNMENT PRINTING OFFICE: 1994 300-125/00128